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SID 5 Research Project Final Report

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Project identification

1. Defra Project code: AW1132
2. Project title: A comparative study to assess the welfare of laying hens in current housing systems.
3. Contractor organisation(s): University of Bristol
4. Total Defra project costs (agreed fixed price): £ £262,126.00
5. Project: start date .... 01 September 2004
   end date .... 01 September 2007

6. It is Defra's intention to publish this form.
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(b) If you have answered NO, please explain why the Final report should not be released into public domain

Executive Summary

7. The executive summary must not exceed 2 sides in total of A4 and should be understandable to the intelligent non-scientist. It should cover the main objectives, methods and findings of the research, together with any other significant events and options for new work.

The conditions under which laying hens are housed remain a major animal welfare issue for consumers, the egg production industry and legislators. This study examined the costs and benefits of each housing system using measures which are directly comparable between husbandry systems. The aims of the study were to: (1) Assess, in a cost-effective manner, the welfare of hens in a representative range of current UK housing systems. (2) Assess the potential for practical, affordable improvement in areas where welfare is compromised. (3) Develop an open framework, with all assumptions clearly stated, within which the welfare costs and benefits of different systems can be clearly identified.

Objective 1

Twenty six flocks were enrolled, representing conventional cages, furnished cages, barn and free-range systems. Each flock was visited 3 times throughout the laying period. During Visit 1, data were collected on the history of the hens prior to placement, and the housing and husbandry to be used throughout the laying period. On Visits 1, 2 and 3, the researchers collected data on the current husbandry, climate, health and welfare of the hens. On all 3 visits, behavioural observations and faecal samples were collected as indicators of welfare that were considered to be important, valid and fair (i.e. not confounded by the housing system). To collect long-term climate data, data loggers programmed to record air temperature, relative humidity and light intensity at 1-hr intervals were installed. At the end of lay, 150 hens from 19 of the flocks underwent post-mortem examination by a team of 5 trained staff. The hens were weighed, numbered and assessed for beak deformities, skin damage, parasites, plumage damage, plumage soiling, vent damage (not from pecking), evidence of vent pecking, foot condition, keel protrusion and fractured keel bones. During Visit 1, the producers were asked to complete and return a 'Weekly Welfare Assessment' form. This contained questions on a range of welfare indicators and also changes in husbandry. In addition, the producers were asked to complete at 30, 50 and 70 weeks of age a 'Causes of Mortality' form. Producers also supplied production records at the end of the study.

Results: researcher collected data

Five welfare indicators collected by the researcher visits were significantly influenced by the type of housing system. These were, gentle feather pecks, mean feather damage score, mean % hens with feather damage, mean % hens using the perches, and, faecal corticosterone. Barn hens had the highest feather damage score, the highest number of hens with feather damage, and the greatest faecal corticosterone concentrations. Free-range hens did most gentle feather pecking, but had the lowest feather damage scores (reflecting the fact that it is severe feather pecking that results in plumage loss). Hens from furnished cages had the lowest faecal corticosterone. For all systems, both the feather damage score and the number of hens with feather damage increased with time. Faecal corticosterone concentrations followed an inverted 'U' pattern over the duration of the laying period.

Results: post-mortem

Body conformation - Barn hens had the lightest body-weight at post-mortem and had the greatest prevalence of severe keel protrusion. Hens from conventional cages were the heaviest at post-mortem and also had the lowest prevalence of keel protrusion. Many hens (not only from conventional cages) had large fat deposits indicative of pathological change.

Integument damage – Barn hens had worst plumage condition. Free-range hens were the most likely to have been vent pecked. Hens from conventional cages had the least skin damage. Furnished cage hens had the least feather damage and the lowest prevalence of vent pecking.

Skeletal injuries – Barn hens had the greatest prevalence of old keel fractures. Conventional cage hens had the greatest prevalence of new keel fractures. Hens from furnished cages had the lowest prevalence of keel fractures.

Results: climate

Air temperature - Barn systems had the highest recorded maximum air temperature, lowest recorded minimum air temperature and the greatest ranges of temperature.

Relative humidity (RH) - Furnished cage systems had the greatest maximum RH and Barn systems had the greatest mean RH. The highest recorded maximum and mean RH were both in the furnished cages. Conventional cages had the lowest maximum and mean RH.

Ammonia - Barns had the greatest maximum and mean ammonia concentrations. Free-range systems had the greatest range of mean ammonia concentrations. Furnished cage systems had the lowest maximum and mean ammonia concentrations, and also the smallest ranges of both these measures.

Results: System-independent risk factors

Many risk factors that were distributed across the 4 housing systems affected hen welfare. These included age at placement, hours of light, number of daily inspections and captures, perch width and climatic variables. There were positive correlations between max. air temp. and the proportion of hens found dead, and the proportion found dead due to injurious pecking. Furthermore, there were positive correlations between average air temp. and % hens affected by red mite, and weight of hens found dead. Greater variation in air temp. and RH were both positively correlated with increased deaths.

Data Collected by the Producers

Return rates - Weekly return rates of questionnaires from the producers were satisfactory, however, some questions were less likely than others to be answered. There appeared to be a large increase in not answering questions during the later parts of the study. We also noted discrepancies in data often related to the forms being completed by different staff.

Results - Hens in barns had the greatest percentage of eggs with calcification spots, greatest percentage of eggs with blood-stained eggshells, the greatest age-related increase in blood-stained eggshells, and the greatest age-related increase in proportion of hens placed found dead. Hens from furnished cages had the lowest mortality, vent pecking, keel fractures, eggs with blood or calcification spots on, number that were vent pecked, and the lowest concentrations of faecal corticosterone. Hens in conventional cages had the best body conformation and fewest keel breaks whilst in the cages. Free-range hens had the best feather score.

Objective 2

A workshop to consider the potential for improvement was scheduled for 3rd February 2009, at the FAI Field Station in Oxford. However, due to adverse weather conditions was rescheduled and held in the July 2009.

Objective 3

A framework setting out the welfare costs and benefits of each housing system has been devised. It achieves a number of goals, setting potential current benchmark levels based on current and previous data, highlighting systems that meet these benchmarks, highlighting significant differences between systems, and indicating the extreme variability found between flocks and systems for many welfare indicators.

Project Report to Defra

8. As a guide this report should be no longer than 20 sides of A4. This report is to provide Defra with details of the outputs of the research project for internal purposes; to meet the terms of the contract; and to allow Defra to publish details of the outputs to meet Environmental Information Regulation or Freedom of Information obligations. This short report to Defra does not preclude contractors from also seeking to publish a full, formal scientific report/paper in an appropriate scientific or other journal/publication. Indeed, Defra actively encourages such publications as part of the contract terms. The report to Defra should include:

- the scientific objectives as set out in the contract;
- the extent to which the objectives set out in the contract have been met;
- details of methods used and the results obtained, including statistical analysis (if appropriate);
- a discussion of the results and their reliability;

- the main implications of the findings;
- possible future work; and
- any action resulting from the research (e.g. IP, Knowledge Transfer).

Objective 1 *Assess the welfare of hens in a representative range of current UK housing systems in a valid and cost-effective manner. This will be achieved by an assessment of the condition of birds at start and end-of-lay, coupled with a full objective description of their housing system, management and environment and analysis of records relating to production and mortality.*

From the inception of this project it was known, and discussed with DEFRA, that sampling just 6 or 7 flocks per system would provide limited power to detect housing system differences *per se*. However, the project aims were not just to compare housing systems, but to obtain basic information on welfare-relevant information across a range of systems, to engage farmers in the process of data collection and to analyse risk factors for welfare problems that transcended system differences.

Flock Recruitment: Most of the flocks were recruited with the kind assistance of Noble Foods. We wrote to producers explaining the aims and purpose of the study, what we would be requesting from them, and followed this with a phone call approximately one week later. We also advertised the project in 'The Ranger' (a newsletter for free-range egg producers) and requested interested independent producers to contact us. The study was conducted on 26 flocks of a range of sizes and strains housed on 15 commercial layer units across the UK (Table 1). Flocks entered the study at between 16 to 20 weeks of age, and stayed within the study for a mean of 49 weeks (47 weeks for Barn (B) and Conventional Cage (CC) systems, 50 weeks for Free Range (FR), and 53 weeks for Furnished Cages (FC)).

Table 1 – Summary Information Of The Flocks Studied

Type Of System	Post-mortem	Used in AW0234	Strain	Rearing System	Beak Trimmed	No. Hens In Flock	Time in study (weeks of age)
FC	Yes	Obj 1	Hyline	litter	yes	1,056	18-71
FC	Yes	Obj 1	Hyline	litter	yes	1,440	18-71
FR (mobile)	No		Hyline	litter	**NO**	2,000	18-66
FR (mobile)	Yes	Obj 1	Lohmann	litter	**NO**	2,093	17-72
B	Yes	Obj 1 & 2	Hyline	litter	yes	5,740	19-69
FR (static)	No		Hyline+Lohmann	litter	yes	6,000	17-56
B	No		Hyline	litter	yes	6,350	17-57
FR (static)	Yes	Obj 1 & 2	Hyline	litter	yes	6,500	17-71
B	Yes	Obj 1 & 2	Hyline	litter	yes	7,655	19-69
FR (static)	No	Obj 2	Lohmann	litter	yes	8,000	17-66
FC	Yes	Obj 1	Hyline	litter	yes	11,550	18-71
FR (static)	Yes	Obj 2	Hyline	litter	yes	12,000	18-70
FR (static)	Yes	Obj 2	Hyline	litter	yes	13,248	17-71
B	Yes	Obj 1 & 2	Hyline	litter	yes	15,000	19-73
B	Yes	Obj 1 & 2	Hyline	litter	yes	15,000	19-73
B	Yes		Hyline	litter	yes	15,000	19-61
B	Yes		Hyline	litter	yes	15,000	19-61
FC	Yes	Obj 1	Bovan Goldline	litter	yes	28,650	20-79
FC	Yes		Hyline	litter	yes	29,000	20-72
CC	No		Lohmann	litter	yes	39,760	16-68
CC	Yes		Lohmann	litter	yes	39,760	16-72
FC	Yes		Isa Brown	litter	yes	45,450	16-64
CC	Yes		Lohmann	litter	yes	66,323	20-68
CC	Yes		Lohmann	**cage**	yes	98,950	19-70
CC	No		Hisex	litter	yes	106,400	17-70
CC	No		Hyine+Lohmann	litter	yes	107,581	16-39

Housing systems differed in a number of characteristics shown in Table 2

Table 2 – Significant Differences Between Housing Systems in Housing Characteristics

Housing Characteristic	Mean (SEM)	Test	p =	Order Of Systems
Age of the system (years)	8.2 (1.1)	$F_{3,23} = 9.1$	0.001	FC<FR<CC<B
Number of hens placed	30,143.4 (7,370.2)	$F_{3,25} = 20.5$	<0.001	FR<B<FC<CC
Duration of inspection (mins)	44.5 (9.3)	$F_{3,25} = 8.8$	<0.001	FR<B<FC<CC
Number of drinkers hen has access to	135.7 (55.9)	$F_{3,25} = 3.2$	0.041	CC<FC<FR<B
Number of feeders hen has access to	10.9 (4.8)	$F_{3,25} = 5.2$	0.007	CC=FC<B<FR
Total length of feeders (m)	181.3 (55.8)	$F_{3,25} = 14.6$	<0.001	CC<FC<FR<B
Length of feeder available (cm/hen)	6.6 (0.6)	$F_{3,25} = 22.5$	<0.001	FR<B<FC<CC
Total length of perches (m)	201.2 (86.5)	$F_{3,25} = 4.2$	0.016	CC<FC<FR<B
Length of perches available (cm/hen)	5.3 (1.2)	$F_{3,25} = 26.1$	<0.001	CC<FR<B<FC
Total length of perches (m)*	261.6 (109.4)	$F_{2,19} = 4.1$	0.036	FC<FR<B
Length of perches available (cm/hen)*	6.9 (1.4)	$F_{2,19} = 21.9$	<0.001	FR<B<FC
Number of nests hens have access to	88.7 (9.7)	$F_{3,25} = 26.4$	<0.001	CC<FC<FR<B
Nest opening length (cm)*	95.4 (7.1)	$F_{2,19} = 113.7$	<0.001	FC<B<FR
Nest length (cm)*	96.6 (6.5)	$F_{2,19} = 189.8$	<0.001	FC<B<FR
Nest width (cm)*	39.8 (2.1)	$F_{2,19} = 16.2$	<0.001	FC<B<FR
Nest height (cm)*	38.8 (2.4)	$F_{2,19} = 4.1$	<0.035	B<FR<FC
Total area covered by nests (cm^2)*	4,405.8 (282.1)	$F_{2,19} = 33.1$	<0.001	FC<B<FR
Number of tiers of nests*	1.3 (0.2)	$F_{2,19} = 50.1$	<0.001	FC<FR<B
Nests/tier*	34.9 (6.6)	$F_{2,19} = 15.1$	<0.001	FC<FR<B

* Data for CC were omitted from the analysis

In terms of categorical differences, cage systems used only nipple drinkers whilst B and FR systems also used bell drinkers. Systems varied in how dawn/dusk was achieved, and in the shape and construction material used for perches (where present).

Data Collected By Researchers: Each flock was visited 3 times throughout the laying period, at approximately 1 week after placement, 30 and 70 weeks of age. During Visit 1 only, researchers completed a 'Background' questionnaire regarding the history of the hens prior to placement (Appendix 1), and the housing and husbandry was characterised in great detail by completing a 'Housing' questionnaire (Appendix 2). On Visits 1, 2 and 3, the researchers also completed a 'Current Husbandry, Environment, Welfare and Health' questionnaire (Appendix 3).

On all 3 visits, behavioural observations, a health check, assessment of fear, and faecal samples were collected as welfare indicators. We did not take recordings of all behaviours, e.g. comfort behaviours, inter-bird interactions, vocalisations as these were likely to be confounded by the housing system. Behavioural observations of feather pecking comprised continuous sampling for 1-min on each of 30 focal hens randomly selected from all areas of the house and range. For free-range farms, 15 hens were observed indoors and 15 hens outdoors. All behavioural observations began after 12.00h to reduce nesting and laying behaviours biasing the data. We recorded the frequency of 'gakel' calls (frustration vocalisations), gentle feather pecks (received or given), aggressive pecks (received or given), severe feather pecks (received or given) and cannibalistic pecks (received or given) (Appendix 3). The health of each focal hen was assessed without handling the hen, by collecting data on feather and skin damage on 10 areas of the body, and other indicators of general health (e.g. posture, abnormal scratching). Damage was scored on a 4 point scale from 0 being 'no damage' to 3 being 'very much damage'. Also on each visit, between 6 and 10 fresh, uncontaminated faecal samples were collected. For cage systems, samples were collected from each tier, and for free-range flocks, 4 samples were collected from inside and 4 from outside. Each sample was analysed for corticosterone content using an ImmuChem™double antibody corticosterone 125|RIA kit. Before running the assay, faecal samples were freeze-dried, ground and sieved, weighed, added to a methanol mix (90% methanol,10% distilled water), vortexed and then centrifuged (3000rpm) for 30 mins in preparation for running the assay on the extracted supernatant.

Also on each visit, the researchers recorded the light intensity (RadioSpares light-meter) and ammonia concentration (Drager tubes) at various sites representative of the conditions experienced by the hens. To collect long-term climate data, 'Hobo' data loggers (Tempcon Instruments) were placed in a site representative of conditions experienced by the hens. These were programmed to record air temperature, relative humidity and light intensity at 1-hr intervals. Data loggers were installed during Visit 1 and replaced by a second logger at Visit 2 which ensured climate data were collected for the duration of the laying period. Data were downloaded from the loggers using the Greenline™ software.

Post-mortem Examination: At the end of lay, 150 hens from each flock underwent post-mortem examination. After the hens had been culled by gas, they were immediately chilled (4ºC) and examinations carried out the following day by a team of 5 trained staff. The hens were weighed, numbered, and their feet washed for examination. They were assessed for beak deformities, skin damage, parasites, plumage damage, plumage soiling, vent damage (not from pecking), evidence of vent pecking, foot condition (including bumble-foot), keel protrusion, keel deformation, and fractured keel bones. Damage was scored on a 4 point scale with 0 being ‘no damage’ to 3 being ‘very much damage’, and breaks were classified as recent (no evidence of healing) or old (some evidence of healing). Exemplar photographs (Appendix 4) were used to standardise scores between different flocks and staff.

Data Collected By Producers: During Visit 1, the producers were asked to complete and return a ‘Weekly Welfare Assessment’ form (Appendix 5). This contained questions on a range of welfare indicators such as mortality, the prevalence of red mites, the number of hens performing injurious pecking, and also changes in husbandry. The producers were asked to examine a maximum of 10 hens found dead each week and provide information on a range of welfare indicators and possible causes of death. They were provided with full verbal and written instructions on how to complete the forms and a set of exemplar photographs (Appendix 4) for standardising scores of e.g. feather damage. They were also asked to examine 100 eggs prior to grading, and record the number of egg shells with calcification spots or rings, or blood-stains. At the end of the study, producers supplied the normal production records for their flocks. In addition, the producers were asked to complete at 30, 50 and 70 weeks of age a ‘Causes of Mortality’ form (Appendix 6).

Objective 1 Results

(i) Effect of Housing System and Visit (Time) on Data Collected During Lay

The data on welfare indicators collected on each of the 3 visits by researchers were analysed by repeated measures ANOVA with the mean for the flock as the between-subjects variable, and the mean flock value of the welfare indicator as the within-subjects variable. Five welfare indicators had significant effects due to the housing system – these are presented in Table 3 below. Values are means (SEM). Because there were six missing values for the faecal corticosterone data on visit 3 (3 B, 1 CC, 1 FC and 1 FR) the repeated measures analysis for faecal corticosterone was conducted on 20 rather than 26 flocks. Therefore an additional analysis was performed examining faecal corticsterone values for all 26 flocks over the first two visits. This revealed the following means: B 18.17 (2.42); CC 16.87 (2.61); FR 16.71 (2.42); FC 10.80 (2.61); There was no significant effect of housing type when data from only the first 2 visits were included. Plumage scores from different body parts were highly correlated allowing construction of a mean feather damage score.

Table 3 - Significant Housing System Effects on Welfare Indicators Recorded by Researchers

	Gentle Feather Pecks Given (Pecks/hen/min)	**Mean Feather Damage Score¶**	**Mean % Hens With Feather Damage‡**	**Mean % Flock Using Perches***	**Faecal Corticosterone**
CC	0.01 (0.09)	0.49 (0.05)	24.7 (2.3)	n/a	14.0 (2.4)
FC	0.06 (0.08)	0.45 (0.04)	24.9 (2.1)	26.62 (0.86)	10.7 (2.4)
B	0.16 (0.08)	0.53 (0.04)	26.9 (2.1)	2.05 (0.79)	21.8 (2.6)
FR	0.38 (0.08)	0.29 (0.04)	15.5 (2.1)	2.46 (0.79)	15.6 (2.2)
Housing	$p = 0.045$ $F_{3,19} = 3.2$	$p = 0.005$ $F_{3,19} = 5.9$	$p = 0.006$ $F_{3,19} = 5.7$	$p < 0.001$ $F_{2,15} = 269.7$	$p = 0.047$ $F_{3,16} = 3.31$
Visits	$p = 0.541$ NS	$p < 0.001$ $F_{2,38} = 267.4$	$p < 0.001$ $F_{2,38} = 254.6$	$p = 0.364$ NS	$p = 0.389$ NS

* Data for CC were omitted from the analysis

(ii) Effect of Housing System and Visit (Time) on Data Collected Post-Mortem

To analyse the effects of housing system on post-mortem indicators, we first calculated a flock mean for each indicator. These flock means were analysed by non-parametric Kruskal-Wallis test where the contributing data were measured on an ordinal scale, or by ANOVA where the contributing data were measured on a ratio scale. The average median flock values for the Kruskal-Wallis tests, and results of the analyses are given in Table 4.

Table 4 - Effects Of Housing System On Non-Parametric Post-Mortem Welfare Indicators

Welfare Indicator	**CC**	**FC**	**B**	**FR**	**Test Statistic**	**p =**
	Median scores					
Skin damage	0.59	1.05	1.31	1.68	$\chi2 = 8.29$	< 0.05
Plumage damage neck	2.00	1.94	2.26	1.64		NS
Plumage damage back	1.8	2.4	2.73	2.73		NS
Plumage damage wings	2.11	1.93	1.89	1.44		NS
Plumage damage tail	1.67	1.84	1.93	1.79		NS
Plumage damage vent and abdomen	1.96	2.19	2.55	2.15	$\chi2 = 8.43$	< 0.05
Severity of vent damage	0.05	0.01	0.10	0.29		
Other vent damage (prolapse)	1.41	1.81	1.38	1.70		NS
Footpad dermatitis	1.91	1.55	1.37	2.17		NS
Keel protrusion	0.91	1.00	1.12	1.21	$\chi2 = 8.80$	< 0.05
Beak deformity	0.12	0.11	0.09	0.09		NS

Plumage soiling	1.11	0.80	0.90	0.89		NS

Table 5 – Effects Of Housing System On Parametric Post-Mortem Welfare Indicators

	Mean scores					
Welfare Indicator	**CC**	**FC**	**B**	**FR**	**Test statistic** $F_{3,18}$	**p =**
Bodyweight (kg)	1.945	1.804	1.716	1.855	4.5	0.019
% of vent pecked hens	6.2	1.6	10.0	22.5	3.83	0.03
% of hens with old keel bone fractures	17.7	31.7	69.1	59.8	22.0	< 0.001
% of hens with recent keel bone fractures	24.6	3.63	1.2	1.33	9.64	< 0.001
Any keel bone fracture	50.4	37.2	70.8	66.2	8.97	< 0.001

(iii) Housing System and Climate Data

The data loggers recorded climate information at hourly intervals throughout the laying period, and the ammonia concentrations collected by the researchers on each of 3 visits. Means were calculated for each flock, and using these, means then calculated for each system. (Note: At the lower light intensities frequently encountered in poultry sheds, the data loggers appeared to record 'stepped' light intensities, rather than continuous. Therefore, the data on light intensity are considered unreliable and are omitted.)

Table 6 – Climate Data

	Maximum		**Minimum**		**Mean**	
	Mean	**Range**	**Mean**	**Range**	**Mean**	**Range**
Tempertaure (^{0}C)						
CC	31.8	26.3-34.5	10.3	3.1-14.5	20.5	18.2-22.5
FC	33.5	24.3-38.2	6.8	3.9-9.2	17.0	15.2-18.5
B	33.4	22.4-38.2	6.0	-2.6-14.4	16.1	12.9-19.4
FR	32.3	30.7-35.3	4.9	1.1-10.9	16.5	14.1-19.9
	p = 0.863		p = 0.165		p < 0.001 $F_{3,24}$ =7.4	
Relative humidity (%)						
CC	81.8	71.5-85.7	33.8	22.0-39.0	60.7	53.6-66.6
FC	90.9	82.1-98.9	32.2	23.8-42.2	67.1	58.8-75.4
B	90.2	82.9-96.3	32.6	13.4-48.6	71.5	68.6-73.1
FR	86.9	76.1-94.6	33.9	28.4-43.2	66.2	50.4-70.1
	p = 0.044 $F_{3,24}$ = 3.2		p = 0.976		p = 0.031 $F_{3,24}$ = 3.6	
Ammonia (ppm)						
CC	8.16	4.0-12.0	2.08	1.0-4.0	4.79	2.5-8.6
FC	3.16	1.0-5.0	0.33	0.0-1.0	1.41	0.3-3.0
B	16.85	10.0-25.0	2.14	0.0-4.0	8.94	5.5-9.8
FR	9.42	5.0-20.0	1.71	0.0-5.0	5.08	2.3-9.0
	p < 0.01 $F_{3,25}$ = 8.9		p = 0.104		p < 0.001 $F_{3,24}$ = 10.1	

Discussion of Data Collected by Researchers

Feather pecking (of gentle severity) was most frequent in the FR hens; numerically, it was more than twice as frequent as recorded in the B hens. Barn hens had the highest feather damage score, the greatest number of hens with feather damage, and the greatest faecal corticosterone concentrations - almost twice those of the lowest concentration found in hens from FC. Despite FR hens having the highest frequency of gentle feather pecking, these hens had the lowest feather damage score and lowest number of hens with feather damage. A lack of correlation between gentle feather-pecking activity and feather loss has been reported previously, and it is known that feather damage and loss are due primarily to severe feather pecking. The prevalence of severe feather pecks received was numerically greatest in B hens (1.3, 0.6, 0.5 and 0.2 pecks/hen/min for B, FC, FR and CC respectively) which corresponds with B hens also having the highest feather damage score and greatest prevalence of hens with feather damage. Hens from FC had the second lowest frequency of gentle feather pecking and feather damage score, and the lowest faecal corticosterone.

Both the feather damage score and the number of hens with feather damage, increased over the duration of the study. This is not particularly surprising as both abrasion and feather pecking are likely to increase during the laying period, rather than decrease. The significant effect of Visits for faecal corticosterone revealed an inverted 'U' response over the duration of the laying period. Possibly, this indicates increasing stress during the initial stages of the laying period followed by a gradual habituation to the stressors associated with the corticosteroid response, or the values could have reached maximum ceiling values that the hens were able to excrete.

Bodyweight and keel protrusion are indicators of possible emaciation. Barn hens were the lightest at post-mortem and had the greatest prevalence with severe keel protrusion, however, the greatest proportion of hens with some degree of keel protrusion was noted in the FR flocks. Hens from CC were the heaviest at post-mortem and also had lowest prevalence of severe keel protrusion. However, it was noted on many occasions that hens (not only from CC) had central fat deposits considerably larger than was expected by experienced researchers. In chickens, physiological stress can cause lipid accumulation in the liver (Puvadolpirod and Thaxton, 2000), and more generally, chronic elevation of glucocorticoid hormones can result in a redistribution of fat reserves, with increased central fat accumulation (Macfarlane et al., 2008).

Barn hens had the worst vent and abdomen plumage, and skin damage that was worse only in free-range hens. Free-range hens were also more likely to be vent pecked than birds in other systems. Pötzsch et al. (2001) reported that UK farmers estimated vent pecking occurred in 37 per cent of their non-cage flocks, with an average of 3.5% of the hens being affected. This is considerably less than the present study so either vent pecking has increased in prevalence, or farmers underestimated vent pecking in the 2001 study. Hens in FC systems were least likely to be vent pecked.

Some flocks in the current study were also studied in Defra project AW0234 (Table 1). Of the 19 flocks subjected to post-mortem in the current study, 9 had been independently assessed in project AW0234, where 20 hens per flock were dissected at the abattoir. The correlation between the % of old fractures found in these nine flocks between the two studies was 0.82, $p < 0.001$. From our data, hens in FC had the lowest overall prevalence of keel fractures (old and new combined), whilst B hens had the greatest prevalence of old keel fractures. New fractures, were nearly 5 times more common in CC hens than hens from other systems. These breaks were almost certainly caused by the keels being broken during depopulation, handling and transport, exacerbated by osteoporosis due to low mobility in this housing system. Wilkins et al. (2004) reported an incidence of 50 to 78% of old fractures in the keel and furculum bones dissected from hens from colony units, with no difference in incidence between the hens that had access to free-range and those that did not. In the present study, 55.7% of all the hens experienced a fracture, of which 84.8% were old fractures, i.e. 47% of all hens experienced a keel break during their laying period – this lies at the lower end of the range reported by Wilkins et al. (2004) reflecting the slightly lower risk in cage systems.

There was a significant effect of housing system on mean air temperature. CC systems had the greatest mean temperature, although FC systems had the greatest maximum temperature. Considering the differences between the highly automated regulation of temperatures in the indoor systems compared to the outdoors (FR), there was unexpectedly no significant effect of housing system on the max. or min. air temperatures. The ranges of values show that Barns had the (equal) highest recorded max. air temperature, lowest recorded min. temperature and the greatest ranges of max., min. and mean temperature.

There was a significant effect of housing system on the max. and mean relative humidity. FC systems had the greatest max. relative humidity and Barns had the greatest mean relative humidity. The ranges of values show that highest recorded max. and mean relative humidity were both in the FC systems. CC systems had the lowest max. and mean relative humidity.

There was a significant effect of housing system on the max. and mean ammonia concentrations. Barns had the greatest max., min and mean ammonia concentrations, and were equal for the greatest range in max. concentration with FR. FC systems had the lowest max. and mean ammonia concentrations, and also the smallest ranges of both these measures. Kristensen et al. (2000) showed that laying hens, when given a choice, prefer fresh air over air with 25 ppm or 45 ppm ammonia. This indicates that at least the highest maximum recorded in the B systems may have been aversive to the hens, although concentrations amongst the systems overall could be considered low.

(iv) Data obtained from producers: mortality and production

There was no significant effect of housing system on the proportion of hens placed found dead (ANOVA: $p = 0.258$), however, given the obvious implications for animal welfare, we present here data on the mortality recorded during this study. The total number of hens placed in the study was 705,506, of which 46,685 died and

1,268 were culled, giving an overall mortality rate of 6.8%. Because cage systems housed larger numbers of birds it is important to note the relative rates of mortality in each system (Table 7).

Table 7 – Mortality Rates In The Housing System

Housing System	Mean % hens found dead per flock	Mean % of hens culled per flock	% of hens in study housed in this system	Relative contribution of hens *found dead* to total study mortality	Relative contribution of hens *culled* to total study mortality
CC (6)	6.3	0.18	65.0	4.095	0.12
FC (6)	5.2	0.09	16.6	0.863	0.015
Barn (7)	10.4	0.29	11.3	1.175	0.03
FR (7)	7.2	0.29	7.1	0.511	0.02
Total				6.64%	0.185%

Because some flocks were depopulated early, we also examined mortality over the period 20-39 weeks, when data from all 26 flocks were available. Mortality was CC 2.14%, FC 1.11%, B 1.34%, FR 2.36%, with no significant housing system differences. Finally, we compared the mortality figures sent to us via the weekly sheets, with the house production records accessed retrospectively. For 13 flocks where house production records were available we compared the overall mortality reported on the weekly returns. The correlation between the two sets of data was highly significant (r^2=0.67; $p < 0.001$) but there were some notable discrepancies. Some producers reported more mortality on their weekly returns than in their production records, whilst others reported lower mortality on the weekly returns than in their production records.

Causes of mortality: The producers were asked to indicate a likely cause of death of any hen found dead during the weekly reports during the laying period. Only three categories of ascribed causes of mortality had sufficient data for analysis to detect significant differences between systems. These were hens found dead due to 'illness', 'unclear reasons', or, 'injurious pecking', and there was no significant effect of housing system on any of these welfare indicators. The producers were also asked to conduct a more thorough investigation of hens found dead at 30, 50 and 70 weeks of age, and send the carcasses for full veterinary post-mortem if possible. In total, only 336 hens (between 4 and 30 per flock) were inspected for causes of mortality at 30, 50 and 70 weeks of age - a number rather lower than expected. Only 100 hens from 13 of the flocks were sent for full veterinary post-mortem.

A comparison of the causes of mortality ascribed by farmers during their simple post-mortems and on their weekly recording sheets is given in Table 8

Table 8 – Causes Of Mortality Ascribed By Producers

Cause of mortality ascribed by producers' post-mortem examination	30 wks	50 wks	70 wks	Total	%	Cause of mortality ascribed by producers' weekly sheets	%
Trapped	10	7	8	25	8.65	Trapped	0.9
Broken wing	2	1	1	4	1.19	Physical trauma or injury	3.7
Broken keel	0	1	0	1	0.30		
Broken leg	0	1	0	1	0.30		
Neck trauma	0	1	0	1	0.30		
Smothered	0	1	0	1	0.30	Smothered	0.2
Egg bound	1	1	1	3	0.89	Egg bound	0.2
Green crop	2	0	0	2	0.59		
Peritonitis	1	4	0	5	1.49		
Prolapse	1	2	1	4	1.19	Prolapse	0.2
Runt	1	0	0	1	0.30		
Possible pecking	1	0	0	1	0.30	Injurious pecking	12.4
Pecked	5	2	2	9	2.67		
Vent pecked	3	0	0	3	0.89		
Weak	0	0	6	6	1.78		
Predated	0	3	3	6	1.78	Predated	0.4
Not specified	0	11	3	14	4.17	Unclear	33.4
						Heat stress	1.7
						Illness	46.6
No physical trauma	90	118	81	289	86.0		

Due to the low frequencies in each of the categories, it was not possible to test for significant effects due to housing system, but comparisons between the producer estimates provided routinely and those provided after following detailed instructions are interesting. Neither system permitted farmers to ascribe a cause of death for the majority of hens.

Production: Retrospective production records were obtained from 13 flocks (three CC, six Barn, four FR). Unfortunately no production records could be obtained for the Furnished cage flocks, limiting our potential to analyse these data. We simply extracted information on the % hens in lay (Table 9)

Table 9

Age (weeks)	% hens in lay (Mean ± SD)	Range	N
25	89.0 ± 3.7	83.8 - 94.6	13
35	85.4 ± 9.3	58.0 - 93.9	13
45	85.5 ± 4.7	74.2 - 91.3	13
55	81.2 ± 4.5	69.6 - 89.6	13
65	70.8 ± 9.8	50.5 - 81.6	13
70	64.6 ± 11.3	43.2 – 77.8	13

Production tended to increase with increased feeder length per hen and with increased number of drinkers per hen, and to decrease with more diet changes, with a greater range in temperature and if birds were placed at a young age. Poorly producing flocks were inspected more frequently, but cause and effect is difficult to establish here.

Discussion of Mortality Data

Overall, 6.8% of hens placed at the start of lay were found dead or were culled although, because of the size of the flocks in the conventional cage systems, this figure is biased towards this system. Mortality rates in layer flocks have previously been reported as between 2.9 and 9.0% in FC (Appleby et al., 2002), 6.9% in a survey of 25 FR farms (Whay et al., 2007), and between 6 and 7% in CC and FC (EFSA, 2005). However, higher figures have been reported such as between 5 and 20% mortality in B (Nicol et al., 2006) and 8.3% for CC, 7.1 to 15.5% for FC and 11.8% for non-cage systems (Blokhuis et al., 2007). These indicate that mortality in the present study was lower than usual, possibly because the selection of producers sufficiently enthusiastic to enrol in this study may have inadvertently selected particularly good producers. Despite this, the very low percentage of birds that were culled raises important questions about the inspection of large flocks. It is not reasonable to suppose that all of the birds found dead had shown no prior signs of morbidity.

Some of the reasons for hen mortality could be relatively easily prevented. For example, 1.7% of all mortalities were due to heat stress. With a national layer flock of 33 million hens, this percentage equates to over 38,000 hens dying annually from a cause that is almost certainly preventable. There were obvious rises in mortality during warm periods which might easily (although perhaps not inexpensively) be offset by having improved ventilation systems. We note that although trapping was numerically more prevalent in FC and CC, it was reported for all 4 housing systems and throughout the laying period. The percentage of mortality from hens died being trapped (0.9%) translates to over 20,000 hens dying from a cause which could be avoided by improved housing design.

The causes of mortality were not always clear, but the high prevalence indicates that further research is needed to improve welfare. In the present study, 80% of deaths were because of ‘illness’ or ‘unclear’ reasons, i.e. the producer could not give a clear answer as to why the hen had died. This percentage equates to 1.8 million hens dying each year for unknown reasons. Research on understanding why these hens die and thereby providing the opportunity for preventing these deaths would represent a substantial improvement to the welfare of laying hens. Similarly, the producers reported that 12.4% of hens died due to injurious pecking – this represents over 0.25 million hens of the national flock. Such great losses should be of considerable economic and welfare concern. Furthermore, this figure might considerably underestimate losses due to injurious pecking as Blokhuis et al. (2007) stated that a third of all layer hen deaths were possibly due to feather pecking and cannibalism; this figure is more than double the figure reported by producers in the present report This clearly suggests that further investigation is required to clarify the prevalence and causation of injurious pecking and to develop methods to ensure that it is recognised.

(iv) Data obtained from producers during lay

Data from the producers were provided on a weekly basis, however, it would be pseudo-replication to analyse these weekly data-points as statistically independent units. Moreover, Kolmogorov-Smirnov tests indicated that the raw data of all the producer-collected welfare indicators were non-normally distributed. Therefore, for each flock we calculated a flock-mean representing the welfare indicator over the duration of the laying period, and conducted a Kruskal-Wallis analysis on these means testing for differences between housing systems. The change in some of the welfare indicators with bird age was also of interest. Therefore, regression coefficients were calculated for each flock, and entered into a Kruskal-Wallis analysis to test for differences between housing systems. Data are presented below (Table 10) for those welfare indicators for which there was a significant effect of housing system.

Table 10 – Significant Effects Of Housing System On Welfare Indicators

	Percent eggshells with calcification spots	Percent bloodstained eggshells	Weight of hens found dead (kg)	Temporal change in bloodstained eggshells (regression coefficient)	Temporal change in proportion of hens found dead (regression coefficient x 10^{-4})
CC	3.5 (4.0)	0.98 (1.6)	1.870 (0.129)	0.13 (0.30)	0.30 (0.27)
FC	1.2 (1.3)	0.83 (0.5)	1.575 (0.165)	0.05 (0.04)	0.26 (0.08)
B	4.1 (1.9)	2.05 (0.58)	1.661 (0.116)	0.19 (0.11)	1.03 (0.49)
FR	1.7 (1.2)	1.42 (1.35)	1.767 (0.122)	-0.02 (0.08)	0.48 (0.30)
	$p = 0.029$ $\chi^2_3 = 9.05$	$p = 0.038$ $\chi^2_3 = 8.43$	$p = 0.008$ $\chi^2_3 = 11.7$	$p < 0.02$ $\chi^2_3 = 9.87$	$p = 0.007$ $\chi^2_3 = 12.1$

There were no significant housing system effects for the other data reported by producers, with the exception that repeated measures analysis of variance (not accounting for the data distribution) showed significant housing effects for the proportion of hens found dead ($F_{3,16}=5.2$; $p = 0.011$) and the percent of hens with red mite ($F_{3,12}=4.00$; $p = 0.034$)

We tested whether temporal changes in welfare indicators were best approximated by a linear or quadratic relationship by using the curve estimation function in SPSS. This was done using each flock's raw data for each week, i.e. for most weeks there would be 7 data-points each for FR and B, and 6 data-points each for CC and FC. The results of this analysis are available on request, and the associated scatter-plots are shown in Appendix 7.

The following welfare indicators had a strongly significant linear relationship with time ***all increasing with age*** and showing a similar relationship in all housing systems, unless stated otherwise: proportion of eggs with calcification spots, proportion of eggs with blood, proportion of hens culled, proportion of hens found dead, proportion of hens dead due to injurious pecking, proportion of hens dead due to unclear causes, severity of red mite, percent hens affected by red mite.

There were four exceptions to this:

1) Calcification spots for FC hens significantly decreased linearly with age, but for the other 3 systems all were a 'U' type relationship.
2) The proportion of eggs with blood on them for the FR hens did not have a significant linear or quadratic regression against age, but was significantly linear for all the other three systems.
3) The proportion of hens culled for the FC hens did not have a significant linear or quadratic regression against age, but was significantly linear for all the other three systems.
4) The proportion of hens found dead due to injurious pecking for the FC hens was a very shallow curvilinear inverted 'U' regression against age, but increased linearly for all the other three systems.

Discussion of Data Recorded During Lay by Producers

We found significant differences in egg calcification with housing system. Under conditions of stress, hens will delay laying eggs which results in additional calcium carbonate being deposited on the eggshell (Reynard and Savory, 1999), so calcification spots may be a good non-invasive and readily available indicator of stress. Hens in barns had the most eggs with calcification spots (Table 9), almost four times as many as for hens in FC systems. Notably, calcification spots for the FC hens decreased linearly with age but increased in all the other systems from approximately 45 weeks of age after an initial decrease from higher levels just after coming into lay (see Appendix 7).

Blood might be found on eggs for a number of reasons including the eggs being too large for the cloaca, prolapse, or vent pecking, all of which indicate both a direct reduction in welfare and an indirect reduction in welfare due to an increased potential for disease or infection. Barn hens had both the greatest percentage of eggs with blood on, and the greatest positive coefficient of regression of this welfare indicator on age. The percentage of eggs with blood on for the B hens was more than twice that of the lowest percentage, recorded from hens in the FC (Table 9), and the coefficient of regression was three times as steep as the lowest positive regression, again recorded from the FC hens, indicating that the proportion of affected hens increased more sharply with age in the B system. Unlike other systems, FR hens had more blood on eggs at earlier ages, with little further change with age.

Hens from the FC had the lightest bodyweight when found dead, and hens from the CC had the heaviest (Table 9). However, the data from the post-mortem examinations of 150 hens randomly selected from each flock show that CC hens were the heaviest and FC hens almost the lightest. Possibly, this effect of housing system on the weight of hens found dead simply reflected body weight of hens in the systems.

Overall, all the four systems showed increases with age in the proportion of hens culled, found dead, found dead due to injurious pecking, and, found dead for unclear reasons (except for some indicators for FC). The slopes for these increases were small indicating the proportion did not increase rapidly, but they do indicate that welfare for most layer hens progressively decreases throughout their lives. The B hens had the highest regression coefficient; this was almost four times greater (steeper) than for the lowest value, which was recorded from the FC hens (Table 9 and Appendix 7).

The severity of red mite and the proportion of hens with red mite significantly increased with age throughout the laying period (Appendix 7), but generally the numbers of hens affected were low, and there was no statistically significant effect of housing system. However, 100% of hens in one CC flock were reported to have red mites throughout the laying period (Appendix 7). Data on the prevalence of red mite could be highly dependent on the incidence and timing of when the producer sprayed for mites. To examine this, we analysed the efficacy of spraying for mites with the assumption that if mite spraying was effective, this would be evident in the data reported by the producers. Flocks were sprayed 0-8 times per flock. The mean number of times that each flock was sprayed was calculated. For 20 valid spraying reports, there was no significant difference between the reported percentage of hens with red mite in the week they were sprayed (28.1% + 7.3 (mean + SEM)) and the reported percentage with red mite the following week (24.5% + 7.4). These data indicate that either the sprays have little effect on the mites, or possibly, that producers were unable to estimate the number of hens with mites with sufficient accuracy to detect the effectiveness of the sprays.

(v) The effect of system-independent risk factors on hen welfare

Here we present the significant relationships between risk factors and welfare indicators with the data pooled for all four housing systems, in recognition of the fact that differences within systems can sometimes exceed differences between systems. The purpose is therefore to identify factors that are distributed across all four types of housing system that influence layer hen welfare. This has involved multiple tests on the same data-set, therefore, we have adopted a highly conservative approach to this analysis. First, to avoid housing system bias, we have discussed only those relationships with risk factors that have no significant differences due to the type of housing system. For example, stocking density is highly likely to influence welfare indicators, but there are obviously highly significant differences between systems in stocking density. For the following, we have presented only those risk factors for which there were no significant differences between housing systems. Second, to avoid Type I errors (accepting a ‘false positive’) we have used a more conservative level of statistical significance ($p < 0.02$) than is usually used. Third, for the correlational analysis, if visual appraisal of the data indicated that a single outlier might have influenced the relationship, the correlation was re-calculated with this data point omitted; data are only presented for those relationships which remained significant ($p < 0.02$) after this recalculation. For some risk factors, e.g. the presence of nests or perches, there would have been considerable bias as these were never encountered in conventional cages, therefore, data for CC were omitted for some tests.
The risk factors included in the analysis were -
General Husbandry: Age of the housing system, number of hens placed, age of hens at placement, age of hens at point of lay, hours of light, source of light, light intensity at feeder height, hours of light at point of lay.
Feeders and Drinkers: feeder number, feeder type, feeder length per hen, feeder position, number of diets; drinker number per hen, drinker type, drinker position.
Inspections and Capture: number of inspections per day, duration of inspections, number of hens captured per week.
Perches: number, total length, length per hen, maximum height, width, material, shape.
Nests: number, dimensions, communal or single, construction material, opening dimensions, number of banks, number of tiers, number of nests per tier, floor material, lighting in nests, separation material, method of access to first and second nest tiers, % of nests shared.
Climate: Air Temperature: Mean; Max; Min; Range; SEM
Relative Humidity: Mean; Max; Min; Range; SEM
Ammonia: Mean; Max; Min; Range; SEM

Several other risk factors were *not* included in the analysis due to there being insufficient variation in the data, insufficient data, or the data were clearly biased by one or more systems. These included: number of sheds, flocks and hens on site, inspector experience, shed dimensions, rearing system, stocking density, beak-trimming, diet type, restricted feeding, supplements given, litter provisions, total space available, total floor space available, area of slats.

The outcome variables examined in the analysis were:

Mortality and morbidity: weekly proportion of hens culled, found dead, found dead for unclear reasons, found dead due to illness, found dead due to injurious pecking, weight of hens found dead, change in rate of hens culled with age, change in rate of hens found dead with age
Post-mortem: weight, skin damage, vent damage, feather damage.
Stress and disease: proportion of eggs with calcification spots, proportion of eggs with blood, faecal corticosterone, change in calcification spots with age, change in eggs with blood with age, red mites.
Behaviour: % hens giving and receiving gentle feather pecks, % hens receiving severe feather pecks, rate of gentle feather pecking, fearfulness, % hens using perches.

Correlations:

Full correlational analysis is available on request and scatterplots are shown in Appendix 8.

Hens placed at a later age were lighter in weight at post-mortem, possibly an indicator of poorer welfare ($p < 0.05$). This relationship appeared particularly strong for the FR hens. A positive correlation between age at placement and feather damage ($p < 0.009$) indicate that placing hens at an earlier age reduces the amount of feather damage and the number of hens with feather damage. Given that feather damage is likely to attract feather pecking and this might subsequently develop into cannibalism, placing the hens at an early age could be a method of improving welfare.

A negative correlation between the number of inspections and fearfulness ($p = 0.001$) indicates that if producers made more inspections, the hens were less fearful. Fear is a great welfare concern, and these data suggest that by making more frequent visits, producers might be able to improve welfare. There were several significant correlations between the number of inspections and mortality. It seems rather unlikely that increases in inspections would increase mortality directly, unless the hens were panicking severely during inspections – an extremely unlikely possibility. Rather, it could be that by making more frequent inspections, producers are detecting a greater number of dead hens before these are consumed by the other hens, or disappear in some other manner.

A positive correlation between the hours of light and hens found dead ($p = 0.002$) might indicate that longer day-lengths are contrary to the welfare of the hens. Although overly long day-lengths are likely to be a stressor, the maximum day-lengths reported by the producers during this project do not appear unduly long. There was no significant correlation between Number of inspections and Hrs of light, suggesting this increased mortality might be genuine increases in deaths, rather than simply an increase in the finding of carcasses.

In some flocks, the hens were captured by the producers on a regular basis for weighing and examination. A positive correlation between the number of captures and feather damage ($p = 0.001$) is unlikely to be due to handling of the hens causing feather damage as so few hens are handled in proportion to the entire flock. Rather, it seems more likely that some co-variable such as disturbance of the flock might increase feather pecking or other causes of feather damage.

A negative correlation between feeder length/hen and gentle feather pecks (GFP) received ($p = 0.019$) indicates that greater feeder space for hens reduced the number of GFPs received by hens. Although GFP causes relatively little damage to the feathers of other hens, it is believed this behaviour can develop into severe feather pecking with subsequent injurious pecking developing. This indicates that producers should increase the length of feeder space/hen to reduce GFP and possibly improve welfare.

The width of perches was significantly positively correlated with indicators of mortality ($p = 0.009$), feather damage ($p = 0.02$) and calcification spots ($p = 0.018$). It would seem most likely that the width of perches would have an effect on these indicators by influencing the perching behaviour of the hens. Perch widths in the farms ranged from 3.0 to 5.0cm. This is quite a considerable difference considering that very similarly sized hens with similarly sized claws were using the perches. Possibly, the wider perches allowed more perching thereby reducing stress (as indicated by the negative correlation with calcification spots) but increased feather damage caused by hens remaining still and in close proximity. Future research could investigate the optimum with of perch for hens in these housing systems.

A positive correlation was found between the number of nests being shared and the change in calcification spots with age ($p = 0.007$). This could possibly indicate that sharing of the nests is stressful for the hens, or the factors that are causing the hens to share nests are stressful. Relatively little is known about the preferences of hens for sharing nests – further work could assess the factors influencing this behaviour and the consequences for welfare. Several welfare indicators were correlated with air temperature, perhaps most importantly, indicators relating to mortality, as shown in Table 11.

Table 11 – Correlations Between Welfare Indicators And Climate

	Temperature (C)				Relative Humidity (%)
	Maximum	**Minimum**	**SEM**	**Range**	**Range**
Proportion of hens found dead this week for injurious pecking		0.001 (-ve) r^2=0.39	0.001 r^2=0.42	<0.001 r^2=0.66	0.001 r^2=0.68
% of hens affected by red mite		0.012 r^2=0.24			

Fearfulness score	0.002 (K) (-ve) r^2=0.3	0.014 (K) r^2=0.17	0.002 (K) (-ve) r^2=0.14	0.01 (K) (-ve) r^2=0.35	

When data from all housing systems were included, there was a significant association between a categorical variable, light source, and an outcome variable, the % of birds using perches. Under fluorescent lighting 19.8% of birds used the perches, whereas under incandescent lighting just 5.28% of hens used perches (Kruskall Wallis: 1 df; p = 0.004). When data from CC systems were excluded (as features such as perches were not relevant) then there were significant effects of the presence of perches on the change in the weekly proportion of birds found dead (χ^2=5.58; p = 0.018). With no perches this increase was steeper. However, the proportion of birds found dead due to unclear causes (χ^2=7.0; p = 0.008) was higher when perches were present. Perch material influenced the number of hens using perches, with more birds using plastic or combination perches than metal or wood (χ^2=10.1; p = 0.018). The nest material influenced the proportion of hens placed that were culled, with greater culling rates when wood and metal nests were used, than when plastic or wire mesh nests were used (χ^2=13.3; p = 0.021). The nest material used also influenced perch use, with more birds perching when metal or wire mesh nests were used (χ^2=15.4; p = 0.009). Finally, the method of accessing the first tier of nest-boxes was strongly associated with the severity of red mite (χ^2=13.6; p = 0.009). Nests level with the slats or nests where no ramp or rail access was provided had flocks with more severe red mite infestation.

Return Rates of Questionnaires

The approach of requesting producers to provide welfare-related data on a weekly basis has, to the best of our knowledge, not been used previously. Here, we briefly discuss the positive and negative aspects of this approach. Overall, the weekly return rates from the producers were very satisfactory and certainly provided invaluable information on the temporal changes of some of the welfare indicators, e.g. calcification spots and blood on the eggs, mortality. However, it was noted that some questions were more likely than others not to be answered – these appeared to be questions which asked the producers to make quantified estimates, e.g. ‘Please estimate the percentage of hens affected by cannibalism’. We also noted on several occasions that data from one week were highly unlikely (if not impossible) based on the data provided for the previous or subsequent weeks. These were often related to the forms being filled in by different staff, who presumably differed in their estimating techniques and capabilities. There appeared to be a large increase in not answering questions during the later parts of the study, at least for 3 of the 4 questions asked (Table 12). Future studies using questionnaires to gain data from producers on a regular basis should ensure the questions are structured such that as few as possible are numeric estimates. In addition, some form of encouragement or incentive is likely to be needed to ensure high return rates at later stages of the study. If data on the returned questionnaires are clearly highly unlikely, strategies for training producers may be required, or possibly, better information provided on the questionnaire or report form. The data in Table 12 represent the percentage of times a question was NOT answered, or the ‘Weekly Welfare Assessment’ form was not returned. To standardise the beginning and end of forms being returned, these data are limited to when the flocks were between 16 and 65 weeks of age.

Table 12 – Missing Data From Questionnaires

	Percent of weeks that questions were not answered or form not returned							
Flock	**Calcification spots**	**Hens culled**	**Hens found dead**	**Hens died of injurious pecking**	**Deaths due to unclear reasons**	**Mites present**	**Vent pecking**	**Cannibalism**
1	6.1	0.0	0.0	0.0	0.0	2.0	2.0	2.0
2	8.2	2.0	2.0	2.0	2.0	4.1	18.4	2.0
3	2.0	4.1	4.1	4.1	4.1	4.1	4.1	4.1
4	6.1	4.1	4.1	4.1	4.1	6.1	4.1	8.2
5	12.2	2.0	2.0	2.0	2.0	6.1	2.0	2.0
7	4.1	0.0	0.0	0.0	0.0	4.1	0.0	0.0
8	4.1	2.0	2.0	2.0	2.0	2.0	2.0	2.0
9	14.3	8.2	8.2	8.2	8.2	28.6	12.2	10.2
10	10.2	4.1	4.1	4.1	4.1	16.3	10.2	4.1
11	8.2	4.1	4.1	4.1	4.1	8.2	8.2	6.1
13	8.2	4.1	4.1	4.1	4.1	4.1	55.1	8.2
14	6.1	2.0	2.0	2.0	2.0	2.0	2.0	2.0
15	8.2	6.1	6.1	6.1	6.1	10.2	6.1	6.1
16	10.2	6.1	6.1	6.1	6.1	8.2	6.1	6.1
18	20.4	16.3	16.3	16.3	16.3	16.3	16.3	16.3
19	20.4	8.2	8.2	8.2	8.2	8.2	8.2	8.2
20	6.1	6.1	6.1	6.1	6.1	6.1	65.3	6.1
21	8.2	6.1	6.1	6.1	6.1	8.2	61.2	6.1
22	10.2	6.1	6.1	6.1	6.1	6.1	51.0	6.1

23	24.5	18.4	18.4	18.4	18.4	20.4	18.4	18.4
25	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2
26	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2

Table 13 indicates the return rates of the forms over the duration of the study by presenting the percent of missing answers to 4 randomly selected questions.

Table 13 - Percent Of Answers Missing To 4 Questions On The 'Weekly Welfare Assessment' Form

Question	**Percent of missing answers**	
	20 – 49 weeks	50-70 weeks
Calcification of eggs	5.4	16.4
Number of hens found dead	0.4	0.2
Severity of red mite	12.3	24.3
Percent hens affected by vent pecking	3.8	10.5

Conclusion

From the inception of this project it was known, and discussed with DEFRA, that sampling just 6 or 7 flocks per system would provide limited power to detect housing system differences *per se*. However, the project aims were not just to compare housing systems, but to obtain basic information on welfare-relevant information across a range of systems, to engage farmers in the process of data collection and to analyse risk factors for welfare problems that transcended system differences. All of these objectives were achieved.

Extent to which the objective has been met

A vast amount of information on the performance of these 26 flocks has been obtained in cost-effective manner by engaging the farmers themselves, employing simple data loggers and backing these methods up with regular researcher visits to farms. Some relatively simple methods of assessing bird stress (e.g. calcification spots on eggs) produced valid and useful data, and these methods could be used in future studies. Some aspects of the study were less successful (e.g. farmers were reluctant to send dead birds for post-mortem). Despite the low sample size there did appear to be some important system differences in hen welfare (addressed below in Objective 3). Other influences on hen welfare were independent of system.

Main implications of the work

1. Producers will engage in accurate recording of relevant information about their flocks. Further training and encouragement may be needed to improve participation, standardisation and accuracy.
2. There are a number of important welfare issues that are common to hens housed in all current housing systems. These include mortality figures above breed standards, the high prevalence of skeletal problems including old keel fractures and (in conventional cages particularly) fractures sustained at depopulation, a high prevalence of hen emaciation at end of lay, the low % of hens that are culled in relation to the number found dead, the higher than expected number of birds showing evidence of vent-pecking. In addition, the frequency and severity of the majority of welfare problems increased with bird age.
3. The lack of accurate information on the major reasons for flock mortality is a cause for concern. Farmers ascribe most deaths as being for 'unclear' reasons or due to 'illness'.
4. Some causes of mortality should be avoidable (trapping, heat stress) with modifications to housing systems.
5. The physical and physiological condition of the hens in the FC system was better than that of birds in the other systems. FC hens had the lowest faecal corticosterone, fewest hens with keel fractures, fewest hens that were vent pecked, lowest numbers of eggs with blood on or eggs with calcification spots, and the shallowest slope for the regression of the proportion of hens placed found dead as this changed with age. This could indicate that overall welfare was best for the hens in the FC. However, it is important to note that the current study did ***not*** study the full repertoire of behaviour of hens in each system, and this information needs to be factored in to any overall conclusions about system effects on welfare.

Possible future work

1. The benefits of producers recording relevant data on the health and welfare of their flocks need to be evaluated.
2. Many of the generic welfare concerns could relate to extreme production demands placed on hens in all systems. Future research could examine the production demands on modern layer hens, how these influence welfare, and how production strategies might be developed to protect long-term bird health and welfare.
3. The major causes of flock mortality need to be investigated in partnership with specialised veterinary practitioners.
4. Calcification spots on eggs appear to be an easily recorded stress indicator. Potentially these could be monitored routinely on-farm to allow the producer to monitor this aspect of flock welfare. Future research should examine the relationship between egg calcification and other indices of stress in more detail, and then assess

variables such as how many eggs should be examined and how often to give a valid and cost-effective monitoring tool.

Any actions (KT/IP)

The findings of this research need dissemination to the industry and other relevant stakeholders. To achieve this, we will be presenting the work at various conferences (at least two are planned for this year), workshops (at least one is planned for summer this year) and publications (at least one is currently being written). Knowledge transfer is also on-going with several related projects here at the University of Bristol underway in which regular visits are made by researchers to 120 laying hen farms. In time, this report will also be placed on the Defra web-site, further increasing dissemination of the information.

Objective 2 *Audit the realistic potential for improvement in areas where welfare is compromised.*

Conclusion

A meeting between Dr Sherwin, Prof Nicol and Defra staff was held in December 2008. It was agreed that the best way to conduct this audit was to arrange a workshop to discuss the outcomes of Objectives 1 and 3 with the industry and other relevant stakeholders. A joint workshop with Prof Dawkins of Oxford University, was therefore scheduled for 3rd February 2009, at the FAI Field Station in Oxford. However, due to unusually severe snow, this meeting had to be cancelled, and will now be held in the summer of 2009.

Extent to which the objective has been met

Main implications of the work

Possible future work

Any actions (KT/IP)

Objective 3 *Develop an open framework, with all assumptions clearly stated, within which the welfare costs and benefits of current systems can be clearly identified, and what the implications would be if realistic improvements were implemented.*

Considerations

In drawing overall conclusions about the welfare of hens in these different housing systems, we follow Weeks and Nicol (LayWel, Workpackage 7) and first consider the following questions.

Is The Evidence Comprehensive? We obtained a broad range of information on physical health and condition of layer hens and on faecal corticosterone concentrations. Information obtained regularly by producers was complemented by detailed information obtained during farm visits and by post-mortem examination of large numbers of randomly selected hens by trained personnel. The evidence available to us on physical condition of the hens is more extensive (a broader range of measures taken) and detailed (some information obtained repeatedly over time) than that obtained in most studies of commercially housed hens. Behavioural data were obtained on pecking behaviour and fear responses, however, it is important to note that the current study did ***not*** study the full repertoire of behaviour of hens in each system. Prior studies (reviewed by Weeks and Nicol, 2006) show that an inability to perform high priority behaviours such as nesting, perching and comfort activities such as wing stretching, have major effects on hen welfare, and this prior information needs to be factored in to any overall conclusions about system effects on welfare.

Is The Evidence Valid? Considerable progress has been made in recent years in developing indices that relate to animal welfare. We consider most of the indicators evaluated in this project to be valid indicators of welfare, with certain caveats. Careful interpretation is required to relate bodyweight to hen welfare, and the validity of measures such as plumage soiling or beak deformity is less clear than for most other measures. Certainly, it is possible that the gas stunning procedure used to kill the hens at the end of lay might have contributed to apparent vent prolapse, as hens will often convulse during this method of stunning.

Is The Evidence Recent? The data were collected between 2005 and 2007 and has high relevance for the current state of the UK laying hen flock.

Is The Evidence Of High Quality? Much of the evidence presented in this report was gathered by personnel that were specifically trained for this project, or have considerable experience in collecting and analysing on-farm and questionnaire-derived data. Key personnel have previously used identical or similar techniques to collect such data, and subsequently analysed and published results in international peer-reviewed scientific journals. For the climate data, we used data loggers that had specified accuracies considered appropriate for this study. Some data were collected by producers who received appropriate training by experienced research personnel. The questionnaires completed by the producers were designed to ask closed, unambiguous questions, and they provided information to standardise data sampling methods and scores between farms (e.g. by providing exemplar photos when asking for reports of plumage damage). Overall, we believe these measures have resulted in this evidence being of the highest practicable quality.

Is The Evidence Un-Confounded? A problem identified in the LayWel project (Blokhuis et al., 2007) was that welfare-related information had been collected from different systems in different ways, and information on certain measures was available for some systems only. Thus, when the LayWel report was drafted, there was little or no information on foot damage, keel bones, or mortality due to injurious pecking for hens in free-range systems. One of the starting premises of the current project was to employ measures that were not unduly confounded by housing system. The current project therefore makes a major contribution in its systematic recording of the same information across systems.

However, we have to be aware of other potential sources of confounding, including hen genotype and flock size. Table 1 shows that the frequencies with which different strains and flock sizes were used in the different housing systems was not equal. Clearly there are potential strain x system and flock size x system confounds. It is also possible that the relative novelty of FC systems means these were run as 'experimental' systems, possibly attracting more attention from the producers than the other less novel systems which could have result in improved diligence and therefore perhaps better welfare in these systems. We also note that of the 6 FC systems studied here, 4 were on the same site and sometimes managed by the same staff.

Is The Evidence Collected At The Right Level (i.e. System Rather Than Flock)?

We need to note that there was no such thing as a 'typical' system within the current study. Differences *within* systems could exceed the differences that exist *between* systems. Continuing rapid innovations by commercial producers such as the insertion of curtains and partitions in alternative systems, or the removal of partitions and addition of larger pecking and scratching areas within cages, blurs distinctions between systems. Variations within systems will themselves significantly affect hen health, production and welfare. To address this, we scrutinised the information on housing and design obtained during the initial interviews and visits, and identified any important factors that might differ between flocks regardless of system (e.g. whether flocks were fed mash or pelleted food). We looked for factors with just 2 or 3 levels, as any factors that were more variable thus might provide a well-fitted description of one or two individual flocks, but we would have insufficient flock replication to analyse its potential effect. Of 73 recorded risk factors (including climate variables), we identified 53 as candidates for analysis with respect to welfare indicators, and this analysis was reported in Objective 1, section 5 above.

Framework development to show welfare costs and benefits

Not withstanding the points above, it is still a valuable exercise to examine the welfare costs and benefits of the four different housing systems for laying hens. We cannot simply rank the systems on the basis of their scores for each welfare indicator e.g. 1= best welfare, 4 = worst welfare. First, the different measures are not independent – thus we have three different measures of keel damage which, although not measuring exactly the same thing, are likely to be measuring parts of the same thing. Second, the measures have different validities (our degree of certainty that they measure welfare) and different impacts on hen welfare (severity of problem reflected). Attempts to deal with this issue in other contexts have focussed on methods of assigning relative weightings to different indicators, and then integrating the weighted parameters (e.g. work-packages within the EU FP6 Welfare Quality programme, Scott et al., 2003). Weightings are usually ascertained by surveying expert opinion using a variety of psychometric techniques (Main et al., 2003) The tautological problem is that the 'experts' themselves may have little objective basis on which to base their opinions. Thus, even if all experts agreed that the occurrence of red mites was more important than keel bone deformity, they may be wrong. The validity indicators given in the Table below therefore reflect our own best judgements based on previous published evidence and the likelihood of that indicator being related to high, medium or low intensities of suffering. Third, as noted above, some relevant measures of hen welfare (especially behavioural) were not included in our study.

The LayWel study (Blokhuis et al., 2007) built on the European Food Safety Authority method (EFSA, 2005) of comparing different housing systems by using a 'traffic light' approach to compare welfare outcomes and risks to good welfare across systems. In Table 13 below, we borrow from this approach, but with some important differences. Our Table deliberately uses some of the same categories of potential welfare problem (for comparative purposes), but it draws conclusions in a different manner. To facilitate discussion for Objective 2, we deliberately suggest possible current benchmark values that could be evaluated and audited by the industry.

Our framework therefore attempts to do a number of different things:

1. Set a current benchmark value for each welfare indicator. This is not intended to be absolute or to indicate that there would be no welfare problems if this benchmark was achieved. It is intended to stimulate discussion about how to improve hen housing systems and these current benchmark levels could be revised as further data become available. The current benchmark values have been set at zero where at least one flock in the current study achieved a zero value. Otherwise, the current benchmark value is derived from an examination of levels achieved by the lowest 4 flocks in this study (regardless of system) together with information from industry standards and best results obtained from commercial flocks as reported in the literature.

Performance at or below the current benchmark value is highlighted in green

Performance that is above the current benchmark value but within one standard deviation (using the current data set) of the benchmark value is highlighted in orange
Performance that is more than one standard deviation (using the current data set) above the current benchmark value is highlighted in red.

KEY		
	(red)	More than 1 SD (from current data) above current benchmark value
	(orange)	Above current benchmark value but within 1 SD (from current data) of target
	(green)	At or below current benchmark value
	(white)	Not assessed

2. An indication of statistically significant differences obtained between systems in this study
Values within a row with no letters in common are significantly different

3. An indication of the overall variability in the welfare indicator obtained in this study.
It is important to provide information on the variability that currently exists in the UK layer hen flock. Each indicator is coded according to the coefficient of variation (standard deviation/mean) obtained in this study, as high (CV over 100%), medium (CV 50 to 100%) or low (CV less than 50%).

4. An indication of the extent to which each indicator measures hen welfare
This is based on background work and literature reviews and reflects the risk of poor welfare if current benchmark values are exceeded. These values are coded as high, medium or low.

Table 14 Cost and Benefit Framework

Indicator	Current Benchmark Value	CC	FC	B	FR	Coefficient of Variation	Risk of poor welfare if values exceed current benchmark value
Mortality (overall %)	5.0% total by 72 weeks (based on published breed standards and previous data)	6.1a	5.0a	10.6a	8.3a	0.72 (72%) SD = 5.58 Mean = 7.75	High
% of deaths ascribed to FP /cannibalism in beak trimmed flocks	2.6% based on lowest 4 flocks	3.48	8.67	25.57	5.94	1.87 (187%) SD = 21.41 x = 10.92	High
% of deaths ascribed to FP/cannibalism in non- trimmed flocks	Insufficient data	n/a	n/a	n/a	29.25	1.19 (119%) SD = 34.94 X = 29.25	High
% of deaths ascribed to disease	7% based on figures from Laywel study	33.3 (90.1)	11.2 (62.5)	9.58 (63.5)	14.3 (52.1)	1.60 (160%) SD = 26.8 x= 16.7	High
% of deaths ascribed to predation	0%	0	1.16	0.21	3.52	2.59 (259%) SD = 3.29 x = 1.27	High
% of deaths ascribed to smothering	0%	0a	0a	0.57ab	6.76b	2.98 (298%) SD = 5.87 x = 1.97	High
Injury and Disease							
External parasites (red mite etc)	2% based on lowest 4 flocks in	25.99a	3.27b	3.04b	3.57b	1.87 (187%) sd = 16.01	High

	current study					x = 8.53	
Keel bone deformation	0%	0	0	0	0	0	Low
Depopulation keel fractures	0% based on 3 flocks having no depopulation breaks	24.6a	3.6b	1.2b	1.3b	1.77 (177%) SD = 10.5 x = 5.9	Medium
Old keel fractures	18% lowest flock means obtained in recent studies, also lowest 4 flocks in current study	17.7a	31.78a	69.11b	59.77b	0.49 (49%) SD = 22.94 x = 46.54	High
Bumble foot	0%	0	0	0	0	0	Medium
Beak trimming	Beak trimming should not be required as standard.	100	100	100	71.4		Medium
Body Condition							
Body weight	1.94 kg at 72 weeks (based on published breed standards)	1.945ab*	1.804cd	1.716c	1.855a bd	0.066 (6.6%) SD = 0.12 x = 1.81	Medium
Keel bone protrusion	0.8 based on lowest 4 flocks	0.91	1.00	1.12	1.21	1.80 (180%) SD = 1.91 Mean = 1.06	Medium
Plumage soiling score (1-4)	0.7 based on lowest 4 flocks	1.11	0.80	0.90	0.89	0.22 (22%) SD = 0.21 Mean = 0.92	Low
Plumage loss score (brown hens) (1-4)	1.65 based on lowest 4 flocks	1.93	2.07	2.25	1.88	0.13 (13%) SD = 0.28 x = 2.06	Medium
Injurious Pecking							
Injurious pecking – mean average skin damage score	0.61 based on lowest 4 flocks	0.64a	1.037a	1.388b	1.622b	0.41 (41%) SD = 0.50 x = 1.208	High
Injurious pecking – % of vent pecked hens	1% based on lowest 4 flocks	6.2a	1.6a	10.0ab	22.5b	1.26 (126%) SD = 11.80 x = 9.36	High
Gentle FP (received) in beak trimmed flocks	0.03 based on lowest 4 flocks	0.0106a	0.056a	0.184ab	0.326b	1.58 (158%) SD = 0.242 x = 0.153	Low
Stress and fear							
Corticosterone (faecal)	12.0ng/ml based on lowest 4 flocks	14.3b	11.2b	21.6a	16.1ab	0.46 (46.9%) SD = 7.25 x = 15.46	Medium
Environment							
Ammonia	25ppm (RSPCA Welfare Standards, 2008)	8.2b	3.2a	16.8c	9.4b	0.68 (68%) SD = 3.57 x = 5.2	Medium

- * although the bodyweights of hens in Conventional Cages were above current benchmark levels, we believe that in many individuals this was due to large amounts of fatty deposits which in themselves would indicate poor welfare.

Derivation of Current Benchmark Levels

Breed standards for mortality and bodyweight:
Hisex, Bovans; http://www.hendrix-genetics.com/layerbreeding/template.php?sectoin Id=2;
Lohmann Brown http://www.ltz.de/html/gb_page_76_107.htm
Hyline http://www.hy-line.co.uk/downloads/alt_brochure.pdf
Isabrown http://www.hendrix-genetics.com/layerbreeding/template.php?sectoin Id=2;

We note here that current benchmark levels for % causes of mortality need to be interpreted with care – the overall aim must be to reduce mortality from all causes.

Conclusion
Assuming all welfare indicators are independent we can now use the framework to draw overall conclusions. Of the welfare indicators with high welfare relevance, if red scores 3, amber 2 and green 1, then minimum possible = 9; maximum = 27.
CC = 16; FC = 14; B = 19, FR = 20
If all welfare indicators are included then minimum possible score = 20; maximum = 60
CC = 36; FC = 32; B = 38; FR = 39

If welfare indicators are regarded as non-independent then it would be possible combine information to present one value for mortality, one for skeletal problems, one for emaciation, one for plumage and skin damage, and one for stress. Doing so results in similar conclusions. Minimum possible score = 5; maximum = 15.
CC= 8.8; FC=8.4; B=11.4; FR=10.0

The ability to perform important behaviours such as nesting, dust-bathing, comfort behaviours and perching was not assessed in this study, but most of these behaviours are severely restricted in conventional cages, permissible to some extent in FC and are readily performed by most birds in B and FR systems.

Taking all evidence into account, the welfare of laying hens is currently best in FC systems. However, the very high variation obtained between flocks shows that there is considerable scope for improvement in hen welfare on B and FR systems. But this improvement needs to be implemented and audited.

Extent to which the objective has been met
An open framework has been produced, setting out the costs and benefits of each housing system.

Main implications of the work
The coefficients of variation for most of the welfare indicators are extremely high, indicating a great diversity of performance between different flocks (within as well as between systems).

Possible future work
Future work could address the current benchmark values suggested in the framework above to determine how appropriate these are for the UK industry – particularly where these have been estimated from the current data. Once these current benchmark values are established, long-term research projects monitoring welfare could address whether the industry is moving closer to achieving the current benchmark levels.

Any actions (KT/IP)
Producers need to be made aware that current benchmark values for laying hen welfare can be (have been) suggested and that by taking appropriate action, they can attempt to achieve these if they are not doing so already.

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9. This section should be used to record links (hypertext links where possible) or references to other published material generated by, or relating to this project.

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