Stocking density: Can we judge how much space poultry need?

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11.1 Introduction

Stocking density or “crowding” is one of the most sensitive issues in poultry welfare. The initial response of someone seeing commercially housed layers, turkeys, or broiler chickens is often to say that they are so crowded together that their welfare “must” be affected (Busch & Achim, 2015; de Jonge & Hans, 2013; Hall & Sandilands, 2007). This public perception that crowding causes serious welfare problems is reflected in widespread calls for stocking density to be reduced and for producers to give their birds more space (Appleby, 2004; European Union, 2007; RSPCA, 2013). On the other hand, of all the factors that affect commercial production, one of the most influential is how many birds can be kept in a given space, as reducing the numbers of birds in a given space is seen as having an almost inevitable effect on the financial viability of an enterprise (Feddes, Emmanuel, & Zuidhof, 2002; Knowles et al., 2008; Petek, Ustuner, & Yesilbag, 2014; Shanawany, 1988; Utnik-Banas, Zmija, & Sowudla-Skyrzynska, 2014). There seems therefore to be an apparent conflict between the welfare interests of the birds that would seem to point to giving each bird more space and the commercial interests of producers that would seem to be in the direction of putting more birds into the same space. Central to resolving this conflict is understanding what the space needs of poultry actually are.

However, despite over 25 years of research (reviewed on broilers, e.g., Arnould & Leterrier, 2007; Bradshaw, Kirkden, & Broom, 2002; Bessei, 2006; Buijs, Keeling, Rettenebacher, Van Poucke, & Tuyttens, 2009; Bokkers, de Boer, & Koene, 2011; Estevez, 2007; Robins & Phillips, 2011; for turkeys by Marchewka, Watanabe, Ferrante, & Estevez, 2013) there is still no agreement on how much space poultry need and this is reflected in the wide range of regulations, codes, and recommendations currently covering space allowances for poultry across the world. Apart from the obvious difficulties of translating lbs and square feet into kilograms and square meters, the way in which the basic relationship between space and poultry is expressed varies widely. For adult laying birds, it is usually measured as the number of birds per unit area (ft^2 or m^2), and this can be also expressed as a derivative of this—the amount of space each bird has such 0.68, 0.70, 0.75 ft^2/bird. This is often augmented by how much perching space or feeding trough space each bird has, which clearly acknowledges the complexity of what “space” is for poultry and how their needs may vary depending on what they are doing. For rapidly growing

birds, however, such as broilers or turkeys, the number of birds in each square foot or square meter has a very different effect depending on their size and age and so a measure of bird weight is usually introduced to try and express this, such as the lbs or kg of bird to be found in 1 ft^2 or $1/m^2$.

There is thus a wide diversity of opinion about how to measure “space” as well as how much of it poultry “need” that is apparent in both research findings and legislative requirements and there are two quite different approaches to dealing with this diversity. The first is to argue that the diversity of opinion comes from a lack of research or at least a lack of research of the required standard. The solution here is therefore to undertake more research with agreed methodology with the hope that better science will resolve the differences and enable a consensus to be arrived at. The second approach is to argue that no such consensus is possible because the health and welfare needs of poultry extend so far beyond the physical space available to them that it is positively misleading and actually detrimental to their welfare to attempt to capture their

needs in ft^2 or m^2. It might satisfy legislators to be able to have a precise area per bird above which welfare could be deemed to be satisfactory and below which welfare would be regarded as poor, but if there is in fact no such threshold, or even a range of values, the welfare of poultry will not be improved by pretending that there is. The solution here is to resist calls for single numbers that refer to just one aspect of welfare and to see space needs as part of a much wider range of factors that contribute to the well-being of poultry. In support of this latter view is that most scientists working in the field agree that "welfare" or "well-being" is multi-factorial both in the sense that many different measures should be taken to assess it (Fraser, Duncan, Edwards, Grandin, & Gregory, 2013) and also in the sense that many different factors (such as age, breed, environment, and social grouping) affect that final assessment. "Space," despite its emphasis by the public and its favored status in the eyes of legislators, should be no exception. Just because it is simple to measure does not mean that it should assume the status of the predominant welfare indicator that takes precedent over the others.

The aim of this chapter is to decide whether it is possible to define the space needs of poultry in a way that is scientifically valid and makes sense in terms of the welfare of the birds themselves or whether the attempt to define space "needs" as if they were separate from other welfare needs is impossible and even damaging to poultry welfare. As both approaches call for a definition of "needs," I will start with a brief discussion of what "needs" might mean in the context of space.

11.2 "Needs" and the assessment of welfare

The term "needs" in the context of animal welfare has a long and somewhat confused history (e.g., Hughes & Duncan, 1981; Thorpe, 1965; Vestergaard, 1982) but is now most usefully divided into two kinds of need (Dawkins, 1983). The first ("ultimate") kind of need is where animals die or become ill as a result of not having something. In this sense, animals need food and water because without them they die. But hens do not die through being kept in cages where they cannot

dustbathe, so to argue that hens have a "need" to dustbathe is to use the term in a somewhat different ("proximate") sense, to imply that they are "highly motivated" to dustbathe or that they are frustrated or stressed by being unable to do this behavior. These two meanings of "need" can be summarized by defining good welfare as good health (satisfaction of needs sense 1 above) and the animal having what it wants (satisfaction of needs in sense 2).

This simple dichotomous definition of needs and welfare (Dawkins, 2008) has the advantage that it points directly to the kind of evidence that can show what an animal's needs are. For example, to establish whether an animal "needs" the opportunity to show a certain kind of behavior, we can look for evidence that being able to behave in a particular way either improves its health and/or is something the animal wants to do, as demonstrated by it (for example) learning to peck keys, or push weighted doors, to be given the opportunity to behave in that way. We now have available many different ways of establishing that animals are in a positive emotional state (Boissy, Manteuffel, Jensen, et al., 2007; Paul, Harding, & Mendl, 2005). Animals "having what they want" is a colloquial shorthand for animals being in a positive emotional state.

This dichotomous approach has the further advantage that it encapsulates, but in a simplified and easy to remember way, other more detailed definitions of welfare. Of the 5 Freedoms (FAWC) for example, two of them (freedom from hunger and thirst and, freedom from injury and disease) refer to physical health, whereas the other three (freedom from discomfort, freedom to perform most normal patterns of behavior, and freedom from fear and distress) refer to positive emotional states expressed as what animals want or what they want to get away from. The 10 welfare principles of the World Organisation for Animal Health (Fraser et al., 2013; OIE, 2012) and the 12 criteria of the Welfare Quality can also be summarized in this way. The 12 criteria of the WQ are "absence of prolonged hunger, absence of prolonged thirst, comfort around resting, thermal comfort, ease of movement, absence of injuries, absence of disease, absence of pain induced by management procedures, expression of social behavior, expression of other natural behavior, good human-animal relations and positive emotional state." This list is long and quite difficult to remember but can be summarized as "health" (absence of disease, injury, and pain) and the provision of "food, water and bedding" and the animal having "what it wants" (comfort, ability to move, interactions with others, and positive emotional state).

When it comes to the space needs of poultry, therefore, we can ask two questions: (1) can we define how much physical space poultry need for their physical health? and (2) can we define how much space poultry want? Most research has been done on broiler (meat) chickens but layers, turkeys, and ducks are covered whenever possible.

11.3 Assessment of space needs: Physical health

As Estevez (2007) has pointed out, there are a number of reasons why trying to find a single space allowance that is best for poultry health is extremely difficult.

Chief of these is that different measures of health give different results for the amount of space poultry need for to keep them healthy. We can illustrate this by looking at the results obtained using different health measures.

11.3.1 Mortality

The most basic measure of health is whether animals live or die. Indeed, in its Directive on broiler welfare, the European Union used this to define the maximum stocking density that broiler chickens should experience during their lives as 33 kg/m^2, although this could be increased if certain conditions were met, such as a consistently low level of mortality during 7 flocks (EU, 2007). However, although this put considerable emphasis on mortality as a key welfare indicator, mortality has been found to vary relatively little with current space allowances and therefore not to be particularly useful for defining space needs (Feddes et al., 2002; Thomas, Ravindran, Thomas, et al., 2004). Buijs et al. (2009) found no effect on mortality in broilers kept in small groups kept between 6 and 56 kg/m^2 and Knierim (2013) found no effect between 18 and 40 kg/m^2. In trials on farms in India, Ghosh, Majumder, and Goswami (2012) found no effects between 0.8 and 1.2 ft^2/birds and in trials in the United Kingdom and Denmark, Dawkins, Donnelly, and Jones (2004) similarly found no effects between 30 and 46 kg/m^2. With laying hens kept in aviaries, Steenfeldt and Nielsen (2015) found that between 6 and 9 hens/m^2, mortality was not affected by stocking density. Lack of the effect on mortality, particularly for short-lived birds such as broiler chickens, is not, however, an adequate measure of health and only a very crude measure of welfare.

11.3.2 Growth rate

A consistent finding is that growth rate in poultry is affected by stocking density—that is, birds grow more slowly at higher densities. This holds for broilers (Benyi, Avhafunani, Kgabo, & Eastonce, 2015; Dawkins et al., 2004; Dozier, Thaxton, Branton, Morgan, et al., 2005; Feddes et al., 2002; Petek et al., 2014; Sørensen, Su, & Kestin, 2000; Sirri, Minelli, Folegatti, Lolli, & Meluzzi, 2007), and is also true for turkeys (Jankowski, Mikulski, Tatara, & Krupski, 2015) and ducks (Xie et al., 2014). On the other hand, it is difficult to define a critical density at which a reduction in growth rate occurs. Cravener, Roush, and Mashaly (1992) found that when stocking density exceeded 40 kg/m^2, body weight was significantly lower than at 34–38 kg/m^2, whereas Dozier et al. (2006) found a 6% reduction above 35 kg/m^2.

Although high growth rate is sometimes seen as a welfare problem (Cooper & Wrathall, 2010), lowered growth rate seen at higher stocking densities is also seen as a sign of reduced health. Abudabos, Samara, Elsayad, Al-Atiyat, and Al-Haidary (2013) showed that at very high stocking densities (45 kg/m^2) broilers showed a marked elevation of body temperatures over broilers kept at 26.5 kg/m^2, suggesting that they were under heat stress. The depression in growth rate may also be affected by changes in gut microbiota at higher stocking densities. Guardia et al. (2011)

found that between 12 and 17 birds/m^2, reduced body weight was associated with changes in the bacterial communities found in the crop and caeca.

Interpreting the welfare impact of reduced growth rate in broilers where growth rate itself is regarded as having caused welfare problems (Cooper & Wrathall, 2010) is problematic. The growth rate of broiler breeders is deliberately reduced by feed restriction to prevent health problems caused by overweight (de Jong, van Voorst, Ehlhardt, & Blokhuis, 2002). As a result of their lower growth rate, the birds are healthier, suffer fewer cardiovascular problems, and have better gaits.

11.3.3 Injury, leg health, and lameness

A number of studies have found that at higher stocking densities, broilers, turkeys, and ducks have greater signs of injury such as more foot pad dermatitis and hock lesions (Bergmann et al., 2013; Buijs et al., 2009; Cravener et al.,1992; Dozier, Thaxton, Branton, Morgan, et al., 2005; Hall, 2001; Petek et al., 2014; Sorensen, 2000; Ventura, Siewerdt, & Estevez, 2010; Xie et al., 2014). For example, Knierim et al. (2013) showed higher levels of leg and foot

lesions between broilers kept at 18 or 25 kg/m^2 and those kept at 35 or 40 kg/m^2, and Dozier et al (2006) found that foot pad lesions and skin scratches became more abundant above 30 kg/m^2.

Once again, there is no consensus on how to interpret these results in terms of "space needs," that is, the point or even a range of values, at which the health of the birds is critically affected. One of the major confounding factors is the fact that relatively few studies distinguish between the effects of crowding or stocking density *per se* and the consequences of having a large number of birds in a given space such as a deterioration in air and litter quality. Higher numbers of birds will mean greater litter moisture, increased microbial activity, and increased temperature and ammonia concentration which can give rise to hock burn, dermatitis, and breast blisters (Bessei, 2006). High stocking densities therefore exacerbate the deterioration of air and litter quality but may not themselves be the primary cause of these injuries, as shown by the fact that the low levels of hock burn and pododermatitis can be achieved through better ventilation leading to improved air and litter quality (Dawkins, Donnelly, et al., 2004; Jones, Donnelly, & Dawkins, 2005). This of course does not mean that stocking density is unimportant to birds but that trying to define space needs without taking into account the quality of their environment could be very misleading and fail to improve the welfare of the birds at all (Estevez, 2007). Stocking density may also affect walking ability or gait through the secondary effects of environmental deterioration (Dawkins, Donnelly, et al., 2004; Dozier, Thaxton, Branton, Morgan, et al., 2005; Knowles et al., 2008).

11.3.4 Loss of immunity and susceptibility to disease

"Stress" measured as a rise in glucocorticoids, organ damage, and other physiological change (e.g., Jang, Hyon, Young, & Yang, 2014; Najali, Idrus, Nurfarahin, Abdoreza, et al., 2015) is difficult to interpret in welfare terms (Rushen, 1991). For example, laying hens allowed access to an area where they could scratch and

dustbathe showed higher levels of fecal corticosteroids than hens allowed access to the same space with a wire floor (Dawkins, Edmond, Lord, Solomon, & Bain, 2004). But where stress measurements can be related to loss of immunity or greater susceptibility to disease, then connection becomes much clearer. Tsiouris et al. (2015) challenged (with vaccine or *Clostridium*) broiler chicks in pens at low stocking density (15 birds/m^2) or high stocking density (30 birds/m^2) and showed that the birds at the higher stocking density had higher lesion scores in the gut and liver. However, in this case it was not clear whether this was a space issue or because the litter was worse. Gomes, Quinteiro-Filho, et al. (2014) found that higher stocking density in broilers decreases macrophage activity and antibody titer against Newcastle disease and also increases susceptibility to *Salmonella*. On the other hand, stocking density effects on corticosteroids and HL ratio in broilers are not consistent (Das & Lacin, 2014; Hushmand, Azhar, Zulkifli, Bejo, & Kayab, 2012) and Buijs et al. (2009) found no difference in corticosteroid levels between 6 and 56 kg/m^2.

11.3.5 Conclusions on health measures

The health measures that are easiest to observe and record (mortality, growth rate, leg and foot disorders, lameness) do not give clear cut results in relation to space available and are frequently inconsistent (De Jong, Berg, Butterworth, & Estevez, 2012; Estevez, 2007). In any case, physical health on its own is not an adequate measure of welfare and additional ways of assessing good welfare are needed.

11.4 Assessment of space needs: Behavior and what the animals want

11.4.1 Choice tests

Faure (1994) conducted an experiment to find out how much space laying hens want by training them to peck at one key to decrease the amount of space available to them and another key to increase the space. Hens were kept in groups of four and each key peck moved a wall by 10 cm in 10 seconds, either moving it back so that the four hens could have a maximum of 6100 cm^2 between them or moving it forward so that they had a minimum of 1600 cm^2 between them. The results were equivocal. Of eight groups of hens, one group learnt to increase the amount of space, four showed no particular preference, and two actually chose to reduce the space, never allowing their cage size to go above 3000 cm^2 (750 cm^2/bird). On the other hand, Buijs, Keeling, and Tuyttens (2011) showed that when given a straight choice, broiler chickens preferred a compartment with a lower stocking density (9.3 or 12.1 birds/m^2) over one with higher (14.7 birds/m^2). Furthermore, the birds preferred the low stocking density even when they had to cross a barrier that had previously deterred up to 25% of them from gaining access to food when 6 hours

food deprived. Unfortunately, not enough studies of spatial preference have been carried out to draw any general conclusions and in any case it is difficult to extrapolate from small experimental pens to commercial poultry houses. As a result, less direct methods potentially more applicable to on-farm analyses have been used to understand how much space birds want.

11.4.2 Spatial distribution

The way birds position themselves with respect to each other—that is, whether they appear to be clustering together or trying to space out as much as possible within a given space—has been used as a way of establishing whether birds want more space, but with contradictory results. Febrer, Jones, Donnelly, and Dawkins (2006) used the spatial distribution that broiler chickens adopt in commercial broiler houses and found that at stocking densities between 30 and 46 kg/m^2 (14–21 birds/m^2) the birds were more clustered than expected from a random distribution, suggesting that they were choosing to move toward each other even at the highest density and did not find close proximity of other birds aversive. On the other hand, Leone and Estevez (2008) used a different method, the nearest neighbor distance, of much smaller groups of 10–20 broilers in small pens to argue that birds were only attracted to each other at very low stocking densities (2.2–3.4 birds/m^2) and were repelled at stocking densities higher than this. Buijs, Keeling, Vangestel, Baert, and Tuyttens (2011) also used nearest neighbor distance to show that, in groups of 20 birds (at 15 kg/m^2), the birds appeared to be socially aversive in the last 3 weeks of life. But spatial distribution can be difficult to interpret. In one study, adult laying hens observed in small groups were found to be feeding together more often than expected at random but this appeared to be due to common resource use rather than social attraction (Collins, Asher, Pfeiffer, Browne, & Nicol, 2011). In general, however, studies involving small numbers of birds in small pens provide such a different environment from that of large commercial broiler houses with many thousands of birds that extrapolations from one to the other are difficult, a problem that bedevils the study of stocking density generally.

11.4.3 Area covered

Rather than using the distance that birds choose to put between each other, another method of inferring how much space they need is to measure the area covered by the birds themselves and then use this to calculate the minimum space that is needed by each bird (Ellerbrock & Knierim, 2002; Hurnik & Lewis, 1991; Petherick, 1983), taking into account the fact that different behaviors take up different amounts of space (Bokkers et al., 2011; Dawkins & Hardie, 1989; Mench & Blatchford, 2014). Bokkers et al. (2011) used overhead images of pens of either 8 or 16 broiler chickens (1250 or 625 cm^2/bird) and concluded that at the higher stocking density, some of the behaviors were compressed and that the maximum stocking density should not exceed 16 birds/m^2 (39.4 kg/m^2). Giersberg, Hartung, Kemper, and Spindler (2016) took over 3000 overhead photographs of standing and

sitting broiler chickens at different ages. By preweighing each bird before placing it in the photo box, they were able to show that there was a strong correlation between bird weight and area covered for both standing and sitting but that even at final target weight (up to 3.2 kg) sitting occupied no more than 77.7% of 1 m. They thus argued that from a purely physical point of view, there is enough room for all birds to sit down at the same time within the space specified in the EU Directive on broiler welfare (2007/43/EC). Using the same method, Spindler, Giersberg, Briese, Kemper, and Hartung (2016) showed that, depending on breed, weight, and age, laying hens occupied an average area of 353–542 cm^2, broiler breeder females between 440 and 537 cm^2, broiler breeder males between 623 and 945 cm^2, male fattening turkeys up to 1808 cm^2, Muscovy drakes up to 873 cm^2, and Peking ducks up to 627 cm^2.

These figures and other calculations of the area covered are, of course, only the minimum space requirement for the behavior to be performed and do not reflect the space the animals themselves prefer to have (see Section 4.1) or whether they want to share that space with other individuals (Section 4.2). In order to translate “area covered” into “space needed,” we need additional information about how poultry use space for particular behavior patterns and the effects of different space allowances. Space available at resources such as feeders may be particularly important, since low-ranking individuals may choose to avoid feeding near dominant birds (Grigor, Hughes, & Appleby, 1995) or, if they try to feed, have their behavior interrupted because there is insufficient space around this key resource. For example, when the amount of space available at a feeder was reduced, laying hens were found to spend less time feeding and to desynchronize their feeding times (Thogerson et al., 2009). The amount of space available for perching can also be important, particularly for laying hens, since hens tend to perch simultaneously at night and each hen requires at least 12–15 cm of perch space, depending on breed (Hester, 2014). For laying hens in furnished cages, the number of individual nest boxes available has more effect on aggression than the total amount of space they have (Hunniford, Torrey, Bedecarrats, Duncan, & Widowski, 2014) and may also have more effect on the amount of floor-laying in ducks (Makagon & Mench, 2011). Designation of space needs for specific behaviors, such as feeding,

perching, and nesting, may turn out to be a more fruitful and evidence-based way of defining space needs than expecting one single measurement to be sufficient on its own.

11.4.4 Behavior showing inferred aversion or negative emotional state

The most widely used method for measuring how much space poultry want is to record the incidence of behaviors that are presumed to indicate that a bird finds the space restriction unpleasant. For example, jostling of other birds, disturbance of resting birds, and birds climbing on top of one another are widely recorded as increasing at higher stocking densities, particularly those above 40 kg/m^2 (Buijs, Keeling, Vangestel, et al., 2011; Dawkins, Donnelly, et al., 2004; Hall, 2001;

Knierim, 2013; Thomas, Son, Ravindran, & Thomas, 2011). Where climbing on other birds results in scratching and damage to the body surface (Estevez, 2007; Thomas, Ravindran, Thomas, et al., 2004) the negative effects are clearly related to the physical health of the birds but even when there is no physical damage, interruption of walking and disturbance of rest can be inferred to have negative effects on birds' welfare (Malleau, Duncan, & Widowski, 2007).

11.5 Complicating factors in the assessment of space needs

11.5.1 Is methodology to blame?

As will be apparent, with the various scientific studies that have been carried out there is still little consensus on the amount of space poultry need for good welfare, and certainly little agreement on a critical threshold or boundary between good and bad welfare (De Jong et al., 2012; Estevez, 2007). Part of the reason for this lack of consensus is undoubtedly methodological: different studies take different measurements and use different methods of analyses. In addition, there is the far larger methodological problem of extrapolating between controlled laboratory studies on small groups of birds and what happens out on commercial farms where thousands of birds are kept together. The differences between these two situations (in group size, air and litter quality, degree of control, for example) potentially have massive effects on how birds respond to changes in stocking density and therefore on the conclusions that are drawn about their needs for space.

However, although methodological difficulties can account for some of the discrepancies in conclusions, it is also necessary to take into account the possibility that there are so many factors affecting the way poultry respond to their environment that the whole concept of "space needs" may have to be questioned as a useful criterion for policy makers. The phrase "it depends" may have to be added so often that it swamps the usefulness of the concept itself. Some of these qualifications (such as whether the study is conducted in the laboratory or on farms or whether the authors have distinguished between the primary effects of stocking density or the secondary consequences on air and litter quality) have already been touched upon. In this section we look at some of the other factors that make giving exact measurements to space needs so hard.

11.5.2 Who is in the space—Social factors

A small empty cage and a larger cage filled with other birds might each give the same physical space but have completely different consequences for an individual bird. Poultry are highly social animals, with changing social behavior as they grow. In young chicks unable to control their body temperature, the close proximity of other birds may be highly attractive, whereas as they grow to maturity and start to

form hierarchies this can change. For growing broilers, the size of group in which they are kept (for similar stocking density) seems to have little effect on behavior (Leone, Christman, Dougllas, et al., 2010), whereas for adult layers, group size seems to be more important than stocking density within the range studied (Pereira, Batista, Sanches, Teiceira, et al., 2013). In adult birds, aggressive pecking actually increases with smaller group size (Hughes, Carmichael, Walker, & Grigor, 1997; Liste, Campderrich, Beltran de Heredia, & Estevez, 2015; Nicol, Gregory, Knowles, Parkman, & Wilkins, 1999). This seems to be because in smaller groups, birds encounter the same individuals repeatedly and start to form dominance hierarchies, whereas with large groups they are less likely to do so (Pagel & Dawkins, 1997). "Space" is not empty for poultry. Who is in that space (source of warmth, a known rival, an unknown

stranger) will be among many social factors that will affect their need for more or less space, which may change radically as they grow and mature. Males and females may also have quite different responses to changes in stocking density (Zuowei et al., 2011) as do different breeds.

11.5.3 What is in the space—Environmental factors

Just as space needs can be influenced by whether birds want to approach or avoid other birds, it can also be influenced by the physical environment the bird encounters. An area of bare wire floor can be just the same size as an area of litter in which a bird can scratch and dustbathe but have very different consequences for the bird. Recently, attention has been given to the quality of space provided when birds are given barriers, perches, daylight through windows, straw bales, etc. These have had mixed results. Ventura et al. (2012) showed that for layers, barrier perches reduced aggression and disturbances. However, for broilers Baille and O'Connell (2015) found that straw bales did not have much effect and Heckert, Estevez, Russek-Cohen, and Pettit-Riley (2002) showed that perches can actually increase stress through reducing the floor space available.

11.5.4 How space is achieved—Thinning

"Space" is not just a quantity a bird has at a particular time. It also depends on how that space allowance is achieved. A common practice among producers in some countries is "thinning," in which a proportion of a flock is removed as the target stocking density is approached and the reduced number of remaining birds is allowed to grow to target weight (Tuyttens, Vanhonecker, & Verbeke, 2014). This enables producers to keep at all times within the specified space limits but to grow a total of more chickens. However, the operation of thinning involves withdrawal of food and the disruption of the catching team entering the house has aroused concern about negative impacts on the welfare of the birds. Here too, focus on one aspect of welfare—space—has not necessarily improved the welfare of the birds themselves.

11.6 Conclusions

The difficulties of defining the space needs of poultry are only partly due to methodological discrepancies between studies and therefore only partly rectifiable by more research. Certainly more on-farm studies, more careful analyses of the direct effects of stocking density and its consequences (such as deteriorating air and litter quality) would help to clarify a number of issues. But even with more research, we would be left with the conclusion that "space" for poultry is far more complex than can be summed up in one single number measured in lbs or kg, or fitted into m^2 or ft^2. Good welfare requires more than just physical space and to place too much emphasis on space as the primary criterion for welfare is potentially to have a damaging effect on the welfare of the birds themselves. First, giving prominence to space allowances (for example in welfare regulations or recommendations) gives the impression that space is paramount and gives producers the message that as long as they are compliant with space requirements, that is all they need to be concerned about. Second, and even more seriously, if stocking density is not the key determinant of welfare that has been claimed, then much effort and expense will go into making changes that will not substantially improve bird welfare. Third, over-emphasizing space needs of birds above others leads to practices such as "thinning" that formally fulfill space needs but may be positively bad for welfare. A possible way forward is to be more specific about the space needs that poultry have for performing specific behavior patterns that either have an effect on their health or can be demonstrated to be important to the birds themselves. That way, we can concentrate on ensuring that birds have sufficient space for the behavior that is most important for them. But a good evidence base is essential. Persuading producers to adopt practices that could be costly for them means that we should press first and foremost for changes that will actually improve welfare for the birds themselves.

References

Abudabos A.M., Samara E.H., Elsayad O.S., Al-Atiyat R.M. and Al-Haidary A., Influence of stocking density on welfare indices of broilers, *Italian Journal of Animal Science* **12**, 2013, e35.

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

Arnould C. and Leterrier C., Welfare of chickens reared for meat production, *Productions Animales* **20**, 2007, 41–45.

Baille C.L. and O'Connell N.E., The influence of providing perches and string on activity levels, fearfulness and leg health in commercial broiler chickens, *Animal* **9**, 2015, 660–668.

Benyi K.N., Avhafunani J.M., Kgabo T.G. and Eastonce T., Effect of genotype and stocking density on broiler performance during two sub-tropical seasons, *Tropical Animal Health and Production* **47**, 2015, 069–974.

Bergmann S., et al., Prevalence and severity of foot pad alterations in German turkey poults during the early rearing phase, *Poultry Science* **92**, 2013, 1171–1176.

Bessei W., Welfare of broilers: A review, *World's Poultry Science Journal* **62**, 2006, 455–466.

Boissy A., Manteuffel G., Jensen M.B., et al., Assessment of positive emotions in animals to improve their welfare, *Physiology and Behaviour* **92**, 2007, 375–397.

Bokkers E.A.M., de Boer I.J.M. and Koene P., Space needs of broilers, *Animal Welfare* **20**, 2011, 623–663.

Bradshaw R.H., Kirkden R.D. and Broom D.M., A review of the aetiology and pathology of leg weakness in broilers in relation to welfare, *Avian and Poultry Biology Reviews* **13**, 2002, 45–103.

Buijs S., Keeling L.J., Vangestel C., Baert J. and Tuyttens F.A.M., Neighbourhood analysis as an indicator of spatial requirements of broiler chickens, *Applied Animal Behaviour Science* **129**, 2011, 111–120.

Buijs S., Keeling L.J. and Tuyttens F.A.M., Using motivation to feed as a way to assess the importance of space for broiler chickens, *Animal Behaviour* **81**, 2011, 145–151.

Buijs S., Keeling L., Rettenebacher S., Van Poucke E. and Tuyttens F.A.M., Stocking density effects on broiler welfare: Identifying sensitive ranges for different indicators, *Poultry Science* **88**, 2009, 1536–1543.

Busch G.S. and Achim C.S., Citizens' evaluation of animal welfare on pictures of intensive broiler fattening, *German Journal of Agricultural Economics* **641**, 2015, 131–144.

Collins L.M., Asher L., Pfeiffer D.U., Browne W.J. and Nicol C.J., Clustering and synchrony in laying hens: The effect of environmental resources on social dynamics, *Applied Animal Behaviour Science* **129**, 2011, 43–53.

Cooper M.D. and Wrathall J., Assurance schemes as a tool to tackle welfare problems in farm animals: Broilers, *Animal Welfare* **19**, 2010, 51–56.

Cravener T.L., Roush W.B. and Mashaly M.M., Broiler production under varying stocking population densities, *Poultry Science* **71** (3), 1992, 427–433.

Das H. and Lacin E., The effect of different photoperiods and stocking densities on fattening performance, carcass and some stress parameters in broilers, *Israel Journal of Veterinary Medicine* **69**, 2014, 211–220.

Dawkins M.S., Donnelly C.A. and Jones T.A., Chicken welfare is influenced more by housing than by stocking density, *Nature* **427**, 2004, 342–344.

Dawkins M.S., Battery hens name their price: Consumer demand theory and the measurement of ethological "needs", *Animal Behaviour* **31**, 1983, 1195–1205.

Dawkins M.S., The science of animal suffering, *Ethology* **114**, 2008, 937–945.

Dawkins M.S. and Hardie S., Space needs of laying hens, *British Poultry Science* **30**, 1989, 413–416.

Dawkins M.S., Edmond A., Lord A., Solomon S. and Bain M., Time course of changes in egg-shell quality, faecal corticosteroids and behaviour as welfare measures in laying hens, *Animal Welfare* **13**, 2004, 321–328.

De Jong, I., Berg, C., Butterworth, A., & Estevez, I. *Scientific report updating the EFSA opinions on the welfare of broilers and broiler breeders*. (2012). <http://www.Efsa.europa.eu/publications>.

de Jong I.C., van Voorst S., Ehlhardt D.A. and Blokhuis H.J., Effects of restricted feeding on physiological stress parameters in growing boiler breeders, *British Poultry Science* **43**, 2002, 157–168. http://dx.doi.org/10.1080/00071660120121355.

de Jonge J.T. and Hans C.M., The impact of broiler production system practices on consumer perceptions of animal welfare, *Poultry Science* **92**, 2013, 3080–3095.

Dozier W.A., Thaxton J.P., Purswell J.L., Olanrewaju H.A., Branton S.L. and Roush W.B., Stocking density effects on male broiler grown to 1.8 kilograms of body weight, *Poultry Science* **85** (2), 2006, 344–351.

Dozier W.A., Thaxton J.P., Branton S.L., Morgan G.W., et al., Stocking density effects on growth performance and processing yields of heavy broilers, *Poultry Science* **84**, 2005, 1332–1338.

Ellerbrock S. and Knierim U., Static space requirements of male meat turkeys, *Veterinary Record* **151**, 2002, 54–57.

Estevez I., Density allowances for broilers: Where to set the limits?, *Poultry Science* **86**, 2007, 1265–1272.

European Union, Council Directive 2007/43/EC Laying down minimum rules for the protection of chickens kept for meat production, *Official Journal of the European Union* **182**, 2007, 19–28.

Faure J.M., Choice tests for space in groups of laying hens, *Applied Animal Behaviour Science* **39**, 1994, 89–94.

Febrer K., Jones T.A., Donnelly C.A. and Dawkins M.S., Forced to crowd or choosing to cluster? Spatial distribution indicates social attractiob in broiler chickens, *Animal Behaviour* **72**, 2006, 1291–1300.

Feddes J.J.R., Emmanuel E.J. and Zuidhof M.J., Broiler performance, BW variance, feed and water intake, and carcass quality at different stocking densities, *Poultry Science* **81**, 2002, 774–779.

Fraser D., Duncan I.J.H., Edwards S.A., Grandin T., Gregory N.G., et al., General principles for the welfare of animals in production systems: The underlying science and its application, *The Veterinary Journal* **198**, 2013, 19–27.

Ghosh S., Majumder D. and Goswami R., Broiler performance at different stocking density, *Indian Journal of Animal Research* **46**, 2012, 381–384.

Giersberg M.F., Hartung J., Kemper N. and Spindler B., Floor space covered by broiler chickens kept at stocking densities according to Council Directive 2007/43/EC, *The Veterinary Record* **179**, 2016, 124.

Gomes A.V.S., Quinteiro-Filho W.M., et al., Overcrowding stress decreases macrophage activity and increases *Salmonella enteritidis* invasion in broiler chickens, *Avian Pathology* **43**, 2014, 82–90.

Grigor P.N., Hughes B.O. and Appleby M.C., Social inhibition of movement in domestic hens, *Animal Behaviour* **49**, 1995, 1381–1388.

Guardia S., Konsak B., Combes S., Levenez F., Cauquil J.-F., Moreau-Vauzelle C., et al., Effects of stocking density on the growth performance and digestive microbiota of broiler chickens, *Poultry Science* **90**, 2011, 1878–1889.

Hall A., The effect of stocking density on the welfare and behaviour of broiler chickens reared commercially, *Animal Welfare* **10**, 2001, 23–40.

Hall C. and Sandilands V., Public attitudes to the welfare of broiler chickens, *Animal Welfare* **16**, 2007, 499–512.

Heckert R.A., Estevez I., Russek-Cohen E. and Pettit-Riley R., Effect of density and perch availability on the immune status of broilers, *Poultry Science* **81**, 2002, 451–457.

Hester P.Y., The effects of perches installed in cages on laying hens, *World's Poultry Science Journal* **70**, 2014, 247–263.

Hughes B.O. and Duncan I.J.H., Do animals have behavioural needs?, *Applied Animal Ethology* **7**, 1981, 381–393.

Hughes B.O., Carmichael N.L., Walker A.W. and Grigor P.N., Low incidence of aggression in large flocks of laying hens, *Applied Animal Behaviour Science* **54**, 1997, 215–234.

Hunniford M.E., Torrey S., Bedecarrats G., Duncan I.J.H. and Widowski T.M., Evidence of competition for nest sites by laying hens in large furnished cages, *Applied Animal Behaviour Science* **161**, 2014, 95–104.

Hurnik J.F. and Lewis N.J., Use of body surface area to set minimum space allowances for confined pigs and cattle, *Canadian Journal of Animal Science* **71**, 1991, 577–580.

Hushmand M., Azhar K., Zulkifli I., Bejo M.H. and Kayab A., Effects of prebiotic protein level and stocking density on performance, immunity and stress indicators of broilers, *Poultry Science* **91**, 2012, 393–401.

Jang I., Hyon K.O., Young M. and Yang S., Effect of stocking desnity and strain on the performance and physiological adaptive response in broiler chickens, *Korean Journal of Poultry Science* **41**, 2014, 205–215.

Jankowski J., Mikulski M., Tatara M.R. and Krupski W., Effects of increased stocking density and heat stress on growth, performance, carcass characteristics and skeletal properties in turkeys, *The Veterinary Record* **176**, 2015, 21.

Jones T.A., Donnelly C.A. and Dawkins M.S., Environmental and management factors affecting the welfare of chickens on commercial farms at five densities, *Poultry Science* **84** (8), 2005, 1155–1165.

Knierim U., Effects of stocking density on the behaviour and bodily state of broilers fattened with a target live weight of 2 kgs, *Berlinner und Munchener Tierarztliche Wochenchrift* **126**, 2013, 149–155.

Knowles T.G., Kestin S.C., Haslam S.M., Brown S.N., Green L.E., Butterworth A., ... Nicol C.J., Leg disorders in broiler chickens: Prevalence, risk factors and prevention, *PLOS One* **3** (2), 2008, e1545.

Leone E.H., Christman M.C., Dougllas L., et al., Separating the impact of groups size, density, and enclosure size on broiler movement and space use at a decreasing perimeter to area ratio, *Behavioural Processes* **83**, 2010, 16–22.

Leone E.H. and Estevez I., Use of space in domestic fowl: Separating the effects of enclosure size, group size and density, *Animal Behaviour* **765**, 2008, 1673–1682.

Liste G., Campderrich I., Beltran de Heredia I. and Estevez I., The relevance of variations in group size and phenotypic appearance on the behaviour and movement patterns of young domestic fowl, *Applied Animal Behaviour Science* **163**, 2015, 144–157.

Makagon M.M. and Mench J.A., Floor laying by Pekin ducks:effects of nest box ratio and design, *Poultry Science* **90**, 2011, 1179–1184.

Malleau A.E., Duncan I.J.H. and Widowski T.M., The importance of rest in young domestic fowl, *Applied Animal Behaviour Science* **106**, 2007, 52–69.

Marchewka J., Watanabe T.T.N., Ferrante V. and Estevez I., Review of the social and environmental factors affecting the behaviour and welfare of turkeys (*Meleagris gallopavo*), *Poultry Science* **92**, 2013, 1467–1473.

Mench J.A. and Blatchford R.A., Determination of space use by laying hens using kinematic analysis, *Poultry Science* **93**, 2014, 794–798.

Najali P.Z., Idrus J., Nurfarahin A.F., Abdoreza S., et al., Environmental and stocking density effects on actute phase proteins, heat shock protein 70, circulating corticosterone and performance in broiler chickens, *International Journal of Biometrology* **59**, 2015, 1577–1583.

Nicol C.J., Gregory N.G., Knowles T.G., Parkman I.D. and Wilkins L.J., Differential effects of flock size, on feather pecking and aggression in laying hens, *Applied Animal Behaviour Science* **65**, 1999, 137–152.

OIE. (2012). Introduction to the recommendations for animal welfare. In *Terrestrial animal healthcode*, 21st ed. Paris, France: World Organisation for Animal Health (OIE). Article 7.1.4.

Pagel M. and Dawkins M.S., Peck orders and group size in laying hens: Futures contracts' for non-aggression, *Behavioural Processes* **40**, 1997, 13–25.

Paul E.S., Harding E.J. and Mendl M., Measuring emotional processing in animals: The utility of a cognitive approach, *Neuroscience and Biobehavioral Reviews* **29**, 2005, 469–491.

Pereira D., Batista F., Sanches E.S., Teiceira F., et al., Behavior of hens reared at different stocking densities and group sizes in an enriched environment, *Pesquisa Agropecuaria Brasileirava* **48**, 2013, 68–2688.

Petek M., Ustuner H. and Yesilbag D., Effects of stocking desnity and litter type on litter quality and growth performance of broiler chicken, *Kafkas Universitesi Veteriner Fakultesi Dergisi* **20**, 2014, 743–748.

Petherick J.C., A biological basis for the design of space in livestock housing, In: Baxter S.H., Baxter M.R. and MacCormack J.A.C., (Eds.), *Farm animal housing and welfare,* 1983, Martibus Nijhoff, The Netherlands, 103–120.

Robins A. and Phillips C.J.C., International approaches to the welfare of meat chickens, *World's Poultry Science Journal* **67**, 2011, 351–359.

RSPCA. (2013). *Space requirements and flock size. Welfare Standards for chickens.* (pp. 13–14). <http://science.rspca.org.uk/sciencegroup/farmanimals/standards-for-chickens>.

Rushen J., Problems associated with the interpretation of physiological data in the assessment of animal welfare, *Applied Animal Behaviour Science* **28**, 1991, 381–386.

Shanawany M.M., Broiler performance under high stocking densities, *British Poultry Science* **29**, 1988, 43–52.

Sirri F., Minelli G., Folegatti E., Lolli S. and Meluzzi A., Foot dermatitis and productive traits in broiler chickens kept with different stocking densities, litter types and light regimen, *Journal of Animal Science* **6**, 2007, 734–736.

Sørensen P., Su G. and Kestin S.C., Effects of age and stocking density on leg weakness in broiler chickens, *Poultry Science* **79**, 2000, 864–870.

Spindler B., Giersberg M.F., Briese A., Kemper N. and Hartung J., Spatial requirements of poultry assessed by using a colour contrast method (KobaPlan), *British Poultry Science* **57**, 2016, 23–33.

Steenfeldt S. and Nielsen B.L., Welfare of organic laying hens kept at different indoor stocking densities in a multi-tier aviary system. II. Live weight, health measures and perching, *Animal* **9**, 2015, 1518–1528.

Thogerson C.M., Hester P.Y., Mench J.A., Newberry R.C., Okura C.M., Pajor E.A., ... Garner J.P., *Poultry Science* **88**, 2009, IS9 doi:10.3382/ps2009-00011..

Thomas D.G., Ravindran V., Thomas D.V., et al., Influence of stocking density on the performance, carcass characteristics and selected welfare indictors of broiler chickens, *New Zealand Veterinary Journal* **52**, 2004, 76–81.

Thomas D.G., Son J.H., Ravindran V. and Thomas D.V., The effect of stocking density on the behaviour of broiler chickens, *Korean Journal of Poultry Science* **38**, 2011, 104.

Thorpe, W. H. (1965). *The assessment of pain and distress in animals. Appendix to Report of the technical committee to enquire in to the welfare of animals kept under intensive livestock systems* (pp. 71–77). Chairman F.W.R Brambell Command Paper 2837. London: HMSO.

Tsiouris V., Georgopoulu I., Batzios C., Pappaioannou N., ducatelle R. and Fortomanis P., High stocking density as a predisposing factor for nectrotic enteritis in broiler chicks, *Avian Pathology* **44**, 2015, 59–66.

Tuyttens F., Vanhonecker F. and Verbeke W., Broiler production in Flanders: Current situation and producers' opinions about animal welfare, *World's Poultry Science Journal* **70**, 2014, 343–354.

Utnik-Banas K., Zmija J. and Sowula-Skrzynska E., Economic aspects of reducing stocking density in broiler chicken production using the example of farms in Southern Poland, *Annals of Animal Science* **141S**, 2014, 663–671.

Ventura B.A., Siewerdt F. and Estevez I., Effects of barrier perches and density on broiler leg health, fear and performance, *Poultry Science* **89**, 2010, 1574–1583.

Vestergaard K.S., Dustbathing in the domestic fowl- dirna rhythm and dust deprivation, *Applied Animal Ethology* **7**, 1982, 487–495.

Xie M., Jiang Y., Tang J., Wen Z.G., Huang W. and Hou S.S., Effects of stocking density on growth performance, carcass traits and foot pad lesions of White Pekin ducks, *Poultry Science* **93**, 2014, 1644–1648.

Zuowei S., Yan L., Yuan L., Jiao H., Song Z., Guo Y. and Lin H., Stocking density affects the growth performance of broilers in a sex-dependent fashion, *Poultry Science* **90**, 2011, 1406–1415.

Further Reading

Farm Animal Welfare Council. <https://www.gov.uk/government/groups/farm-animal-welfare-committee-fawc#assessment-of-farm-animal-welfare---five-freedoms-and-a-life-worth-living>. Accessed 09.11.16.

Abstract

The difficulties of defining the space needs of poultry are only partly due to methodological discrepancies between studies and therefore only partly rectifiable by more research along previous lines. "Space" fo poultry is far more complex than can be summed up in one single number and too much reliance on stocking density without considering what space contains is unlikely to improve welfare. Space needs are considere in relation to effects of varying amounts of space on bird physical health, their social responses, and their responses to enrichments. Space needs have been measured in various ways including the animals' ow preferences, spatial distribution, area covered, and behavior linked with positive and negative affect. A possible way forward is to be more specific about the space needs that poultry have for performing specifi behavior patterns that either have an effect on their health or can be demonstrated to be important to the birds themselves.

Keywords: Poultry behavior; animal welfare; space allowances; stocking density

Queries and Answers

Query: The city name has been inserted for the affiliation. Please check, and correct if necessary.

Answer: correct

Query: “de Jonge (2013)”, “Das et al. (2014)”, and “Baille and O’Connell (2014)” have been changed to “De Jonge and Hans (2013)”, “Das and Lacin (2014)”, and “Baille and O’Connell (2015)” as per the reference list. Please check and confirm if the changes made are correct.

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Query: The reference given here is cited in the text but is missing from the reference list – please make the list complete or remove the reference from the text: Dawkins et al. (2004), Sorensen (2000), Knierim et al. (2013), Ventura et al. (2012).

Answer: Dawkins et al., 2004 is present and correct (although there are two papers for Dawkins et al 2004 1. Dawkins, Donnelly and Jones (2004) and Dawkins, Edmond, Lord, Solomon and Bain (2004) These have perhaps been confused? Sorensen (2000) is correct but Knierim et al should be Knierim, U. (2013) and Ventura et al (2012) should be Ventura et al. (2010) as in the reference list

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