



Pettersson, I., Weeks, C., & Nicol, C. (2017). The effect of ramp provision on the accessibility of the litter in single and multi-tier laying hen housing. *Applied Animal Behaviour Science*, 186, 35-40.  
<https://doi.org/10.1016/j.applanim.2016.10.012>

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[10.1016/j.applanim.2016.10.012](https://doi.org/10.1016/j.applanim.2016.10.012)

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1 **The effect of ramp provision on the accessibility of the litter in single and multi-tier laying hen**  
2 **housing**

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7 **Abstract**

8 Level changes in commercial laying hen loose-housing systems may be physically difficult for birds  
9 to negotiate, preventing or limiting access to resources such as the litter area and the outdoor range,  
10 and potentially increasing injury risk. The aim of this research was to investigate bird behaviour at an  
11 important level change (traversing between the raised slats/first tier and the litter), and whether it was  
12 affected by ramp provision or system. Birds were either observed at the edge of a single-tier with a  
13 full width ramp (ST-R), or at a section of tier edge without ramp in multi-tier systems (MT-NR) or in  
14 single-tier systems (ST-NR), both equipped with no ramps or only intermittent ramps throughout.  
15 Compared with single-tier systems, a greater proportion of birds that showed an initial orientation  
16 towards the litter moved away without traversing in the MT-NR group ( $p < 0.05$ ). Traversing birds in  
17 group ST-R showed reduced incidences of behaviours indicative of hesitancy/difficulty. The  
18 behaviours that occurred significantly less frequently in group ST-R compared with both groups MT-  
19 NR and ST-NR were crouching ( $p < 0.01$ ), multiple crouches ( $p < 0.01$ ), pacing ( $p < 0.05$ ) and stepping  
20 on the spot ( $p < 0.01$ ). Multiple head orientations were lower in ST-R compared with ST-NR ( $p < 0.05$ ).  
21 We conclude that the provision of a full-width ramp between the raised slatted area in single-tier  
22 systems or first tier in multi-tier systems could improve bird welfare by increasing the ease of access  
23 to important resources.

24

25 **Keywords:**

26 Laying hens; Welfare; Behaviour; Single-tier; Multi-tier; Ramp use

27

28 **1. Introduction**

29 Hen welfare is of increasing interest to consumers, and legislation to reduce the number of birds kept  
30 in restrictive cage systems can now be found worldwide. For example, following the ban on

31 conventional cages for laying hens in the EU in 2012 (Council Directive 1999/74/EC) 49% of UK egg  
32 production now comes from loose-housing systems (DEFRA 2016).

33 Commercial loose-house systems for laying hens vary widely in design but two fundamental types  
34 can be distinguished, both with littered areas at ground level. Single-tier systems have one raised  
35 slatted area on which the birds can access nestboxes, food and water. In multi-tier systems (also  
36 known as aviaries) the slatted areas are usually up to three tiers high with resources available on each  
37 of these different levels. Either system may have additional outdoor access (free-range) by providing  
38 popholes to the range, which are most commonly accessed via the litter areas. It is therefore essential  
39 in all loose-housing systems that the birds are able to traverse level changes in the house effectively if  
40 they are to reach all of the available resources. In particular, the slats (or first tier) to litter level  
41 change must be negotiated by the hens if they shall have access to foraging material and often the  
42 outdoor range.

43 The importance of access to these resources for bird welfare is well-documented. Feather pecking is a  
44 serious welfare issue particularly in loose-housed laying hens and access to a suitable foraging  
45 substrate is of great importance in its prevention (Nicol et al. 2013). Additionally, dustbathing can be  
46 considered a behavioural need (Weeks and Nicol 2006) and requires a fine, friable substrate for its full  
47 performance (Van Liere et al. 1997). To enhance welfare, various enrichment items and resources are  
48 frequently provided to commercial laying hens in both the indoor environment and outdoors (if free-  
49 range). The outdoor area can provide the opportunity for birds to express their full behavioural  
50 repertoire and has been shown to be beneficial to welfare through a reduced risk of feather pecking  
51 (Nicol et al. 2003).

52 Access to these important resources may be compromised if level changes in the house act as barriers  
53 that are physically difficult for birds to negotiate, inhibiting bird movement. If hens find the level  
54 change difficult, they may either injure themselves trying to traverse or choose to avoid traversing the  
55 level altogether, resulting in reduced behavioural opportunity through a restricted environment.  
56 Certainly, range use is highly variable and often low on commercial farms, with inhibited bird  
57 movement within the house highlighted as a potential causal factor (Pettersson et al. 2016).

58 Although the behaviour of birds traversing perches in experimental setups has been described (e.g.  
59 Taylor et al. 2003, Lambe et al. 1997) there is almost no information regarding the ability of birds to  
60 move between the slats, tiers and litter areas of a commercial single or multi-tier housing unit. Recent  
61 work on a lone multi-tier unit has shown that hen movement occurs in all areas of the system but  
62 whether all birds accessed all areas was unclear (Campbell et al. 2016a). Collisions and poor landings  
63 may occur, potentially leading to injury. Recent work found that 9.1% and 21% of observed flights  
64 failed in two multi-tier flocks (Campbell et al. 2016b). Previous research has shown that the risk of  
65 injury increases when birds have to jump a distance greater than 80cm vertically or jump an angle  
66 between 45 and 90° (for a review see EFSA AHAW Panel, 2015). The shortest transition height to the  
67 litter from multi-tiers is similar to that in single-tier houses, but multi-tier systems may be more  
68 hazardous as birds can get up very high and are therefore more likely to fall from a height. Keel bone  
69 fractures sustained during the lay cycle are highly prevalent in loose-housed hens (Wilkins et al. 2004,  
70 2011) and more so in multi-tier systems (Rodenburg et al. 2006, Käppeli et al. 2011).

71 Some producers provide ramps for the birds between the slats and litter in single-tier systems and the  
72 first tier and litter in multi-tier systems with the intention of aiding them to negotiate this level  
73 change. Providing ramps at different levels in multi-tier set-ups has been associated with reduced  
74 falls, collisions and keel bone fractures and greater controlled movement (Stratmann et al. 2015).  
75 These ramps or ladders may be intermittent, narrow structures along the edge of the slats or in some  
76 single-tier systems, comprise a full width ramp along the entire border of the slatted area with the  
77 litter (Fig 1).

78 Movement in commercial houses is a research area of growing interest and importance, particularly in  
79 multi-tier systems (Stratmann et al. 2015, Campbell et al. 2016a,b). Stratmann et al. (2015)'s research  
80 was based on experimental pens within a commercial house and recent work by Campbell et al.  
81 (2016a,b) studied two flocks in one commercial house. Small scale studies cannot always be widely  
82 applied due to the variety of housing designs seen commercially. It is therefore important to study  
83 multiple houses and there remains a lack of research on bird movement on this scale. This study  
84 aimed to apply existing knowledge of bird movement and flight abilities to the commercial setting

85 with a specific focus on behaviour immediately prior to changing levels. We studied the effects of  
86 house design, specifically single vs multi-tier housing, and ramp vs no ramp provision, on (i) the  
87 likelihood of birds completing a downward traverse to the litter area after initiation of a traverse, (ii)  
88 their behaviour prior to a traverse and (iii) the time taken to reach the litter after initiation of a  
89 traverse.

90

## 91 **2. Methods**

92 In total 16 commercial, free-range laying hen houses were studied when the birds were approximately  
93 40 weeks of age. Twelve of the houses were visited on two occasions (at 40 weeks in different flock  
94 cycles) as part of a wider research project. All flocks were brown genotypes with an average flock  
95 size of 13,044 (see table 1). Stocking densities were between 8 and 9 birds/m<sup>2</sup> in line with UK  
96 legislation. See table 1 for a summary of house and flock information. The four multi-tier flocks were  
97 reared in multi-tier systems and all others in single-tier systems.

98 This study focused on the behaviour of birds as they approached the edge of the slats (or first tier) and  
99 oriented into a position where they could move down from the slatted area (or first tier) onto the litter  
100 area. The 16 houses were split into three groups based on their design. Group ST-R (n=7) consisted of  
101 single-tier houses with a full width ramp across the entire slat-litter level change (as in Fig 1). These  
102 ramps were made of plastic slats. Group MT-NR (n=4) comprised multi-tier houses with intermittent  
103 or no ramps between the first tier and the litter. Group ST-NR (n=5) consisted of single-tier houses  
104 with intermittent or no ramps between the slats and litter.

### 105 *2.1. Behavioural observations*

106 All observations were performed by the same observer. In each house three or four 2m sections along  
107 the edge of the slats (or first tier) were randomly selected (see Fig 1). Where intermittent ramps were  
108 present, a section with no ramp was chosen.

109 For each section, focal birds within this area were studied for 10 minutes. It was not possible to record  
110 all birds that moved down to the litter within the 10 minutes as multiple birds moved at once on some  
111 occasions. The number of focal birds studied therefore varied, although a limit of 10 were observed  
112 per section.

113 A focal bird was selected for observation if it entered the 2m section and was facing the litter when a  
114 direct head orientation towards the litter was observed. The time from this head orientation until birds  
115 reached the ground ('Time to litter'), or moved away ('Time to move away') was recorded using a  
116 stopwatch. A bird was considered to have moved away if it orientated away from the litter and  
117 showed no further intention behaviours for 10 seconds (see table 2).

118 The occurrences of behaviours preceding each traverse to the litter or move away were tallied. See  
119 table 2 for an ethogram of the behaviours recorded in this study. The behaviours 'crouch' and 'head  
120 orientation' were precursors to a jump so two additional variables were calculated in order to pick up  
121 on birds that crouched or head orientated without jumping – the percentage of birds that performed 2  
122 or more head orientations: "multiple head orientations", and the percentage that performed 2 or more  
123 crouches: "multiple crouches". For the ST-R group it was also noted whether the bird jumped/flew or  
124 walked down the ramp.

## 125 *2.2. Analysis*

126 All data were analysed using SPSS 23.

127 Data from focal birds from each section were combined and percentages of individuals that performed  
128 each behaviour were calculated for each house. Mean times to litter or times to move away per house  
129 were also calculated from all observed individuals.

130 As 12 houses were visited twice (two different flock cycles) the percentages for each behaviour and  
131 time to litter for these two visits were averaged to create a single point for each house. The remaining  
132 4 houses were only visited on one occasion so data from this visit only were analysed. House, rather  
133 than flock, was used as the independent statistical unit because the substantial differences in house  
134 design were considered likely to have the greatest effect on bird movement. After checking for the

135 effect of house design on whether birds moved away or not, the data from birds that traversed was  
136 analysed separately from the data from birds that moved away.

137 Standardised residuals of each variable were first checked for normality using a Shapiro-Wilk test and  
138 P-P plots, with logarithmic or square root transformations performed where possible on variables with  
139 non-normal residuals.

140 Data were analysed using one-way ANOVAs with house design group as a factor, and post-hoc  
141 Tukey HSD tests. Levenes test was used to check homogeneity of variances and if homogeneity was  
142 not found a non-parametric test was used. Variables that could not be transformed to achieve normally  
143 distributed residuals were also analysed using the non-parametric equivalent, the Kruskal-Wallis test.  
144 In order to detect group differences following a significant Kruskal-Wallis test, individual Mann-  
145 Whitney U pairwise comparisons were performed and the significance level corrected using the  
146 Bonferroni correction to 0.017 for these tests.

147 A one-way ANOVA was also performed to compare house systems regarding height of the first tier.  
148 Pearson and Spearman correlations were performed on tier-height and behaviour data.

149

### 150 **3. Results**

#### 151 *3.1. Effect of ramp group on likelihood of moving away*

152 A significant effect of ramp group was found on the likelihood of a bird moving away instead of  
153 traversing to the litter ( $F(2,13)=8.949$ ,  $p=0.004$ ). Post hoc testing revealed that a higher percentage of  
154 birds moved away in group MT-NR (26.12%) than both group ST-R (9.57%) and group ST-NR  
155 (11.72%) ( $p<0.05$ ).

#### 156 *3.2. Effect of ramp group on behaviour – traversing birds only*

157 House design had a significant effect on time to litter ( $F(2,13)=6.351$ ,  $p=0.012$ ) and the percentage of  
158 birds performing multiple head orientations ( $F(2,13)=3.827$ ,  $p=0.049$ ). Post-hoc testing revealed that  
159 providing full-width ramps in single-tier systems (ST-R) reduced the percentage of birds performing



160 multiple head orientations ( $p < 0.05$ ) compared with the single-tier non-ramp group (ST-NR) group.  
161 Birds from group ST-R took significantly longer to reach the litter than birds from group MT-NR  
162 ( $p < 0.05$ ).

163 House design significantly influenced pacing ( $F(2,13) = 11.614$ ,  $p = 0.001$ ) and stepping behaviours  
164 ( $\chi^2 = 11.639$ ,  $p = 0.003$ ). A significantly lower percentage of birds paced ( $p < 0.05$ ) or stepped ( $p < 0.01$ )  
165 in group ST-R compared to both groups MT-NR and ST-NR.

166 The presence of a full-width ramp had a significant effect on the percentage of birds that crouched at  
167 least once ( $F = 100.187$ ,  $p < 0.001$ ) and on the percentage that performed multiple crouches ( $F = 25.912$ ,  
168  $p < 0.001$ ). Decreased crouching behaviour was seen when a full-width ramp was present (ST-R)  
169 compared with both non-ramp groups (MT-NR and ST-NR) ( $< 0.01$ ).

170 All traversing birds in groups MT-NR and ST-NR jumped/flew to the litter. Of the 7 houses in group  
171 ST-R, in only 3 were any focal birds observed jumping instead of walking down the ramp. House 2  
172 had 19.57% that jumped, 5.56% jumped in house 7 and 1.79% jumped in house 8. Therefore the  
173 majority of birds used the ramp to walk the entire way to the litter, likely resulting in the overall  
174 slower descent seen in this study in the ST-R group.

175 House design significantly affected the likelihood of crash landings ( $\chi^2 = 10.253$ ,  $p = 0.006$ ). Crash  
176 landings were only observed in three houses, all of which were in the multi-tier group.

177 See table 3 for means and standard deviations of each group.

### 178 *3.3. Effect of tier height on behaviour – traversing birds only*

179 Mean tier height was not significantly different between treatment groups ( $F = 2.829$ ,  $p = 0.096$ ). To  
180 check for the potential effect of tier height on the results across all houses in the study, bivariate  
181 correlations between height and all behaviours revealed no significant correlations. This was repeated  
182 with group ST-R excluded (as a full width ramp may have reduced the importance of tier height) and  
183 again no significant effects of tier height on behaviour were seen.

### 184 *3.4. Effect of ramp group on behaviour – birds that moved away only*

185 When analysing the birds that moved away without traversing, ramp group had a significant effect on  
186 the percentage of birds that paced ( $\chi^2= 6.471$ ,  $p=0.039$ ) and on those that performed multiple crouches  
187 ( $\chi^2= 6.138$ ,  $p=0.046$ ). In multi-tier houses (group MT-NR) a significantly greater percentage of birds  
188 paced or crouched multiple times ( $p<0.05$ ) than those in single-tier houses with full length ramps (ST-  
189 R). Due to lower focal bird numbers contributing to the mean in the dataset of birds that moved away  
190 the effect of tier-height was not investigated as confidence in the dataset was not high enough for a  
191 correlation analysis.

192

#### 193 **4. Discussion**

194 A bird that has no difficulty negotiating a level change (without a ramp) would be expected to  
195 approach, crouch and jump in quick succession and land well. However, this is not always the case  
196 and behaviours indicative of hesitancy were chosen for observation in this study. Crouching as if to  
197 take-off but subsequently hesitating has been described as an ‘intention movement’ (Lambe et al.  
198 1997) and sidestepping may also indicate intention to attempt a jump but difficulty doing so (Lambe  
199 et al. 1997). Some birds may walk away after showing these behaviours instead of jumping. Poor  
200 landings can indicate a jump that is too steep, too long, or obstructed (Scott et al. 1997, Moinard et al.  
201 2005). Gakel calls (Zimmerman et al. 2000) are associated with frustration but in this study it was not  
202 possible to record vocalisations owing to high levels of bird noise in the houses.

##### 203 *4.1. Effect of house design on likelihood of moving away*

204 More than twice the percentage of birds moved away without traversing the level-change in multi-tier  
205 houses compared with single-tier full width ramp houses. It is difficult to explain this effect without  
206 information about where the birds went after moving away from the tier edge. Whether birds were  
207 moving away in order to find a better location to jump (e.g. an intermittent ramp) or whether they  
208 were giving up altogether is not clear although both possibilities have an effect on welfare. If the birds  
209 were moving to find a better location they would be wasting time and energy, and potentially  
210 disrupting other birds. Crowding around intermittent ramps may also occur if birds are choosing not

211 to traverse in non-ramp areas, potentially increasing the risk of a fall as a result of being pushed by  
212 conspecifics as was observed in aviaries by Stratmann et al. (2015). If the hens are actually giving up  
213 altogether and deciding against moving to the litter they will have reduced welfare through lack of  
214 access to important resources. This may be of additional welfare concern in multi-tier systems as  
215 hesitancy at the first-tier to litter level-change may also mean that birds struggle similarly with tier to  
216 tier changes.

#### 217 *4.2. Effect of ramp group on behaviour – traversing birds only*

218 As crouching was seen in over 95% of observations where birds had to jump (MT-NR and ST-NR)  
219 and 100% of observations in group ST-R where birds jumped instead of walking down the ramp, we  
220 can conclude that a crouch was nearly always a precursor to a jump. It is therefore unsurprising that  
221 significantly fewer birds showed at least one crouch (30%) in the full width ramp group than the other  
222 two groups. Most birds in the ST-R group simply walked down the ramp, so they did not need to  
223 jump.

224 The percentage of birds exhibiting multiple crouches, pacing or stepping on the spot was significantly  
225 lower in the full ramp group than in both non-ramp groups. In single-tier houses, fewer birds  
226 performed multiple head orientations in the full ramp group than in the non-ramp group. These four  
227 behaviours are likely indicative of difficulty traversing the level-change. Pacing has been used as an  
228 indicator of frustration during thwarted access to resources (Duncan and Wood Gush 1972) although  
229 this is a more stereotyped behaviour and develops as a result of long-term frustration. In the current  
230 study it is not clear whether long-term frustration was being observed or simply that the pacing  
231 behaviour reflected the indecision of the birds, and dissatisfaction with potential landing spots. Ramps  
232 allowed birds to change their ‘landing’ spot while walking down and this may be why less pacing was  
233 seen in the ramp group. Similarly, stepping may have indicated intention to jump but a need for the  
234 bird to adjust their position repeatedly in preparation for the jump. This movement was similar to the  
235 ‘sidestepping’ recorded by Lambe et al. (1997) and likely indicates a similar intention. As a head  
236 orientation and crouch were typical precursors to a jump, the occurrence of multiple incidences of

237 these behaviours suggests that, in some birds, intentions can be over-ridden, sometimes repeatedly,  
238 before a final decision to jump is made and executed.

239 Whether a bird landed well or crashed into the litter/another bird was also recorded and found to be  
240 significantly affected by house design, with all incidences occurring in multi-tier houses. This is in  
241 line with existing literature showing that keel fractures are higher in multi-tier systems (Käppeli et al.  
242 2011). Nasr et al. (2012a) found that birds with fractures took longer to jump between perches  
243 suggesting poorer mobility. Crashes and fractures could therefore affect future mobility and therefore  
244 welfare. The fact that so few crashes were seen is certainly positive for bird welfare. However, it is  
245 possible that birds were deciding to move away instead of completing the level-change to avoid  
246 potential crashes. If this was the case, birds were having to choose between access to resources and  
247 the risk of injury, not a situation that favours good welfare.

#### 248 *4.3. Effect of tier height on behaviour – traversing birds only*

249 A range of tier heights was measured but this did not appear to have affected the results as mean  
250 heights for each ramp group were not significantly different and correlations indicated no relationship  
251 between tier height and the behaviours recorded. It therefore appears that the presence or absence of a  
252 ramp is more important at the point of level-change, than the height of tier within the range observed  
253 here. Producers may choose to use none or intermittent ramps instead of full-width ramps because the  
254 height difference between the slats and litter in their hen house is smaller than average (e.g. <60cm)  
255 and they believe that the birds do not need the full-width ramp. These results suggest that this may be  
256 an incorrect assumption. In addition, full width ramps take up floor space and minimum litter space  
257 allowances mean that ramps are not practical in some pre-existing house set ups.

#### 258 *4.4. Effect of ramp group on behaviour – birds that moved away only*

259 More of the focal birds that did not traverse were seen to crouch multiple times or pace in the multi-  
260 tier group than the full ramp group. This supports the result from the traversing birds - that the  
261 presence of a full ramp reduces some behaviours indicative of hesitancy at a level change. Average  
262 percentages of the behaviours recorded for the MT-NR and ST-NR groups were very similar (table 3)

263 and the lack of significant results when comparing with the ST-NR group is likely due to the  
264 increased variability of the data. It should also be noted that as the percentages calculated for this  
265 group were based on a lower number of birds than for those calculated for traversing birds, confidence  
266 in these results is slightly lower.

#### 267 *4.5. Limitations*

268 There are some limitations to this study. As birds were observed in non-ramp areas only of houses  
269 with intermittent ramps it is not possible to look at whether greater numbers of birds were seen using  
270 intermittent ramps than non-ramp areas, or whether the behaviour of the birds was different on these  
271 ramps. This would be a valuable point for further study. Additionally, the results may only be  
272 applicable to brown genotypes as genotype is likely to have an effect on ability to jump, manoeuvre  
273 and move throughout the house. Brown birds are nearly always used in loose-housed systems in the  
274 UK and may struggle with level changes more than white birds owing to their heavier build (Scholz et  
275 al. 2014). Although, relatively few birds were observed in each house, we expect good repeatability if  
276 further birds were studied. The flocks studied came from a variety of rearing farms and we were  
277 unable to control for this. Rearing environment can affect mobility in later life (Gunnarsson et al.  
278 2000) but as all birds were reared in a set-up that matched their adult environment (single vs multi-  
279 tier) the results are unlikely to have been confounded by this.

280

## 281 **5. Conclusions**

282 This study has indicated that some laying hens in commercial housing show behaviour indicative of  
283 reluctance to move down onto the litter and that this is influenced by both ramp presence and house  
284 design.

285 More than double the percentage of birds moved away without accessing the litter in multi-tier houses  
286 than single-tier houses. Far fewer hens showed behaviours indicative of difficulty moving down to the  
287 litter when a full width ramp was provided between the slats and the litter.

288 The results of this study suggest that providing full-width ramps could improve hen welfare by  
289 enabling hens to access the litter more readily. Even when intermittent ramps were provided (as in  
290 most houses of groups MT-NR and ST-NR) birds still attempted and struggled to negotiate level  
291 changes in areas without a ramp. The addition of a full-width ramp to a commercial single-tier hen  
292 house is relatively easy and may benefit welfare by providing easier bird movement and access to  
293 resources. Easy movement to the litter area may also reduce crowding on the slats. Where adding a  
294 full-width ramp is difficult or impossible (e.g. some multi-tier systems) further research into  
295 alternative ramp designs would be valuable.

296

## 297 **Acknowledgements**

298 We gratefully acknowledge funding by Noble Foods. The authors would also like to thank all 16  
299 farmers who kindly allowed us to carry out this research on their farms.

300

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361 Table 1: Summary information for each house used in the study (House design groups: Single-tier  
 362 with full width ramp (ST-R), multi-tier with no or intermittent ramps (MT-NR) and single-tier with no  
 363 or intermittent ramps (ST-NR)).

House	Size	No. flocks	Genotype(s)	House design group	Intermittent ramps present?	Height of first tier/slats (cm)	Ramp angle (degrees)
1	16,000	2	Novogen Brown	MT-NR	Yes, ladders (45cm)	70	N/A
2	11,700	2	Novogen Brown	ST-R	N/A	100	56
3	6,950	2	Lohmann Brown, Novogen Brown	ST-R	N/A	90	46
4	16,000	2	Lohmann Brown	MT-NR	Yes, flat ramps (230cm)	88	N/A
5	15,848	2	Novogen Brown	ST-R	N/A	90	49
6	6,000	1	Hyline	ST-NR	Yes, ladders (350cm)	65	N/A
7	16,032	2	ISA Warren, Bován Brown	ST-R	N/A	90	49
8	15,030	2	Lohmann Brown, Novogen Brown	ST-R	N/A	85	47
9	12,525	2	Lohmann Brown	ST-R	N/A	75	39
10	16,032	2	Lohmann Brown, ISA Brown	ST-NR	Yes, ladders (300cm)	95	N/A
11	16,032	2	Shaver	MT-NR	Yes, ladders and integrated slatted step (150cm)	75	N/A
12	12,024	1	Novogen Brown	ST-NR	No	32	N/A
13	16,032	2	Hyline, Lohmann Brown	MT-NR	Yes, ladders and integrated slatted step (150cm)	85	N/A
14	16,000	2	Lohmann Brown	ST-R	N/A	90	49
15	5,760	1	Shaver	ST-NR	Yes, ladders (300cm)	80	N/A
16	10,800	1	Bován Brown	ST-NR	No	70	N/A

364 Table 2: Ethogram of observed behaviours in focal birds.

Behaviour name	Description
Head orientation	The bird lowers its head and neck and looks at the litter.
Crouch	The bird lowers the body while the head is orientated towards the litter.
Pace	The bird walks along the edge of the slats. A pace must be followed by a head orientation/crouch/step within 10 seconds or it is deemed a 'move away'.
Step	While facing out towards the litter, the bird raises its feet individually and places them back down in a similar location as if adjusting its position.
Move away	The bird orientates its body away from the litter, moves away from the edge of the slats or moves along the edge of the slats without showing further intention behaviours for 10 seconds.

365

366 Table 3: Average means and standard deviations for traversing and moved away birds in each ramp group. Significant relationships between variables are  
 367 marked with superscript letters.

GROUP	TRAVERSING BIRDS			MOVED AWAY BIRDS		
	ST-R (n=7)	MT-NR (n=4)	ST-NR (n=5)	ST-R (n=7)	MT-NR (n=4)	ST-NR (n=5)
<b>Tier height (cm)</b>	89 (±7)	80 (±8)	68 (±23)	89 (±7)	80 (±8)	68 (±23)
<b>Total number of focal birds</b>	345	176	150	39	60	20
<b>Average number of focal birds per house (1-2 flocks)</b>	49(±2)	44(±3)	30(±2)	6(±1)	15(±2)	4(±1)
<b>Time to litter/move away (s)</b>	10.6 (±3.8) <sup>a</sup>	4.1 (±0.8)	7.5 (±5.6) <sup>b</sup>	20.5 (±5.8)	16.4 (±4.5)	22.2 (±15.0)
<b>Multiple head orientations (%)</b>	11.81 (±8.35) <sup>a</sup>	17.15 (±4.56) <sup>b</sup>	25.32 (±10.30)	35.60 (±24.88)	30.21 (±16.42)	29.17 (±44.29)
<b>Crouch (%)</b>	29.65 (±12.86) <sup>a</sup>	97.87 (±2.46) <sup>b</sup>	96.55 (±6.19) <sup>b</sup>	28.81 (±15.17)	36.79 (±16.74)	48.00 (±29.80)
<b>Multiple crouches (%)</b>	0.31 (±0.82) <sup>a</sup>	5.99 (±3.03) <sup>b</sup>	13.29 (±8.64) <sup>b</sup>	0.00 (±0.00) <sup>a</sup>	5.58 (±6.11) <sup>b</sup>	5.00 (±11.18)
<b>Pace (%)</b>	1.62 (±2.63) <sup>a</sup>	12.59 (±6.43) <sup>b</sup>	17.28 (±8.19) <sup>b</sup>	1.43 (±3.78) <sup>a</sup>	10.96 (±4.33) <sup>b</sup>	20.00 (±44.72)
<b>Step (%)</b>	0.96 (±1.74) <sup>a</sup>	12.36 (±8.13) <sup>b</sup>	13.91 (±5.07) <sup>b</sup>	0.89 (±2.36)	6.52 (±8.09)	5.00 (±11.18)
<b>Crash landings (%)</b>	0.00 (±0.00) <sup>b</sup>	2.94% (±2.52) <sup>a</sup>	0.00 (±0.00) <sup>b</sup>	N/A	N/A	N/A

368

369 Figure 1: Photograph of a single-tier system with full width ramp (ramp angle:  $46^\circ$ ). An example  
370 section for behavioural observation has been marked on the image.