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Kelly Drake, Christl Donnelly, Marian Stamp Dawkins

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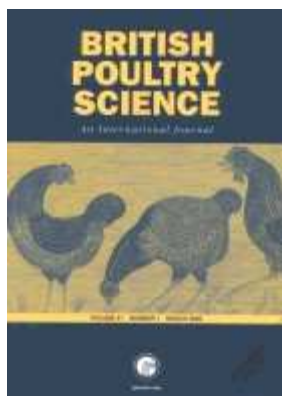
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The influence of rearing and lay risk factors on propensity for feather damage in laying hens

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1 Note to P. Lewis. A few general formatting points. Some phrases in bold, some et al.s not in italics.
2
3 The first para of “Statistical analysis” contains several ‘levels’ – I try to encourage authors to avoid the
4 word – it’s lazy and sometimes ambiguous – wherever possible it should be replaced by the actual
5 measure – concentration, intensity, number etc and sometimes it can even be deleted altogether. Think
6 about its use here. Some probability symbols are lower-case Roman. Ampersands in some text
7 references.

8 **Influence of rearing and lay risk factors on propensity for feather damage in**
9 **laying hens**

10
11 K. A. DRAKE, C. A. DONNELLY¹ AND M. STAMP DAWKINS

12
13 *Department of Zoology, University of Oxford and ¹M.R.C. Centre for Outbreak*
14 *Analysis and Modelling, Department of Infectious Disease Epidemiology, Imperial*
15 *College, London, England*

16
17 **Short title:** Feather damage in laying hens

18
19
20 Correspondence to Prof. Marian Stamp Dawkins. Department of Zoology, University
21 of Oxford, South Parks Road, Oxford OX1 3PS, U.K.

22 Phone: +44 (0) 1865 271215

23 Fax: +44(0) 1865 310447

24 Email: marian.dawkins@zoo.ox.ac.uk

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52**Abstract.**

1. Feather pecking is one of the major problems facing the egg industry in non-cage systems and is set to become even more of an issue with the European Union ban on the keeping of laying hens in barren battery cages which comes into force in 2012 and a UK ban on beak-trimming in 2011. Reducing feather pecking without resorting to beak treatment is an important goal for the poultry industry.
2. We report here a longitudinal study that included over 335 500 birds from 22 free range and organic laying farms. Accelerated failure time models and proportional hazards models were used to examine the effects of a wide range of factors (management, environment and bird) on development of substantial feather damage in lay. Particular emphasis was placed on risk factors during rear and on practices that could feasibly be changed or implemented.
3. The age at which a flock exhibits substantial feather damage could be predicted both by factors in the environment and by early symptoms in the birds themselves. Factors that were associated with earlier onset of severe feather damage included the presence of chain feeders, raised levels of carbon dioxide and ammonia, higher sound and light levels, particularly in younger birds. Increased feather damage (even very slight) in birds at 17-20 weeks of age was also highly predictive of the time of onset of severe feather damage during lay. Increased feed intake also indicated that a flock was at risk of early severe feather damage.
4. Birds that stayed on the same farm for rearing and lay showed later onset of serious feather damage than those that experienced a change in farm from rearing to lay. However, an increased number of changes between rearing and

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3 53 lay (feeder type, drinker type, light intensity etc) was not associated with
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6 54 earlier onset of serious feather damage. Further research needs to be done on
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8 55 the role of the transition from rearing to lay as a risk factor for FP in lay.
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For Peer Review Only

57 INTRODUCTION

58 A major welfare problem in the commercial egg production industry is that of
59 injurious feather pecking (FP) in laying hens (**Savory, 1995; Green et al., 2000;**
60 **Bright, 2009; Bestman et al., 2009**). Injurious FP leads to increased feed
61 consumption due to heat loss (Tauson and Svensson, 1980), a reduction in egg
62 production (El-Lethey et al., 2000), pain and suffering of the injured birds (Gentle and
63 Hunter, 1991) and increased bird mortality, including cannibalism (Huber-Eicher and
64 Sebo, 2001).

65 In 2012, barren cages will be banned in the European Union in line with
66 Directive 1999/74/EU. This will increase the number of birds kept in **non-cage** laying
67 systems (barn, colony, free range and organic), which in turn will increase the
68 numbers of birds at risk of injurious FP and cannibalism (Blokhuis et al., 2007;
69 Fossum et al, 2009). Beak treatments that blunt the beak and so reduce the impact of
70 pecking either by infra-red or hot blade (Dennis et al., 2009) remain the main methods
71 of controlling FP, but raise welfare issues in their own right (Gentle et al., 1990;
72 Hughes and Gentle, 1995). **Furthermore, beak treatments of all types will be**
73 **banned in the UK from 2011.** There is therefore an urgent need to find ways of
74 controlling FP without resorting to beak treatment.

75 Despite the much greater understanding of the factors predisposing hens to
76 feather peck that has been gained from research over the past 25 years, prevention is
77 still not possible (Rodenburg et al., 2004; Dixon, 2008). The problem is multi-
78 factorial and stems from interactions between the bird, the environment and
79 management variables in ways that are not yet understood (Rodenburg et al., 2008a).
80 Environmental factors experienced by birds during rearing have been identified as
81 particularly important to the development of later FP in adult flocks (**Johnsen et al.,**

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2
3 82 **1998**; Gunnarsson et al., 1999; van der Weerd, 2006, Staack et al, 2007; Riber et al,
4
5 83 2007; Rodenburg, et al., 2008b) but it is not clear whether particular factors are
6
7
8 84 critical or whether it is **the** change between rearing and lay factors that **is** most
9
10 85 important. However, even if it is not currently possible to prevent FP altogether, it
11
12 86 would greatly help producers if they were able to predict outbreaks of FP before they
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15 87 occur or at least detect them at the onset. This would allow action to be taken before
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17 88 the welfare and production of the birds was adversely affected and to concentrate such
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19 89 measures on high risk flocks.

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21
22 90 The aim of this longitudinal study was to identify factors (bird, management
23
24 91 and environment) in the early environments of laying hens in commercial non-cage
25
26 92 systems that predict which flocks are at the greatest risk of developing FP later in lay.
27
28 93 Commercial flocks were followed from rear throughout the laying period until
29
30 94 clearance and we **collected data on a variety of factors about the birds themselves**
31
32 95 **(strain, feather cover, feed intake) as well as the environments they were in.** We
33
34 96 looked for signs in young flocks that might indicate they were at high risk of
35
36 97 developing FP later in life and also at factors in the rearing and laying environments
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38 98 that might be associated with severe feather damage. We examined both the role of
39
40 99 particular factors in the rearing environment that might predispose **an** adult flock to
41
42 100 feather damage and also the role of changes between the rearing and the laying
43
44 101 environment that might constitute a particularly high risk.

50 102 MATERIALS AND METHODS

51
52
53 103 Approximately 335 000 commercially reared laying hens were followed from 12
54
55 104 rearing farms on to 19 laying farms between February 2006 and August 2008. The
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57 105 laying farms consisted of 44 houses, the majority of which were internally sub-
58
59 106 divided into colonies (birds physically separated by a barrier but within the same

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4 107 house). This gave a total of 84 colonies, where a colony could be either a whole
5
6 108 house (no internal barriers between flocks) or a single undivided house. A single
7
8 109 colony could contain between 780-4000 birds. As colonies within a house were not
9
10 110 fully independent, data were analysed statistically with house (n=44) as the
11
12 111 independent unit.

13
14
15 112 The study included three different types of laying systems: barn (2 houses/10
16
17 113 colonies), organic free-range (19 houses/19 colonies) and free-range systems (42
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19 114 houses/55 colonies). Flocks were comprised of 5 laying bird **hybrids**: Hyline,
20
21 115 Lohmann (Brown and Traditional), Shaver, **Bovans** Goldline, **Columbian** Black Tail
22
23 116 and a mix of Hyline and Goldline. Birds from 18 out of the 19 farms were beak-
24
25 117 treated at 5-7 d old. One farm which did not beak-treat initially, had to beak treat two
26
27 118 colonies at 30 weeks of age. Another farm had to repeat the beak-treatment for 4
28
29 119 colonies at 35 weeks of age. The methods used for beak treatment were; infra-red (4
30
31 120 houses) and traditional hot-blade (40 houses). Each house was visited on at least 4
32
33 121 occasions; towards the end of rear (<17 weeks), after transfer to the lay house (~18-
34
35 122 22 weeks), peak-lay (~23-30 weeks) and close to clearance (~50 wks). Additional
36
37 123 visits were made to some farms to establish a more thorough database of events. **Due**
38
39 124 **to insufficient numbers in the barn systems and houses using infra-red beak**
40
41 125 **treatments, we were unable to meaningfully compare the impact of these**
42
43 126 variables on propensity for feather damage.

44 45 46 47 48 49 50 51 127 **Feather damage**

52
53 128 Feather damage scores were recorded during each visit for each colony both inside the
54
55 129 house and from birds on the corresponding range outside the house by visual
56
57 130 inspection using the method described by Bright et al. (2006); 100 birds were visually
58
59 131 assessed for feather damage (Table 1) from each colony and 100 from each range
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3 132 outside the house. A random number grid map was used to select the birds. Five
4
5 133 different body regions on the bird were selected (neck, back, rump, tail and wing) and
6
7
8 134 scored on a best (0) to worst (4) scale (Table 1). Feather damage scores were
9
10 135 collected during each visit and averaged to give a mean feather damage score for each
11
12 136 body region and an average total (that is,. summed) feather score for each colony. We
13
14 137 considered mean feather damage greater than or equal to the threshold of 3.8 (at any
15
16 138 age) to be substantial feather damage in an attempt to 'predict' whether a flock was at
17
18 139 risk of becoming a 'feather pecking flock'.
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22 140 **Management and husbandry**

23
24 141 The first visit was conducted at the rearing house (12 - 17 weeks of age). This visit
25
26 142 gathered detailed information on general management, husbandry practices and the
27
28 143 bird. **The following were recorded: season of rear and hatch month, size of farm**
29
30 144 **(number of houses, numbers and ages of birds currently on farm, strain of bird,**
31
32 145 **age of parent flock, flock size, stocking density, drinker type (bell, bell and**
33
34 146 **nipple, nipple, nipple with cup), number of drinkers per house, feeder type**
35
36 147 **(chain, chain and pan, pan), number of feeders per house, litter type (cut straw,**
37
38 148 **newspaper, woodchip), lighting source/number (fluorescent, tungsten, daylight,**
39
40 149 **redlight or combination, enrichments such as perches, bales etc.** Birds were
41
42 150 transferred to the laying houses between 17 – 18 weeks. A record was kept of
43
44 151 whether the laying houses were on the same or a different farm. The first visit to the
45
46 152 laying farm (between 18 and 22 weeks of age) consisted of recording **the**
47
48 153 management, husbandry practices, bird, environment and production variables **listed**
49
50 154 **above and in addition recording details of the laying system (barn, free-range,**
51
52 155 **organic), other species on farm, age at transfer, verandas (Y/N) % of house floor**
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54 156 **slatted or litter, range size, % range area covered by vegetation, vegetation type**
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3 157 (no trees, artificial shelter, small growing trees, mature growing trees, mature
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6 158 trees with artificial shelter).

7
8 159 **Environmental variables**

9
10 160 Environmental variables were measured during each visit. Within each colony, 4
11
12 161 **locations were chosen randomly using a grid map, two in the slatted area and**
13
14 162 **two on litter.** Environmental measures were taken at all 4 **locations and the mean of**
15
16 163 **these calculated for each colony.** The measures taken were: sound (dB) intensity
17
18 164 (using a Sound level meter ST-8850, Farnell in One, Leeds, UK), lux (using a TES
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20 165 1330A Digital Lux meter, York Survey Supply Centre, York, UK), litter pH and
21
22 166 temperature (using a HI-991300 pH/Temperature meter, Hanna Instruments, Bedford,
23
24 167 UK) and ammonia and carbon dioxide gas concentrations (5-100 ppm and 300-5000
25
26 168 ppm respectively) (using RAE gas detection tubes, RAE Systems Inc., California,
27
28 169 USA and a Gastec GV-100S pump, Gastec Corporation, Japan) were recorded. All
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30 170 variables were recorded at bird height (~ 30 cm from ground).

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36 171 **Production variables**

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38 172 Weekly production records were collected by the producers and included percent of
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40 173 birds in lay, percent mortality and feed consumed (gram/hen/d). Production records
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42 174 that were not directly supplied varied from farm to farm, and not all farms collected
43
44 175 the same information; however all recorded those listed above.

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48 176 **Statistical analysis**

49
50 177 The independent unit for analysis was the house (n=44). The aim of the analysis was
51
52 178 to identify which factors contributed to the risk of 'failure', that is a given flock
53
54 179 yielding a mean feather damage score of ≥ 3.8 . Although any arbitrary level of feather
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56 180 damage could be defined as 'failure', 3.8 represents a substantial level when feathers
57
58 181 are severely damaged and/or areas of naked skin are visible (Table 1). This is the level

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3 182 of damage seen in approximately half of all flocks before 40 weeks of age, with some
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5 183 flocks reaching this level earlier and some never (Figure 2). The choice of this
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7
8 184 threshold gives the model better predictive power than by choosing a threshold that
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10 185 was always met or never met.

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13 186 **The aim of our analysis was to describe associations between the time at**
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15 187 **which a flock experiences failure (mean feather damage score of ≥ 3.8) and**
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17 188 **characteristics of the farm, house and flock. If every flock had been observed to**
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19 189 **fail (in other words there were no censored data), then regression would be an**
20
21 190 **obvious choice for describing relationships between predictors and the time at**
22
23 191 **which each flock experienced failure. In our study, however, many flocks were**
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25 192 **never observed to fail. Thus, our analyses needed to allow for censoring. We**
26
27 193 **performed two parallel sets of such analyses, based on accelerated failure time**
28
29 194 **models and Cox proportional hazards models, each indicating whether or not**
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31 195 **(and to what extent) the variable in question had a significant effect on ‘failure’**
32
33 196 **times of flocks. Accelerated failure time models (Wei, 1992) produce estimates of**
34
35 197 **differences (in weeks) in the time to failure associated with different potential**
36
37 198 **predictors (such as with or without transfer to a different farm between rear and**
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39 199 **lay) by regressing the logarithm of the survival time over the covariates, while**
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41 200 **allowing for censored data. In contrast, Cox proportional hazards models (Cox,**
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43 201 **1972) produce estimates of relative hazards (risk of failure), under the**
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45 202 **assumption that the impact of a predictor is multiplicative. In other words, a**
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47 203 **factor that halves risk for a relatively low-risk flock will also halve risk for a**
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49 204 **relatively high-risk flock. The results of the two methods were highly consistent.**
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57 205 We report the results of the accelerated failure time models here because the
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59
60 206 results are in terms of absolute differences (in weeks) in times to failure and therefore

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3 207 have immediate biological meaning. The results are given as the estimated %
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5 208 reduction (or increase) in the age at which flocks showed a mean feather score of 3.8
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8 209 or more, together with 95% confidence limits for the % reduction (or increase) and its
9
10 210 associated *P*-value.
11

12 211

13 212 RESULTS

14 213 **Descriptive results of feather pecking**

15
16
17 214 Figure 1 shows initial bird numbers on transfer into the lay houses (n=44), final bird
18
19 215 number at depletion (mark on bar) and houses which ones developed FP prior to 40
20
21 216 weeks of age (asterisk). There was large variability of number of houses on farms and
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23 217 numbers of birds housed across, and within farms.
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28 218 **Feather scores**

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30
31 219 Figure 2 shows the incidence of feather damage in flocks of different ages for all
32
33 220 colonies (n=84) observed in the study. Feather damage increased with age and **was**
34
35 221 cumulative but 23% of houses never reached the FP threshold of 3.8. Within houses,
36
37 222 16 out of 84 colonies (19%) reached the threshold of ≥ 3.8 by 40 weeks of age, 29
38
39 223 colonies (35%) by 41-50 weeks of age and by 60 weeks of age, 49 colonies (59%) had
40
41 224 reached the feather damage threshold.
42
43
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45
46 225 Table 2 shows that the feather damage score at a given age predicted the time
47
48 226 in the future when a flock **would** reach the FP threshold. (A unit = an increase of 1.0
49
50 227 in the average total feather score as defined in Table 1). Particularly notable is the fact
51
52 228 that predictions **could** be made even by observing young birds less than 20 week of
53
54 229 age, where there **was** relatively little feather damage (Figure 2). The feather damage
55
56 230 scores for birds 17-20 weeks ranged between 0.03-1.18. Nevertheless, the feather
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3 231 damage score measured at this time **were** highly predictive of the age at which a
4
5 232 house would later cross the threshold feather score of ≥ 3.8 (**Table 2**).

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8 233 **Management and husbandry**

9
10 234 The effect of various management systems and husbandry practices are shown in
11
12 235 Table 3. Chain feeders were significantly associated with earlier failure times than
13
14 236 pan feeders. **Low** feeders (those on the ground) **were associated with earlier onset of**
15
16 237 **FP than High** (raised above the ground). Pan feeders were always raised above
17
18 238 ground level.

21
22 239 **Production**

23
24 240 Neither % mortality in the flock nor the % of birds in lay was predictive of when that
25
26 241 flock would reach a FS of ≥ 3.8 (for mortality $p > 0.1$ at all ages; for % birds in lay
27
28 242 $p > 0.5$ at all ages). However, the mean amount of feed eaten (**g/day per individual**)
29
30 243 was significantly predictive, at least when birds were less than 17 weeks and between
31
32 244 20 and 24 weeks of age, indicating that the more feed that was eaten, the earlier
33
34 245 failure time occurred (**Table 4**).

35
36 246 **Environmental variables**

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38 247 **The levels of the environmental variables recorded** (carbon dioxide (CO₂), ammonia
39
40 248 (NH₃), light (lux), noise (dB), litter pH and temperature (°C) are shown in **Table 5**.

41
42 249 **In laying houses, higher CO₂ levels were associated with earlier onset of FP:**
43
44 250 **between 24 and 30 weeks of age, each 200 ppm increase in CO₂ was associated**
45
46 251 **with a 14.8% reduction in time to failure (95% confidence interval -19.7% - -**
47
48 252 **9.5%; p=0.0001). Higher ammonia levels were also associated with earlier onset**
49
50 253 **of FP: every 15 ppm increase in NH₃ recorded between the ages of 15 and 17**
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52 254 **weeks was associated with a 10.1% reduction in time to failure (CI -16.2% - -**
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4 255 **3.5% ; p=0.003); between the ages of 24 and 30 weeks, it was associated with a**
5
6 256 **12.9% reduction in time to failure (CI: -18.7% - -6.8% ; p=0.0001).**

7
8 257 **Light was another risk factor, particularly if light levels were high in**
9
10 258 **young birds. Higher light levels in birds of 17-20 weeks were associated with an**
11
12 259 **earlier onset of FP: each 100 lux increase was associated with a 12.2% reduction**
13
14 260 **in time to failure (C.I.: -18.9% - -3.9% ; p=0.0034). The final factor we found to**
15
16 261 **be associated with earlier onset of FP was sound level. Between 15 and 17 weeks,**
17
18 262 **each 10 dB increase in sound was associated with 25.5% reduction in time to**
19
20 263 **failure (C.I.= -39.6% - -8.2% ; p=0.0056) and between 17-20 weeks, with a 7.9%**
21
22 264 **reduction in time to failure (C.I.= -13.5% - -2.0% ; p=0.0099). No significant**
23
24 265 **differences were found at any age category for either litter pH (p>0.3) or for**
25
26 266 **temperature (p>0.05) measured during the visit.**

267 **Environmental factors during rearing**

268 Factors in rearing that influenced FP later in lay are shown in **Table 6**. The type of
269 feeders and drinkers had a significant effect on age at which FP developed. **FP**
270 developed earlier in flocks that came from rearing houses with chain feeders than
271 from those with pan feeders or a combination of feeder types. FP developed earlier in
272 laying flocks that had been reared in houses with a bell and nipple drinker system than
273 those with nipples only, or nipple/cup systems.

274 **Changes from rearing to laying environment**

275 **Table 7** shows the effects of changes from the rearing environment to the laying
276 environment. Where the feeder system did not change from rear to lay, FP was found
277 to start sooner than when the feeder system changed between farms (**Table 7**).
278 However, it should be noted that the only recorded instances of where the feeder
279 system was the same in rear and in lay were those in which there was a chain feeder in

1
2
3 280 both. Chain feeders appear to be a risk factor in themselves (Table 6). An earlier start
4
5 281 to FP occurred earlier in lay with birds that were moved to a different farm (Table 7).
6
7

8 282 To obtain an idea of whether FP was affected by the number of changes
9
10 283 between rearing and lay, we added together the effects of **all recorded changes**
11
12 284 (veranda, perches, feeder type, drinker type, lighting, transfer to a different lay farm).
13
14 285 This is shown as 'sum' in the bottom row of Table 7 and was not associated with an
15
16 286 earlier risk of feather damage.
17
18

19
20 287 Birds hatched as chicks in July-March showed a delay in reaching the feather
21
22 288 score of ≥ 3.8 of 17.2% compared to birds hatched in April, May or June (2.9-33.5%, p
23
24 289 =0.0169) indicating FP started earlier for those hatched April-June.
25
26

27 290 DISCUSSION

28
29 291 **Our results show that the age at which a flock exhibits substantial feather**
30
31 292 **damage can be predicted both by factors in the environment and by early**
32
33 293 **symptoms in the birds themselves. Environmental actors that were associated**
34
35 294 **with earlier onset of severe feather damage included the presence of chain**
36
37 295 **feeders, raised levels of carbon dioxide and ammonia, higher sound and light**
38
39 296 **levels, particularly in younger birds.**
40
41
42

43 297 Our results also show that it is possible to predict which flocks are at greatest
44
45 298 risk of feather pecking before serious feather damage is apparent. Even in young birds
46
47 299 (under 20 weeks of age), when very little feather damage is seen in any flocks, slight
48
49 300 differences in feather score are predictive of the level of feather damage at later ages
50
51 301 (Table 2). In other words, even slightly raised feather scores in young birds are
52
53 302 associated with earlier onset of serious feather damage, supporting similar studies by
54
55 303 **Bright (2009) and Bestman et al. (2009). This means that just by looking at a**
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3 304 young laying flock, it may be possible to predict how likely they are to develop
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5
6 305 serious feather damage.

7
8 306 Another factor that is suggestive of future problems is feed intake. Flocks
9
10 307 that showed early signs of increased daily feed intake were also likely to show earlier
11
12 308 severe feather damage (Table 4). However, this was only shown to be significant
13
14
15 309 between 20 -24 weeks of age. This is of interest as it is known that birds increase
16
17 310 their feed consumption due to heat loss, if, severely feather pecked (Tauson and
18
19 311 Svensson, 1980). Therefore, the first signs of an increase in food consumption may
20
21 312 indicate a measure in which to 'predict' a problem before it becomes an issue of
22
23 313 welfare or productivity.

24
25
26
27 314 While our results are consistent with the previous studies that have
28
29 315 emphasized the factors in the rearing environment that influence feather pecking
30
31 316 in later life (Blokhuys & van den Haar, 1989, 1992; Norgaard-Nielsen et al.,
32
33 317 1993; Johnsen et al, 1998; Newberry et al., 2007), we have here attempted to
34
35 318 separate the influence of factors in the rearing environment *per se* from the
36
37 319 influence of *changes* between rearing and laying environments. For example,
38
39 320 factors such as light levels in rearing might appear to have little effect on
40
41 321 likelihood of feather damage in lay (Kjaer & Sorenson 2002), but a change in
42
43 322 light level as the birds were moved from rear to lay might have a much bigger
44
45 323 effect. We therefore asked separate questions about the factors in rearing that
46
47 324 were associated with later feather pecking and about whether or not birds had
48
49 325 experienced a change in those factors as they were moved from rearing to laying
50
51 326 houses.

52
53 327 The accelerated failure time models used in this study point to a number of
54
55 328 factors in rearing that are associated with earlier onset of serious feather damage.
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3 329 Factors associated with such a risk include feeder type and position, with chain
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5 330 feeders associated with earlier failure (**Table 6**). It is not clear why chain feeders
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8 331 appear to pose a risk.. **Freire et al. (1999) found that, in modified cages, increased**
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10 332 **feather pecking was associated with lower feed troughs (6 cm above ground)**
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12 333 **compared to 28 cm.. They suggested that this was because hens stepped on each**
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14 334 **other, leading to feather damage and subsequent FP. The possibilities that low**
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16 335 **feeders may hamper movement of an attacked bird, lead to feather damage or**
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18 336 **that they are associated with more restricted feeding would be well worth further**
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20 337 **investigation.** Although our data are suggestive rather than conclusive, a lack of a
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22 338 veranda for young birds during rearing may also be associated with earlier risk of
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24 339 feather pecking. (The value of providing verandas for young birds could usefully be
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26 340 explored). Among environmental factors, poor air quality (levels of CO₂ and
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28 341 ammonia) and higher light levels predispose flocks to develop feather pecking at an
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30 342 earlier age (**Table 6**).

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36 343 In addition, increased sound levels within a house (up to 20 weeks of age)
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38 344 were associated with an early propensity to feather peck. However, as in a study by
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40 345 Bright (2008), it is not clear whether the observed effects were due to noise made by
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42 346 the birds themselves (birds that vocalise a lot have a tendency to FP) or due to
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44 347 environmental noise increasing the tendency to FP. Either way, the role of sound
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46 348 deserves more attention in future (Bright, 2008). It could either be a useful indicator
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48 349 that a given flock is 'at risk' of developing FP or a pointer to the relatively easy
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50 350 intervention of reducing noise levels to reduce risk of FP.

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55 351 **We then examined the effects of *change* between rear and lay.** One factor
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57 352 that seemed to be of considerable importance **was** whether birds **moved** farms
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59 353 between rear and lay. Although the numbers reported here are small, there is a strong

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3 354 suggestion that staying on the same farm may postpone the risk of feather pecking in
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5 355 lay (**Table 7**). This might be because birds staying on the same farm do not
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8 356 experience a long journey or it could be that where rearing and laying houses are on
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10 357 the same farm, they are more likely to provide more similar conditions than if they are
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12 358 on different farms. We attempted to test the idea that ‘amount of change’ in
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14 359 environmental conditions was important by looking at the effects of **the number of**
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16 360 **changes** between rear and lay. We failed to detect any additive effect of the **number**
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18 361 **of changes (Table 9)**. Nevertheless, we suggest that further studies of the transition
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20 362 between rearing and laying environments could be very valuable. Keeping birds on
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22 363 the same farm throughout their lives is not usually possible, but **more** attention to the
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24 364 differences they experience as they move from rear to lay might suggest ways of
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26 365 **reducing** the chances of severe feather damage later on.

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31 366 In conclusion, it is possible to predict which flocks are at risk of FP before
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33 367 serious feather damage has occurred later in lay. Given the multifactorial nature of
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35 368 FP and the difficulties of eliminating it altogether, the ability to identify ‘at risk’
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37 369 flocks could still be of value to producers since it could enable them to target
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39 370 **preventive** action specifically on the flocks most at risk. Future research aimed at
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41 371 reducing the risk of feather pecking could profitably concentrate on the role of feeder
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43 372 layout, air quality, and light and sound levels, as well as the role of changes between
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45 373 rearing and laying environments.

50 374 **Acknowledgements**

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54
55 376 Noble Foods Ltd, Stonegate and farmers for providing facilities which we were
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57 377 permitted to visit.
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Captions to figures.

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11 470 Figure 1. Initial bird numbers on transfer to the lay house and incidence of FP in the
12 study houses. Each bar represents one house and points on each bar represent the final
13 bird number at clearance. Houses on the same farm are grouped by dotted lines.
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15 472 Columns with an asterisk represent flocks that went on to develop FP (mean feather
16 score of ≥ 3.8) prior to 40 weeks of age.
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29 478 Figure 2. Average feather damage score by age category for each house. The solid
30 black horizontal line represents the level of feather damage regarded as 'failure' –a
31 mean flock feather score of 3.8 or greater. Grey lines represent houses that fail before
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Tables

Table 1. Feather damage score

Score	Description of body
0	Well feathered body parts with no or little damage
1	Slight damage to any area of the body with feathers ruffled, body completely/almost completely covered
2	Severe damage to feathers, but localised naked area (<5cm ²)
3	Severe damage to feathers, and large naked areas (>5cm ²)
4	Severe damage to feathers, >5cm ² naked area and haemorrhage or broken skin

Table 2. Feather damage scores (FS) in birds of different ages as predictors of the future time at which a house would reach a mean feather score of 3.8 or more.

Age in weeks	Estimated effect	95% confidence interval		p-value	Comments
15-17	30.3%	-54.3%	271.7%	0.62	
17-20	-38.2%	-55.9%	-13.5%	0.005	Each 1 unit increase in FS associated with 38.2% reduction in time to failure
20-24	-16.2%	-47.3%	33.1%	0.45	
24-30	-15.0%	-25.6%	-2.9%	0.017	Each 1 unit increase in FS associated with 15.9% reduction in time to failure
30-40	-9.6%	-16.1%	-2.7%	0.007	Each 1 unit increase in FS associated with 9.6% reduction in time to failure

Table 3. Management systems and husbandry practices as predictors of the time at which a house would reach a mean feather score of 3.8 or more.

	Estimated effect	95% Confidence interval		p-value	Comments
Organic * (Y/N)	-6.6%	-18.9%	7.4%	0.34	
Veranda (Y/N)	-7.6%	-19.4%	6.0%	0.26	
Perch (Y/N)	-7.1%	-19.2%	6.7%	0.30	
Feeder ** (Chain/pan)	-19.7%	-31.9%	-5.3%	0.009	Houses with chain feeders failed 19.7% sooner than pan
Feeder ht (H/L)	21.1%	5.9%	38.4%	0.005	Houses with high feeders failed 21.1% later than low

*This analysis compared free-range with organic and omitted barn systems

**This analysis omitted houses that had both chain and pan (n=3).

Table 4. Daily feed intake (grams/hen/day) at different ages as a predictor of the time at which a house would reach a mean feather score of 3.8 or more.

Age (weeks)	Estimated effect	95% Confidence interval		p-value	Comments
15-17	-1.0%	-1.78%	0.0%	0.041	Based on very limited data
17-20	-2.6%	-11.7%	7.5%	0.60	
20-24	-13.4%	-23.7%	-1.8%	0.025	Each 20 g/h/d increase in feed associated with a 13.4% reduction in time to failure
24-30	-1.0%	-5.6%	3.9%	0.67	
30-40	-0.6%	-3.1%	2.0%	0.68	

Table 5. Levels of environmental variables measured.

	Mean (sd)	Range
Light (lux)	29.6 (65.4)	2.0 - 869.1
Sound (dB)	59.4 (12.7)	14.3 – 80.0
CO ₂ (ppm)	586 (327)	43-2000
Ammonia (ppm)	21.9 (18.4)	0-100
Litter temp. (°C)	17.5 (4.5)	5.7-27.9
Litter pH	7.13 (2.5)	1.14-13.62

Table 6. Factors in rear as predictors of time at which a house reached a mean feather score of 3.8 or more.

Reared with	Estimated effect	95% Confidence interval		p-value	Comments
Chain feed	-26.8%	-41.6%	-8.2%	0.0068	Houses with chain feeders in rear failed 26.8% sooner than houses with both chain and pan in rear
Bell	-15.0%	-26.3%	-2.0%	0.0255	Houses with bell drinkers in rear failed 15% sooner than houses with nipple + cup drinkers in rear
Bell/nipple	-39.6%	-50.6%	-26.1%	<0.0001	Houses with both bell and nipple drinkers in rear failed 39.5% sooner than houses with nipple drinkers
Nipples +/-cups	-6.8%	-23.8%	14%	0.49	
Light type	29.8%	6.9%	57.8%	0.0086	Houses with fluorescent or natural light in rear failed 29.8% later than houses with tungsten light in rear

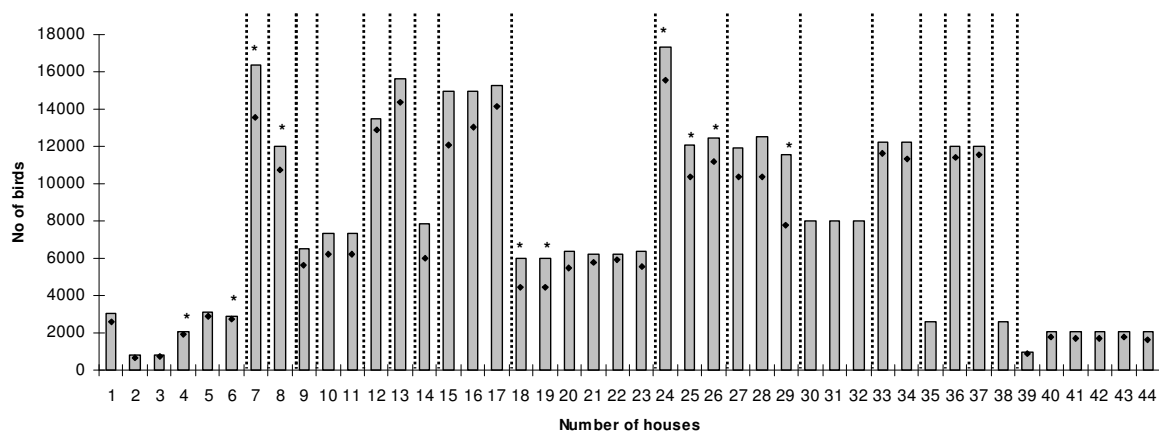
Table 7. Factors that changed between rear and lay as predictors of the time that a house reached a mean feathers score of 3.8 or more.

Change in	Estimated effect	95% Confidence interval		p-value	Comments
Veranda in rear Y/N	9.4%	-4.5%	255.4%	0.19	
Perch Y/N	6.7%	-6.3%	21.7%	0.33	
Feeder type Y/N	-19.2%	-28.5%	-8.7%	0.0006	Houses which had the same feeder type in rear and lay failed 19.2% sooner than houses of birds which experienced a change in feeder type from rear to lay.
Drinker type Y/N	-10.1%	-22.3%	-4.1%	0.15	
Light type Y/N	10.1%	-5.1%	27.6%	0.20	
Farm Y/N	28.4%	6.1%	55.5%	0.010	Houses of birds reared on the same farm as lay failed 28.4% later than houses of birds reared on different farm.
Sum	-1.7%	-8.1%	5.2%	0.62	

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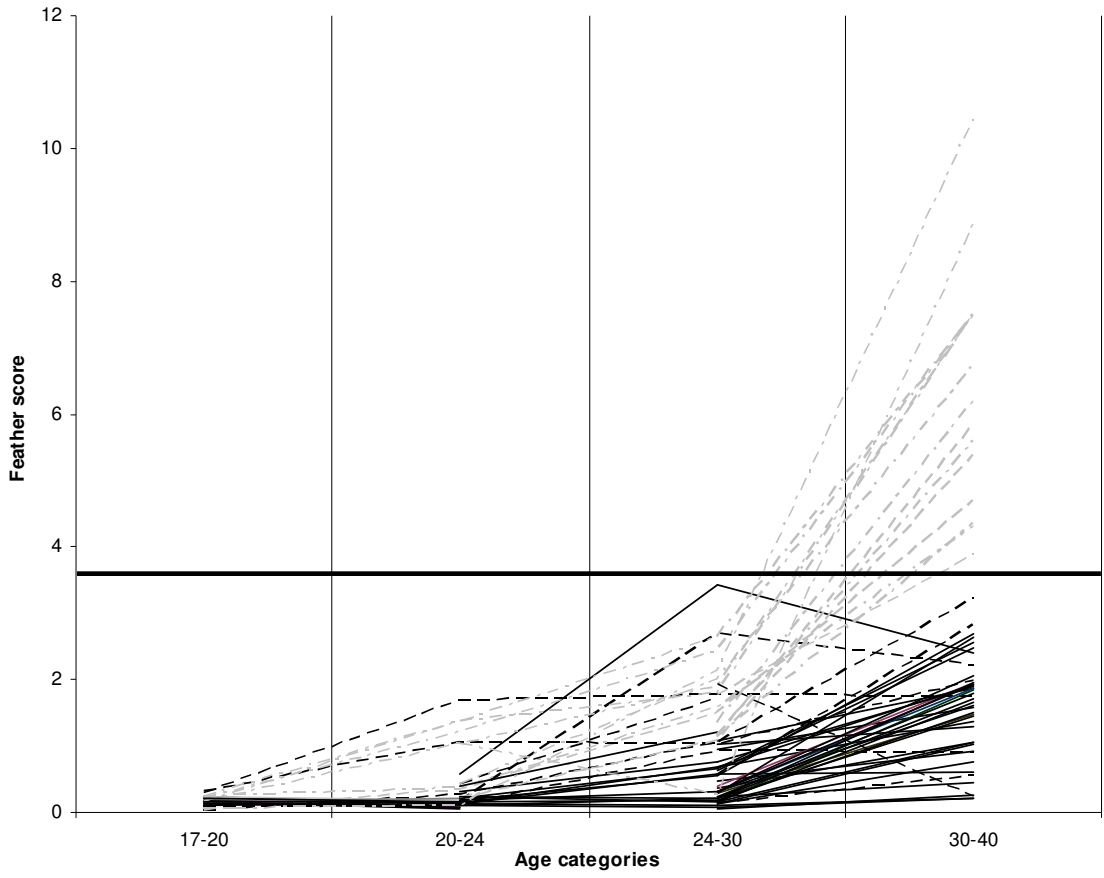
Figure 1.



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Figure 2.



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