21-Final Report – CDFA Agreement 09-0854, "*Determination of Space Use by Laying Hens*" by Joy Mench, Department of Animal Science, University of California, Davis, CA 95616

FINAL REPORT – CDFA AGREEMENT 09-0854

"Determination of Space Use by Laying Hens"

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Background

In 2008, California voters approved Proposition 2: Standards for Confining Farm Animals. This Proposition states that farm animals in confinement must not be prevented, for a majority of the day, from standing up, lying down, fully extending their limbs, and turning around freely. In regards to egg-laying hens, it specifically defines extending limbs as meaning that hens must be able to fully spread both wings without touching the side of an enclosure or other hens. The Proposition does not stipulate what the amount of space provided to hens should be, simply that it should be sufficient to accommodate the specified behaviors. The passage of this Proposition reflects a growing public interest in the treatment and welfare of farm animals, but the Proposition itself poses conceptual problems related to setting legal standards for hen housing.

There is a large body of research assessing the behavior and welfare of laying hens in different housing systems (see review in Lay et al., 2011). Much of this research has been conducted since the European Union (EU) decided in 1999 to ban conventional (battery) cages, effective as of 2012 (Mench et al., 2011). The conventional cage housing system is used for the majority of world egg production (Mench et al., 2011), but came under criticism in the EU because it restricts the behavior of the hens (Appleby, 2003). As of the effective date of the ban, EU producers will be required to house their hens either in non-cage systems (i.e. barns, aviaries, or free range) or in enriched cages. All of these systems must provide perches, nests, and a littered area in which the hens can forage (scratch and peck). These requirements are based on research showing that hens are highly motivated to perform these particular behaviors (Weeks and Nicol, 2006; Lay et al., 2011). The consensus among the animal welfare scientists in the EU who authored the influential Laywel report is that both non-cage systems and furnished cages can provide acceptable hen welfare, if properly configured and managed (Laywel; www.laywel.eu).

Of course, in order for animals to perform particular behaviors sufficient space is also required. Minimum space standards have been established for both cage and non-cage housing for hens in the EU (CEC, 1999). These standards are based upon scientific research, practical experience and discussion occurring during comments on proposed regulations (e.g. Appleby, 2003). The US egg industry has also adopted minimum space standards (UEP, 2010) after a review of existing literature that focused mainly on mortality, feather quality, stress, and egg production data for caged hens (Bell et al., 2004), as well as practical experience for non-cage systems where there was less available published data. These EU and UEP space requirements are summarized in Table 1.

While there has been a significant amount of research on the effects of stocking density in different housing systems on health, production, and use of resources, there has been far less research on the way in which hens utilize space during the performance of particular behaviors. Most of this work has centered on evaluating what hens do in spaces of different sizes, particularly in the context of social interactions and spacing between flock members (see review in Weeks and Nicol, 2006). For example, Keeling (1994) studied groups of three hens kept together in pens that varied in size, providing from 93 in^2 (600 cm^2) to 873 in^2 (5630 cm^2) of space per hen. She found that the hens spaced at different distances from one another depending on the behaviors that they were performing. They were furthest apart when walking (mean 310 cm; 12.2 in), closer to one another when standing (234 cm, 9.2 in) and ground pecking (237 cm; 9.3 in), and closest when preening (154 cm; 6.1 in). As enclosure size decreased ground pecking and walking decreased, suggesting that these behaviors are sensitive to space allocation. Preening did not change with less space, but the amount of time spent standing increased. Savory et al. (2006) evaluated preening, walking, standing and ground pecking behaviors in hens provided with amounts of space varying from 93 in^2 (600 cm^2) to 1860 in^2 (12,000 cm^2) per hen in 5-6 hen groups. They concluded that space allowances of less than 775 in^2 per hen (5000 cm2) resulted in at least some restriction of walking and ground pecking, while standing and preening were increased at lower space allowances.

Table 1. EU and UEP minimum space requirements for different housing systems

System and Aspects		European Union	United Egg Producers
Conventional cages*	Floor area per hen	85.3 in^2 (550 cm^2) of unrestricted space	67-86 in^2 usable space, depending upon hen size and cage configuration
	Enclosure height	No less than 13.8 in (35 cm) at any point; at least 15.7 in (40 cm) over 65% of cage area	No numerical requirement, but must be sufficient for hens to "stand comfortably upright"
Enriched cages	Floor area per hen	116.3 in^2 (750 cm^2) per hen**, 93 in^2 (600 cm^2) of which must be of usable height	No standards for enriched cages
	Enclosure height	Must be at least 17.7 in (45 cm) to be considered "usable;" cage height outside usable area no less than 7.9 in (20 cm)	
	Minimum enclosure size	310 in^2 (2000 cm^2)	
Non-cage systems	Floor/barn‡	1.2 ft^{2**} (9 hens/m^2) usable area	1.5 ft^{2**}
	Floor barn with roosting area over droppings pit	Same	1.2 ft^2** for brown hens, 1.0 ft^2** for white hens
	Multi-level (aviary)	Same	1.0 ft^{2**}

*Will be banned in the EU effective 2012

** Excluding the nest area

‡ A higher stocking density, 12 hens/m^2, could be authorized by Member States until December 31, 2011, for systems installed before August 3, 1999 in which the usable area corresponded to the available ground surface

Interpreting such results to arrive at more global generalizations about the amount of floor space required in a particular hen production system is extremely difficult. Many factors influence how hens use space (Keeling, 1995). In addition, individual hen movements can be constrained by social factors such as the hen's position in the dominance hierarchy.

Another approach to determining space requirements is to measure the amount of space required for free expression of different behaviors. Dawkins and Hardie (1989) conducted video analysis of singly housed hens given 1042 in^2 of space, and evaluated, by measuring the video images, the amount of space required for the hens to stand, ground scratch, turn, wing stretch, wing flap, feather ruffle, and preen; they did not measure the space required for lying. They used Ross Brown hens, which are larger birds than the white birds that make up the majority of U.S. egg production; however, the general approach that they used is appropriate for determining free movement to address the language of Proposition 2.

A new technology, 3-D kinematics, is a more accurate method for determining the amount of space used by animals to perform behaviors than the method used by Dawkins and Hardie (1989), and has the additional advantage of measuring variables in three dimensions. Kinematic research has been used to analyze gaits in many sports animals, such as Greyhound dogs (Hottinger et al., 1996) and thoroughbred horses (Deguerce et al., 1996; Clayton et al., 1998). More recently, this method has been used to assess the amount of space dairy cows use when lying down (Ceballos et al., 2004). The researchers concluded that this method provided an accurate measure of the movements of lying behavior, and also used that information to assess the design of stalls and how that may impede those movements.

The goal of the current study was to use kinematic analysis to evaluate the space required for Hy-Line W36 hens, the strain most commonly used in U.S. egg production, to stand up, lie down fully extend their limbs (i.e. extend both wings, a behavior called "wing flapping"[1]), and turn around freely.

Methods

Ten mature (approximately 1.5 yr of age), well-feathered Hy-Line W-36 hens from the flock housed at the Hopkins Avian Research Facility at the UC Davis were selected to be observed for this study. One hen began molting and had to be removed from the study. Another was euthanized for flock management reasons prior to the recording of lying down behavior (see below); all other hens were returned to the flock after being filmed.

Each hen was marked with black livestock marker on the top of her head, tip of her tail, top of her toes, and tips of her wings. The hens were placed individually in a 3ft x 3ft floor pen (total area: 1296 in^2) for up to 1 hour and video recorded for kinematic analysis. They were recorded: 1) standing in a relaxed posture; 2) turning 180 degrees; and 3) wing flapping. A perch was placed in the pen to stimulate the hens to jump up and down and thus to wing flap. Because none of the hens laid down during the test period, space required for lying was determined by

[1] Hens can perform two kinds of movements when extending both wings (Albentosa and Cooper, 2004). Full extension, which involves raising the wings out to the side/over the head, is called a wing flap. Less-than-full extension is called a wing raise. Previous papers often combine these types of behaviors but refer to them generically as "wing flaps". In this study we recorded the type of bilateral wing movement that is the most space-consuming, the full extension wing flap.

recording the hens from above in their individual 18" x 18" (324 in^2) home cages and superimposing a pre-measured grid over the video recording.

The videos of standing, turning, and wing flapping were analyzed for 3-dimensional space use using Vicon Motus 9.2 software. The average floor space used by the hens was calculated for each behavior using the maximum length and width of the hens. Floor space required for lying was determined by measuring a hen's length from head to tail and her width at the widest cross-section when she was lying down.

Results

Space measurements are shown in Table 2. Because of the wording of Proposition 2, which requires that the hen not touch other hens or the sides of the enclosure when "stretching both wings" (wing flapping), wing flapping is given both as the determined value and with 1 inch added to the maximum determined length and width of the hens to meet this requirement. The selection of 1 inch was arbitrary.

Table 2. The floor area (in^2) used by hens when performing particular behaviors, as well as the height (in), wingspan (in), and wing flap floor area (in^2) with 1 inch added to the length and width of the hen.

Behavior	Area Mean (± SEM)	Range	Height Mean (± SEM)	Height Range	n
Stand	87.3 ± 1.2	60.6 – 111.1	13.7 ± 0.5	12.0 – 16.2	9
Turn (180°)	203.9 ± 3.6	143.5 – 339.6	15.2 ± 0.9	12.1 – 20.6	9
Lie Down	49.3 ± 0.99	45.0 – 52.0	--	--	8
Wing Flap	213.6 ± 2.9	165.6 – 287.0	19.9 ± 0.8	14.8 – 22.5	9
Wingspan	16.7 ± 1.6	14.2 – 18.3	--	--	9
Wing Flap + One Inch	244.0 ± 13.1	192.5 – 321.9	20.9 ± 0.8	15.8 – 23.5	9

The mean body weight of the hens was 3.5 ± 0.2 lbs (1.55 ± 0.7 kg). The range was from 2.9 - 4.3 lbs (1.31 to 1.94 kg).

Discussion

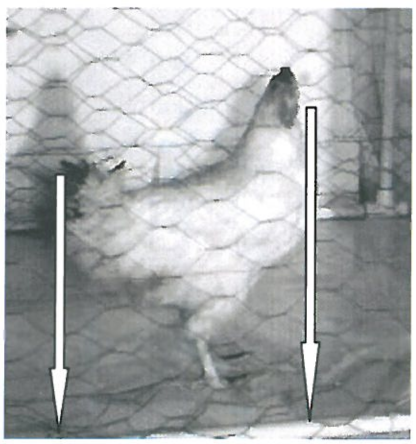
A comparison of these data with those published by Dawkins and Hardie (1989) for brown birds shows the following similarities and differences:

1. The mean value for standing is larger than the value found for brown birds (73.7 in^2), and the range of values is also wider than for brown birds (66.3-91.8 in^2). The hen's head position during standing plays an important role in determining the necessary floor area for the kinematic analysis, since the area is measured using the "drop" from the beak tip and the "drop" from the tail (Figure 1). In the current study the hens were evaluated in standing

positions where their heads were held erect and standing positions where their heads were extended. This may have contributed to the somewhat larger means and wider ranges found.

2. The mean value for turning is very similar to that found for brown birds (197.1 in^2), although the range is larger (152-252 in^2). Animals can, of course, make turns that vary widely in the area covered, depending upon why they are turning around. In the current study turning was defined as a 180 degree turn; the Dawkins and Hardie (1989) study does not state what definition was used.
3. The mean for wing-flapping was smaller than for brown birds (290.0), and the range was narrower (168.2 – 403.9). Brown birds typically have a larger body size than white birds (the hens in the Dawkins and Hardie study ranged from 4.2 to 5.6 lbs, with a mean of 4.8 lbs) and thus some strains may also have a bigger wing span, although Dawkins and Hardie did not provide information about the wing spans of the hens in their study.

A)



B)

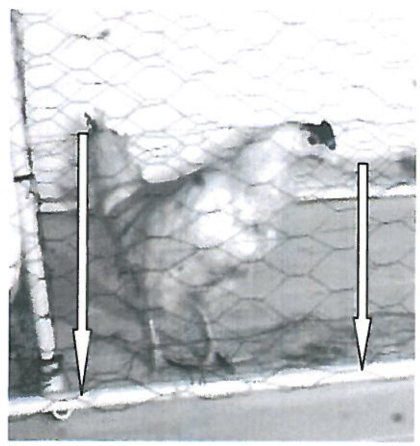


Figure 1. Two standing postures: A) an erect head and tail, using less floor space, and B) an elongated head and tail, increasing the length of the hen and using more floor space. The arrow show the "drop" used in the calculation of the floor area required for free movement.

In terms of Proposition 2, the implications of these data are that enclosures that provide less than 322 square inches in total floor area (the maximum area recorded for wing flapping plus one inch in each dimension), or that do not have either a length or a depth of at least 20.3 inches (the maximum recorded wingspan plus one inch added to each wing so that the hen does not touch the sides of the enclosure), do not meet the requirements of the Proposition[2]. An enclosure that meets (but does not exceed, as per the information discussed below) these standards can house only one hen.

It is also possible that enclosures that do not have a height of at least 22.5 inches (the maximum height recorded for wing flapping) over the minimum 322 square inch floor area might prevent wing flapping because of insufficient height, but this would have to be studied in more detail. Nicol (1987) observed hens kept in cages of varying heights (11.8, 16.7 and 21.7 in; 30.0, 42.5

[2] Note that this area would also accommodate turning, using the average turning area found

and 55.0 cm, respectively). Wing flapping was observed only at the 21.7 cage height. Albentosa and Cooper (2004) compared 15 in (38 cm) tall cages to 17.7 in (45 cm) tall cages, and observed wing flapping only in the latter. In both studies, however, wing flapping was extremely rare and there were no statistically significant differences between treatments, so these data are only suggestive.

Extrapolating beyond these implications to derive a minimum cage space recommendation is very difficult because of the lack of clarity of the Proposition with respect to how many hens need to be able to simultaneously perform the particular behavior(s) listed. One interpretation would be that, in addition to providing sufficient room for one of the hens to have 322 square inches of space to flap her wings without touching other hens or the side of the enclosure, there has to be sufficient room for all other hens to stand. Hens in all housing systems spend a significant proportion of their day standing (e.g. Keeling, 1994; Channing et al., 2001; Savory et al., 2006), and since hens tend to synchronize their activities (e.g. Mench et al., 1986; Webster and Hurnik, 1994; Collins et al., 2011) many hens in the enclosure are likely to be standing at the same time.

With these assumptions, and using the maximum value for wing flapping and the average value for standing found in this experiment, we can estimate the amount of floor space required per hen given different group sizes (n) as follows: $322 + [(n-1) \times 87.3]/n$. This equation was used to generate Figure 2, which shows the amount of space needed per hen for different group sizes. As the figure shows, less space per hen is required as group size increases, although obviously the overall size of the enclosure would also increase (e.g., an enclosure for 5 hens would need to provide at least 671 square inches of usable floor space, one with 10 hens would need to provide at least 1,108 square inches, and one with 60 hens at least 5,472 square inches, with usable floor space defined as space that has sufficient height for hens to stand comfortably; the maximum standing height value found in the kinematic analysis was 16.2 in). The floor space required per hen essentially levels off at approximately 90-91 square inches when the group size reaches 60, although very large groups (1000 or more) require slightly less space per hen (87-88 square inches).

These results accord with theoretical predictions about the relationships between enclosure/group size and freedom of movement. For example, Appleby (2004) modeled the space required for free movement of hens in furnished cages, and demonstrated that larger enclosures were associated with more free movement even if hens were each provided with only slightly more space than their body size. In larger enclosures free space opens up because hens do not use all of the space available to them. Instead, they tend to cluster rather than space evenly (Keeling and Duncan, 1989), mainly because multiple hens are trying to access particular resources in the enclosure at the same time (Collins et al., 2010). Appleby (2004) noted that this additional space allows local freedom of movement important for basic behavior patterns such as feeding, scratching, stretching, preening and sitting. Based on his calculations he recommended that hens be provided with a minimum space of 600 cm^2 (93 in^2) per hen in the main area of their enclosure (meaning, the area not occupied by the nest or the litter area for foraging) in order to allow sufficient free space for local movement.

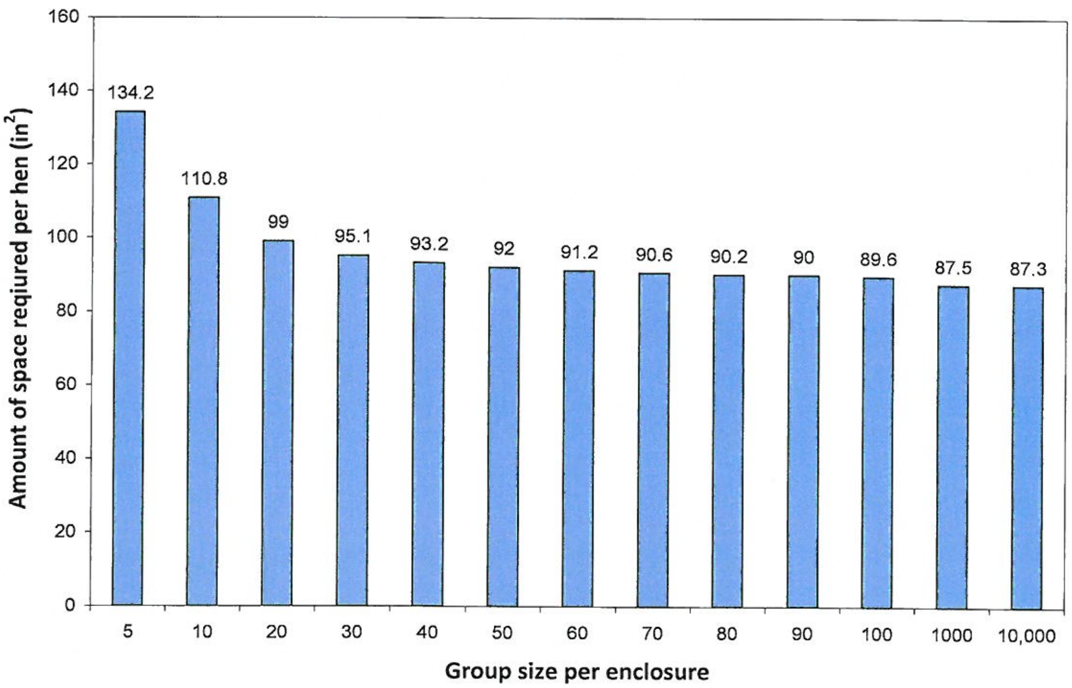


Figure 2. Change in the amount of floor space needed per hen as group size increases. The numbers are based on the assumptions and calculation provided above.

It should be stated that a variety of different factors can affect how much space hens need and how they use that space (Keeling, 1995). These include genetics, group size, environmental factors (e.g. ambient temperature), hen age, social effects (e.g. group size), and most particularly the resources that are provided in the housing system. For example, space needs will be greater in systems where resources are more widely distributed. The space value calculated above (Figure 2) for 60-hen groups is virtually identical to the minimum EU usable floor space requirement for furnished cages (Table 1), which would typically contain from 5-60 hens. However, the value calculated for very large groups (such groups would be housed in non-cage systems in groups of thousands to tens of thousands of hens), is below both the EU and UEP standards. Housing hens at this high of a stocking density in a typical non-cage system would have negative effects on their welfare. Hens in non-cage systems require additional free movement space in order to ensure that they can access feed, water and other resources, since these resources are separated by greater distances than in cage systems. If resources are distributed in such a way that vertical movement is required (for example in aviary systems – see Mench et al., 2011), that can not only impose different space needs but also affect the space that hens use in performing particular behaviors (for example, a hen will need more space to flap her wings during vertical flight than when she is balancing on a perch).

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