A BRITISH FREE RANGE EGG PRODUCERS ASSOCIATION SUSTAINABILITY FUND REPORT

THE USE OF PECKING ENRICHMENTS BY HENS HOUSED IN FREE-RANGE MULTI-TIER SYSTEMS

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SUMMARY

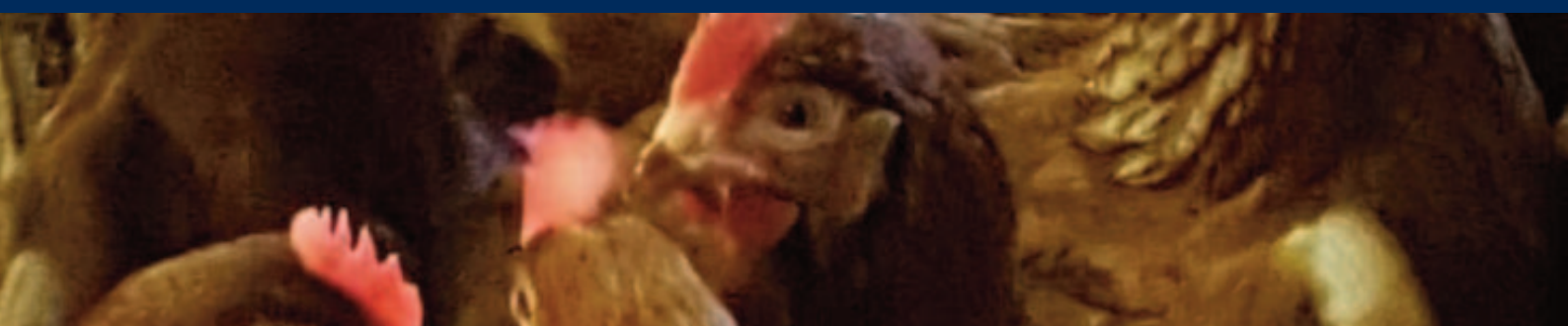
- Of four enrichments (Lucerne hay bales, pecking blocks, pelleted feed scattered in litter, and jute ropes) provided to eight flocks of free-range hens, pecking blocks and bales provided consistent interest to hens, based both on observations of hens in the vicinity of the enrichments (doing anything), interacting with the enrichments, and least walking/running or standing near the enrichments.

- Hens were most interested in pelleted feed at the time of scatter, but pelleted feed was consistently of greater interest (based on observations around the area, interacting with the pelleted feed, and less walking/running or standing in the enrichment area) than ropes, which hens seemed to find least attractive. In fact, ropes were no more attractive to hens than no enrichment at all.

- Feather scores (a proxy measure for feather pecking) worsened with age, but differences between treatments were small and variable between ages, possibly due to lack of data and/or hens mixing between quarters.

- Whilst ropes were by far the cheapest enrichment to provide (based on average replacement rates over the eight flocks studied), behaviour at ropes was indistinguishable from behaviour away from any enrichments and thus do not sufficiently encourage foraging and other behaviours, as is desirable. A balance between encouraging positive hen behaviour and cost to the producer needs to be taken into account in the practical use of any enrichment.

1. INTRODUCTION



Laying hens are highly motivated to show food seeking behaviour in the form of pecking and scratching at the ground (i.e., foraging), even though compound feed is provided on a typically ad libitum basis.

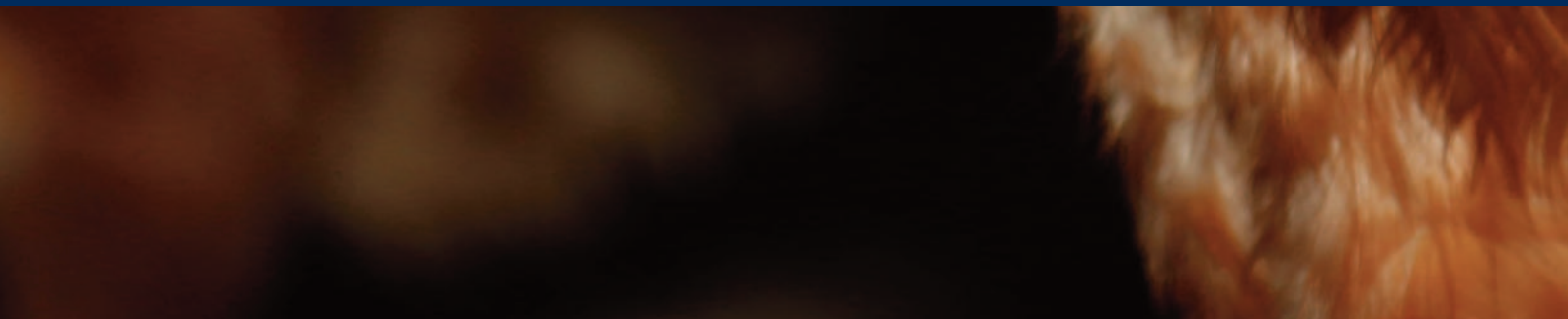
To help fulfil the motivation to forage (and dustbathe), commercial hens housed in alternative systems (e.g. free range and barn systems) must be provided with at least one third of the floor area as litter[1].

However, litter (which is frequently made up of wood shavings, or straw and shavings) provides little positive feedback, because it contains nothing other than litter and hen faeces. Without the opportunities to express these behaviours, hens are more likely to express redirected foraging behaviour as feather pecking, which can lead to pain, feather loss, skin and tissue damage, and even death. Therefore, it is important on a number of levels to provide enrichments that help fulfil these behaviours.

Commercial egg producers are mindful of this, and many provide various enrichments to their hens, but benefits to hens are somewhat unknown.

The objective of this study was to determine which pecking enrichments (of those tested) had a beneficial effect on hen behaviour and feather cover.

2. METHODS



A. HOUSING AND BIRDS

Eight flocks (A-H) of free-range hens at four different farms (2 flocks/farm) were recruited for the study via British Free Range Egg Producers Association (BFREPA) membership. All farms were based in Scotland.

The free-range sheds contained multi-tier structures (all Natura Step, Big Dutchman International GmbH, Germany) of three levels (the litter floor and two tiers) and were split into four 4,000-bird colonies ('quarters'), which were identified as Q1 (nearest the annex where staff first entered from) to Q4 (Figure 1). There were 16,000 hens in total per flock. Normal commercial practice was undertaken at each farm, apart from the provision of enrichments. The bird strains used were all brown egg layers (Lohmann Brown, 3 flocks; Bovan Brown, 3 flocks; H&N Brown Nick, 2 flocks).

Figure 1
Overhead schematic of free-range hen sheds used in the study showing the four quarters. Q1 was always the quarter nearest to the annex, where staff would enter (E). The blue area is where the multi-tier (MT) structure was positioned, the yellow area was the litter, and birds could reach the range via popholes from the litter. The arrow shows the direction that staff would walk, scattering litter from side-to-side in the relevant pelleted feed (PF) treatment/quarter.

	Range area			
E	Q1	Q2 →	Q3	Q4
	MT	MT	MT	MT

B. ENRICHMENT TREATMENTS

Some egg production assurance schemes require that at least two enrichments are provided for every 1,000 hens, some of which must be destructible. Therefore, we used this level and these types of enrichments in our study. All flocks were provided with two different enrichment items per 1,000 hens, and thus 8 enrichments per quarter. Enrichments were installed shortly after pullets arrived at the laying farm, and farm staff were advised of a replacement schedule based on the estimated time each enrichment should last; however, staff were advised to replace as often as necessary to ensure that hens were never without the enrichments (apart from pelleted feed, which was always given twice a day – see below). There were four different enrichments used (Figure 2), all of which were destructible:

i. **Lucerne (alfalfa) hay bales.** Analysed content 16.7% crude protein, 90.4% dry matter. Four bales provided per quarter (1 per 1,000 hens), which were placed into hay nets and suspended over the litter (some farms placed on the floor initially, and hung them up after approximately 3 days). Bales weighed approximately 15 kg and measured 65 x 45 x 35 cm or 102,375 cm3 per bale. Cost: from £6.50 per bale. Estimated to last 3 weeks.

ii. **Pecking blocks** (Pickblock™ medium, Crystalyx® Products GmbH, Germany), compact hard edible blocks made of grains (rye, maize, wheat), calcium carbonate, oyster shells, dextrose, molasses, wheat gluten feed and lucerne meal, crude protein 5.8%, weight 5 kg, dimensions 23 x 16.5 x 13 cm, or 4,934 cm^3 per block. Provided at 1 block per 500 hens, thus eight blocks per quarter, which were placed in pairs onto slats or plastic bucket lids (to stop them getting damp) on top of the litter. Cost approximately £7 per block. Estimated to deteriorate at 1 g/hen/day, thus expected to last approximately 10 days.

iii. **Pelleted feed formulated for layers** (Farmgate Layers Pellets, ForFarmers UK Ltd, Dumfriesshire, UK). Analysed content 16.0% protein, 86.2% dry matter. Provided 2 kg twice a day, scattered from side-to-side covering a roughly 0.5 m width, down the centre of the litter area (Figure 1), thus providing 1 g pellets / hen / day. Staff were provided with plastic jugs marked with a 'fill' line to the correct weight, and feed was stored in plastic bins within the shed quarter for ease of use and rodent control. The timing of scattering was arranged to coincide with staff inspections / collections of floor eggs, and ranged from farm-to-farm between 09:00-11:30 (scatter 1), and 13:00-16:30 (scatter 2). Cost: £8.38 per 20 kg bag, or £419/tonne. Estimated to last up to a few hours.

iv. **Jute ropes** (Ropes Direct, Norfolk, UK). Four ropes (8 mm diameter, cut into 30 cm lengths and looped in half) were attached initially by polypropylene string (flocks A,B), and then cable ties (all flocks) to the first platform or alighting rails of the multi-tier structure, evenly spread along the structure. Cost: just over £0.08 per 30 cm, or £0.33 for 4 rope pieces. Estimated to last 6 months.

The rope was considered the standard (control) enrichment, so combinations of enrichment treatments (known as classification factor 'treatment') for each quarter were:

- 4 bales and 4 ropes (B)
- 4 pairs of pecking blocks and 4 ropes (PB)
- 4 kg pelleted feed and 4 ropes (PF)
- 8 ropes (R)

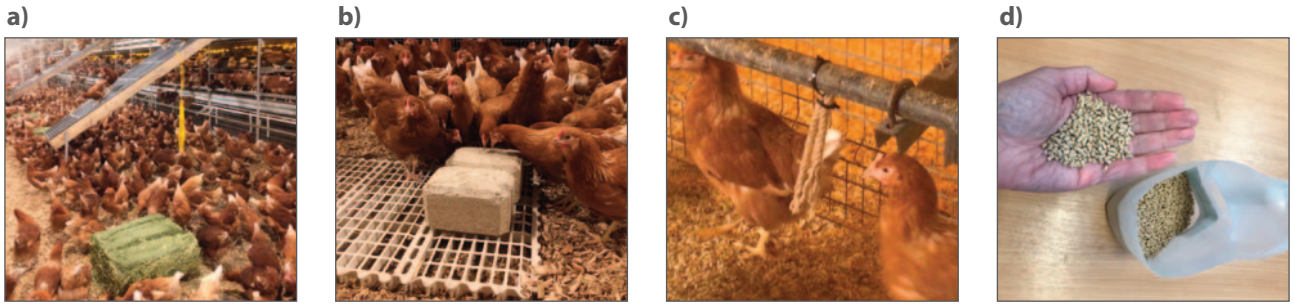


Figure 2
Enrichments a) alfalfa hay bales prior to hanging in the hay nets (yellow), b) pecking blocks paired and on slats, c) jute ropes, and d) pelleted feed scattered from a plastic jug.

Enrichments were offered in a balanced design over all quarters with all treatments provided with each flock, by placing enrichments in each shed based on two Latin squares (Table 1).

Table 1
Enrichment treatments (B, PB, PF, R), and their layout per flock, according to which quarter of the shed the items were provided in (Quarters 1-4; quarter 1 is the section nearest the annex door).

Flock	Bales and ropes (B)	Pecking blocks and ropes (PB)	Pelleted feed and ropes (PF)	Ropes only (R)
A	Q1	Q2	Q3	Q4
B	Q3	Q1	Q4	Q2
C	Q2	Q4	Q1	Q3
D	Q4	Q3	Q2	Q1
E	Q3	Q4	Q1	Q2
F	Q2	Q1	Q4	Q3
G	Q1	Q3	Q2	Q4
H	Q4	Q2	Q3	Q1

C. BEHAVIOUR OBSERVATIONS AND FEATHER SCORES

Observations were due to take place during three visits at 34, 52 and 70 weeks of age (i.e., every 18 weeks) (known as classification factor 'age'). The two flocks on a single farm were observed on two consecutive days, by one of two people. Bird behaviour was recorded using scan sampling methods, at times relative to the first scatter of pelleted feed, -1, 0, and 1 h (known as classification factor 'time'). The observer always began in the quarter with the pelleted feed treatment and then moved up the quarters (i.e., if PF was in Q2, then observed in order Q2, Q3, Q4, Q1). The observer entered the shed quarter and positioned him or herself between the treatment enrichments (B, PB, PF, R) and the control enrichment (R), and remained quiet for 3 min to allow the hens to settle. The observer then scan sampled a 1 m diameter area around three locations: the treatment enrichment ('Enrich'), the control (ropes) enrichment ('ControlR'), plus a 1 m diameter area away from either enrichment ('Away') (known as factor 'location'). For R, both the 'Enrich' and the 'ControlR' observations were at ropes, so one was randomly assigned to ControlR and one to Enrich to give the full complement of three locations. A count of birds within each of the three circles and their behaviours (Table 2) were recorded.

The counts were repeated three times in 15 min (e.g. at 3, 8 and 13 min). Thus, a total of 324 observations per flock were scheduled (i.e., 3 locations x 3 observations per time relative to scatter x 3 times relative to scatter x 4 quarters x 3 ages). The observer moved to the next quarter after 15 min, so that all four quarters per flock were observed within each 1 h period.

Table 2
List of behaviours. The first two behaviours could not be assessed for location 'away' (because there was no enrichment there).
** Only collected at locations ControlR and Enrich*

Behaviour
*Interacting with (e.g. peck, pull, scratch at) enrichment (or in litter where feed is scattered, PF treatment)
*At, but not interacting with, enrichment
Stand/sit
Forage: peck/scratch at litter (but not at location where feed is scattered, PF treatment)
Walk/run
Dustbathe
Feather peck
Aggressive peck
Perch
Other: any other behaviour

Feather scores (i.e. the recording of feather damage on a scale of 0-5, where 0=no damage, 1=slight damage/loss with no bare skin, up to 5=1-2cm^2 haemorrhage or >5x5cm^2 bare skin with <1cm^2 haemorrhage[2]) of five body locations (neck, back, tail, breast, both wings) were carried out remotely (i.e. without handling,[3]) on ten birds in the Away location once per scan sampling time (-1, 0, 1) per treatment (i.e. quarter) at each age (thus 5 feather scores/bird x 10 birds/time x 4 treatments x 3 ages x 3 sampling times = 1800 scores/flock).

Due to a combination of heightened biosecurity related to Avian Influenza and COVID-19, some visits to flocks were prevented. As a result, no feather scores or behaviour data were collected at age 52 weeks for flock G and H, and no behaviour data collected at age 70 weeks for flocks C, D, E and F. Feather scores for C, D, E and F at age 70 weeks were recorded from photographs taken by the farm staff of the birds in the Away location, from ten birds. However, data from photos were judged to be unreliable as they did not follow patterns seen in other flocks, with higher scores than expected at some body locations and lower than expected at other body locations. Therefore, the data from photos were omitted from all means shown and analyses.

D. STATISTICAL ANALYSES

All data were compiled and linked in Excel. Genstat 18 was used for data processing and all statistical analyses. Behaviour data were analysed with the following fixed effects: age (34, 52, 70 weeks), time (-1, 0, 1 h), location (ControlR, Enrich, Away), and treatment (R, B, PB, PF) (and their interactions). For R, both the 'Enrich' and the 'ControlR' observations were at ropes, so one was randomly assigned to ControlR and one to Enrich to give the full complement of three locations to give a full factorial statistical analyses of behaviour data. Random effects were flock, shed quarter, location within shed quarter plus interactions of these spatial effects with age, time within age and scans within time within age, but many of these effects were negligible and so were dropped from some models in order to achieve convergence.

With hen behaviour, three elements were analysed:

- Total counts of birds in each location (ControlR, Enrich, Away) at a scan engaged in all behaviours (because total birds in a particular location might indicate a desire to be there)
- Counts of birds engaged in each particular behaviour in each location at a scan
- Proportions of birds engaged in each behaviour (i.e. counts of birds performing a behaviour/total birds in that location per scan)

Results for counts of birds engaged in particular behaviours are not shown because results are similar for counts and proportions.

Feather scores were summed over all body sites per bird and total feather score was analysed. Fixed effects were age (34, 52, 70 weeks), time relative to scatter (-1, 0, 1), treatment (R, B, PB, PF) (and their interactions). Random effects were flock, shed quarter, plus interactions of these spatial effects with age and time within age. Analyses focused on total feather scores but some analysis is also reported from analysing feather scores from individual sites using LMMs fitted to feather scores (not transformed) or GLMMs applied to binary data feather score>0, adding site and interactions with site to the fixed effects.

To analyse proportions, Generalised Linear Mixed models (GLMMs) were fitted to binomial counts with appropriate binomial totals, logit link function (i.e., for proportion p, loge (p/1-p)), binomially distributed errors and dispersion fixed at 1. To analyse counts, GLMMs were fitted to the counts with log link function, Poisson distributed errors and dispersion fixed at 1. Where data was sparse, GLMMs with all effects included would not converge so random and fixed effects in these models were simplified. Linear Mixed models (LMMs) with all effects included were fitted to the total feather score after log transformation (i.e. $\log_e$(total feather score+1)) and were used as approximations in addition to simplified GLMMs for binomial data and counts. With LMMs, proportion data were first angular transformed to degrees scale (see (1) below) to normalise the distribution of residuals, i.e. for proportion p:

$$\frac{180}{\pi} \quad \sin^{-1}(\sqrt{p})$$

while counts and total feather scores were natural log transformed. Where high-level

interactions are substantial, lower-level effects are not reported.

Due to the large number of tests being carried out results focus on highly significant effects and make clear when results are marginal. In some instances where interactions are marginal, lower level associated effects are also shown. P values are based on approximate F tests when available but otherwise are based on Wald tests; statistics for F tests are given in the results as $F_{ndf,ddf}$, where ndf is the numerator degrees of freedom (the number of effects to be estimated, which is the number of levels for a categorical factor less 1) and ddf is the denominator degrees of freedom; or for Wald tests as $Wald_{ndf}$/ndf to make this comparable with the F statistic. Tables and figures either show raw means along with standard deviations (SD) or model estimates ± standard errors (SE) obtained from the LMMs and GLMMs as well as these estimates back transformed onto the original scale (e.g., proportions or counts) to aid interpretation.

For replacement of enrichments, the mean and SD over flocks (n=8) of the mean days between replacement of each enrichment per flock was calculated. We also briefly investigated the above reported statistical models of behaviour data including covariates on days since last replacement and the cumulative amounts of enrichments replaced at each visit generating P values for the covariates tested last after all other fixed effects and examined estimated coefficients.

3. RESULTS

Actual flock visits took place when birds were 33 weeks 5 days – 34 weeks 6 days old, 51 weeks 6 days – 53 weeks old, and 70 weeks 1 day – 71 weeks 4 days old, but for simplicity they are still referred to as visits at 34, 52 and 70 weeks of age throughout. Mean mortality across flocks was 4.8% (range: 2.60-7.98%). Observation times relative to scatter feed application were in reality 1.5 - 0.47 h before scatter (still called -1 h for simplicity), 0.0 - 0.17 h (0 h) at scatter, and 1.0 - 3.0 h post-scatter (hereon referred to as ≥1 h).

Overall mean proportions of birds observed in behaviours, according to location and treatment, are shown in Table 3. In the area where only ropes were available (ControlR) and in the Away location, most hens were observed standing/sitting, followed by foraging and walking/running. Hens observed in ControlR showed low proportions of birds interacting with the enrichments (ropes). With the Enrich location, the mean proportions of hens in R treatments were mostly standing/sitting, whereas with other treatments much higher proportions of birds were interacting with the enrichments. All proportions of hens observed in dustbathing, feather pecking, perching and other were low.

Table 3
The mean over scans of proportions of hens observed by location and treatment in various behaviours. All behaviours are mutually exclusive, and rows within location by treatment add up to 1.0. At ControlR, the only enrichment to interact with was rope; at Away there were no enrichments. Figures in red are values > 0.500; figures in blue are values between 0.100-0.499.

		Behaviour									
Location	Treatment	Interacting*	At but not interacting*	Stand/sit	Forage	Walk/run	Dustbathe	Feather peck	Aggressive peck	Perch	Other
ControlR	R	0.052	0.000	0.509	0.180	0.170	0.009	0.006	0.000	0.004	0.070
	B	0.033	0.000	0.525	0.203	0.141	0.010	0.004	0.000	0.015	0.069
	PB	0.060	0.000	0.552	0.153	0.147	0.006	0.005	0.000	0.006	0.071
	PF	0.032	0.005	0.564	0.143	0.184	0.004	0.006	0.001	0.006	0.055
Enrich	R	0.048	0.000	0.517	0.166	0.182	0.009	0.003	0.000	0.009	0.066
	B	0.370	0.094	0.218	0.235	0.047	0.002	0.004	0.000	0.000	0.030
	PB	0.599	0.111	0.083	0.169	0.020	0.000	0.001	0.001	0.000	0.016
	PF	0.378	0.437	0.063	0.027	0.038	0.001	0.002	0.001	0.000	0.053
Away	R	NA	NA	0.452	0.238	0.197	0.017	0.012	0.000	0.000	0.085
	B	NA	NA	0.445	0.266	0.170	0.023	0.011	0.001	0.003	0.082
	PB	NA	NA	0.489	0.217	0.191	0.008	0.005	0.002	0.000	0.088
	PF	NA	NA	0.512	0.218	0.190	0.019	0.001	0.002	0.000	0.058

** = with enrichment; NA = not applicable, because there are no enrichments to interact with*

COUNTS OF BIRDS
(OVER ALL BEHAVIOURS)

On average over scans there were 6.8-17.2 hens observed per location by treatment (Table 4).

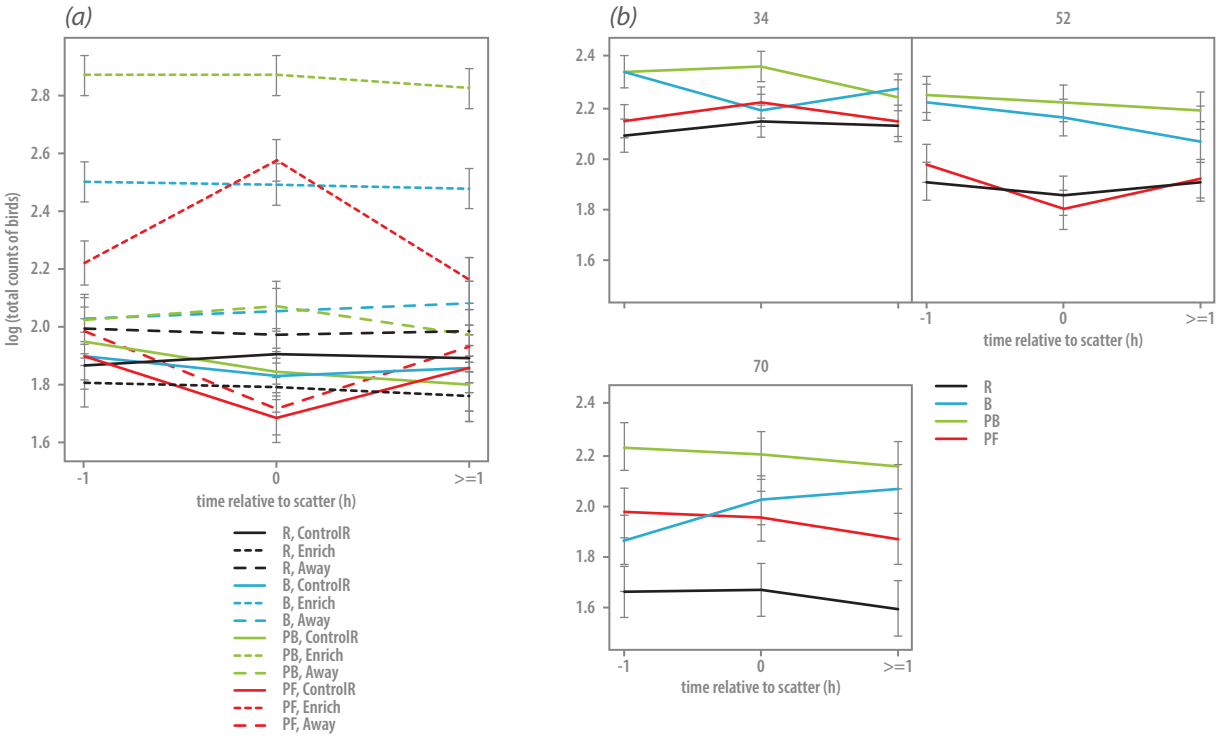
Table 4
The mean ± SD over scans of total counts of birds observed over all behaviours, according to location (1 m diameter around the control ropes (ControlR), the enrichment (Enrich), or away from either (Away)) and enrichment treatment (i.e. ropes (R), bales (B), peck blocks (PB), or pelleted feed (PF)) provided in shed quarters. The estimated means (back transformed from GLMM) are shown in brackets (which adjust for missing data).

	Location		
Treatment	**ControlR**	**Enrich**	**Away**
R	7.4 ± 3.6 (6.6)	6.8 ± 3.1 (6.0)	8.2 ± 3.1 (7.2)
B	7.1 ± 3.4 (6.4)	13.1 ± 4.4 (12.0)	8.7 ± 3.3 (7.8)
PB	7.2 ± 3.6 (6.4)	17.2 ± 4.0 (17.2)	8.3 ± 3.1 (7.6)
PF	6.8 ± 3.4 (6.1)	10.8 ± 3.4 (10.1)	7.3 ± 3.0 (6.5)

There was a highly significant interaction between time, location, and treatment in the total numbers of birds observed over all behaviours (Wald12/ndf=4.62 by GLMM, P<0.001) (Figure 3a). There were more birds in the Enrich locations when the enrichments were not R, with the most birds observed with PB, then B then PF. When feed was scattered (time 0), the number of birds went up only for PF in the Enrich location (and correspondingly went down for PF at ControlR and Away locations, as hens moved away from these areas to the enrichment area), and then returned to -1 levels by time ≥1. In contrast, the numbers of birds in all locations with PB, B and R remained constant across the three observation times.

Figure 3
(a) Mean ± SE log(total counts of birds) observed over all behaviours in various locations (ControlR, Enrich, Away), according to enrichment treatments (R, B, PB, PF) and the time of observation relative to scatter of pelleted feed (-1, 0, >1), estimated from GLMM, with standard error (SE) bars shown.

(b) Mean log(total counts of birds) observed over all behaviours with different enrichment treatments (R, B, PB, PF), according to bird age (34, 52, 70 weeks) and the time of observation relative to scatter of pelleted feed (-1, 0, >1), estimated from GLMM, with SE bars shown.



The total numbers of birds observed, regardless of location, are similar between the different treatments at age 34 weeks but treatment differences increase with age, with at age 70 weeks the greatest number of birds observed for PB and least for R (Figure 3b) (marginally significant interaction age.time.treatment, $Wald_{12}/ndf=1.94$ by GLMM; P=0.026). Other effects of bird age were also marginal, but on average total birds observed declined with age at all locations (interaction of age.location, $Wald_4/ndf=2.69$ by GLMM, P=0.030) (Table 5).

Table 5
Mean ± SE log(total counts of birds) (back transformed shown in brackets) observed over all behaviours by age (34, 52, and 70 weeks) and location (ControlR, Enrich, Away), estimated from GLMM.

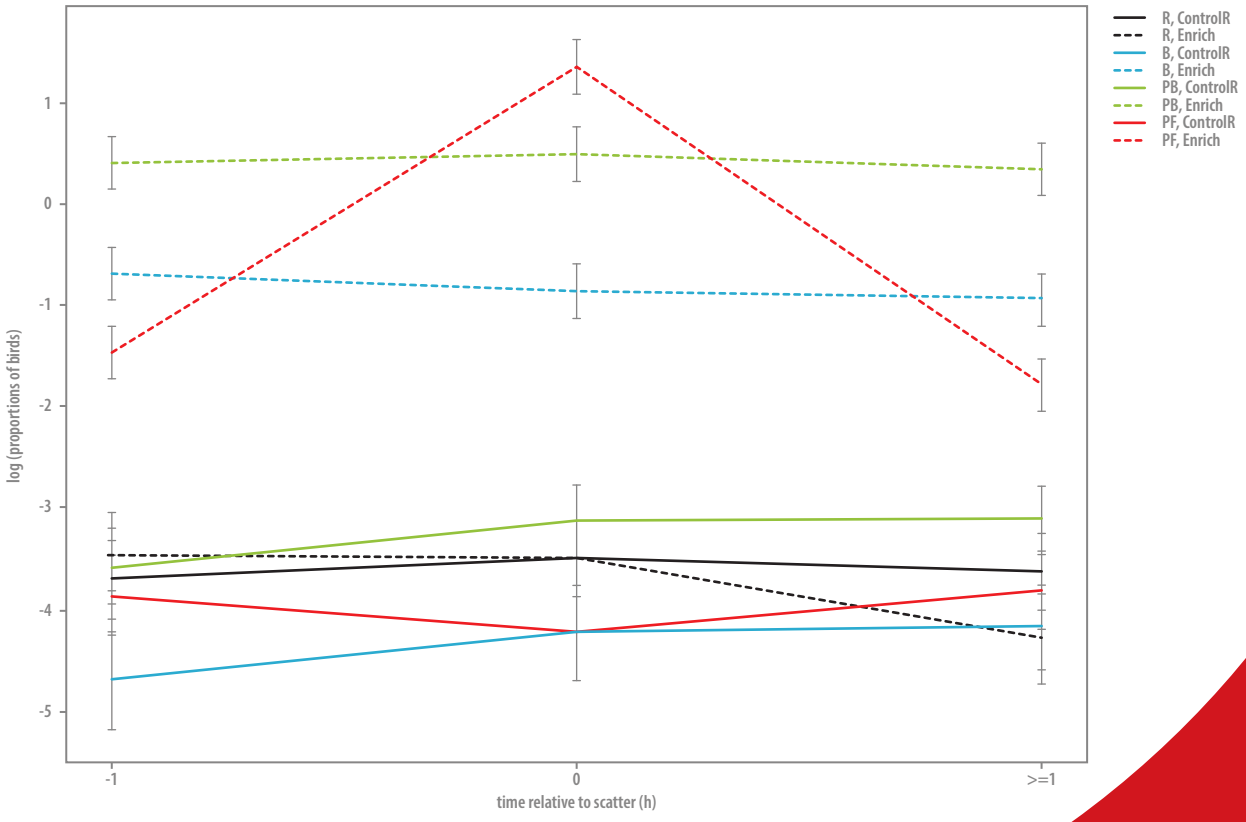
	34 weeks	52 weeks	70 weeks
ControlR	1.94 ± 0.10 (7.0)	1.90 ± 0.11 (6.7)	1.73 ± 0.12 (5.6)
Enrich	2.47 ± 0.10 (11.9)	2.33 ± 0.10 (10.2)	2.27 ± 0.11 (9.7)
Away	2.25 ± 0.10 (9.5)	1.91 ± 0.11 (6.7)	1.79 ± 0.12 (6.0)

BEHAVIOUR

INTERACTING WITH ENRICHMENTS (CONTROLR AND ENRICH LOCATIONS ONLY)

Of the total birds observed, the mean proportion of birds interacting with the enrichments in Enrich locations was higher for PF at scatter feeding time (0), then PB then B, and lowest for R (highly significant interaction time.location.treatment; $F_{6,621}$=8.44 by GLMM, P<0.001), however proportions were consistent across all three times with PB and B, whereas interaction with PF dropped at time -1 and >1 (Figure 4). All interactions with bird age, and the main bird age effect, were not statistically significant for the mean proportion of birds (all P>0.05). Observations of birds in all treatments in the ControlR locations, plus R birds in the Enrich location, showed similarly low proportions of birds interacting with R, compared to B, PB and PF birds in the Enrich location. All interactions with bird age, and the main bird age effect, were not statistically significant for the mean proportion of birds (all P>0.05).

Figure 4
Mean ± SE logit(proportions of birds) observed interacting with enrichments, by time relative to scatter (-1, 0, >1) and location (ControlR, Enrich), estimated from GLMM. With all ControlR locations, the only enrichment there were ropes (R); with Enrich locations there were ropes (R), bales + ropes (B), peck blocks + ropes (PB) or pelleted feed + ropes (PF).

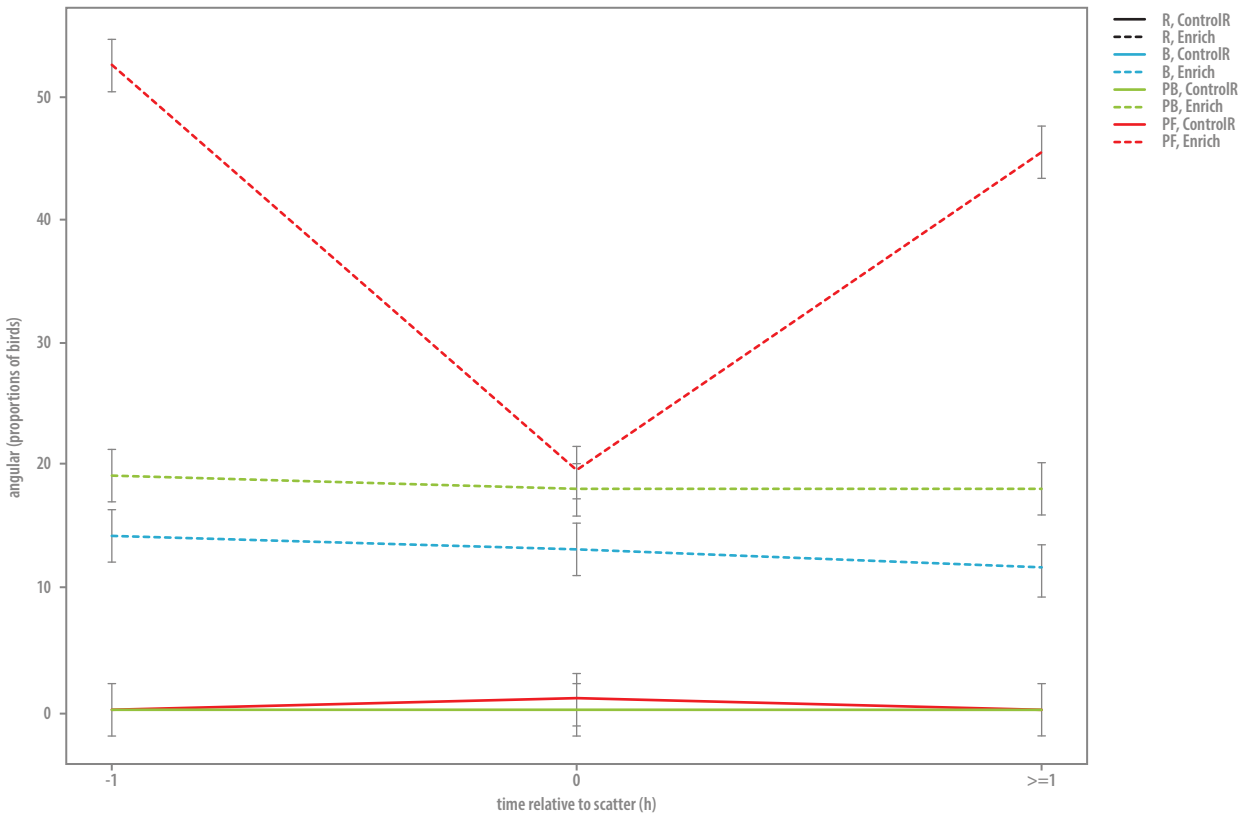


BEHAVIOUR

AT (BUT NOT INTERACTING WITH) ENRICHMENTS (CONTROLR AND ENRICH LOCATIONS ONLY)

The proportion of birds at, but not interacting with, the enrichments was highest with PF outside of scatter feeding time (i.e. at time -1 and >1), and then PB then B in the Enrich locations, with a much lower proportion for R (highly significant interaction time.location.treatment; $F_{6,122}$=13.41 by LMM, P<0.001) (Figure 5). The proportion of birds at, but not interacting with, the PB and B enrichments was consistent across all three observation times. There was a weak and inconsistent effect of age (marginally significant interaction location.age.treatment; $F_{6,63}$=2.49 by LMM, P=0.032) (data not shown). The other three-way interactions were not statistically significant.

Figure 5
Mean ± SE angular(proportions of birds) observed at, but not interacting with, enrichments in Enrich and Control R locations, according to treatment (R, B, PB, PF) and time relative to scatter (-1, 0, >1), estimated from LMM.

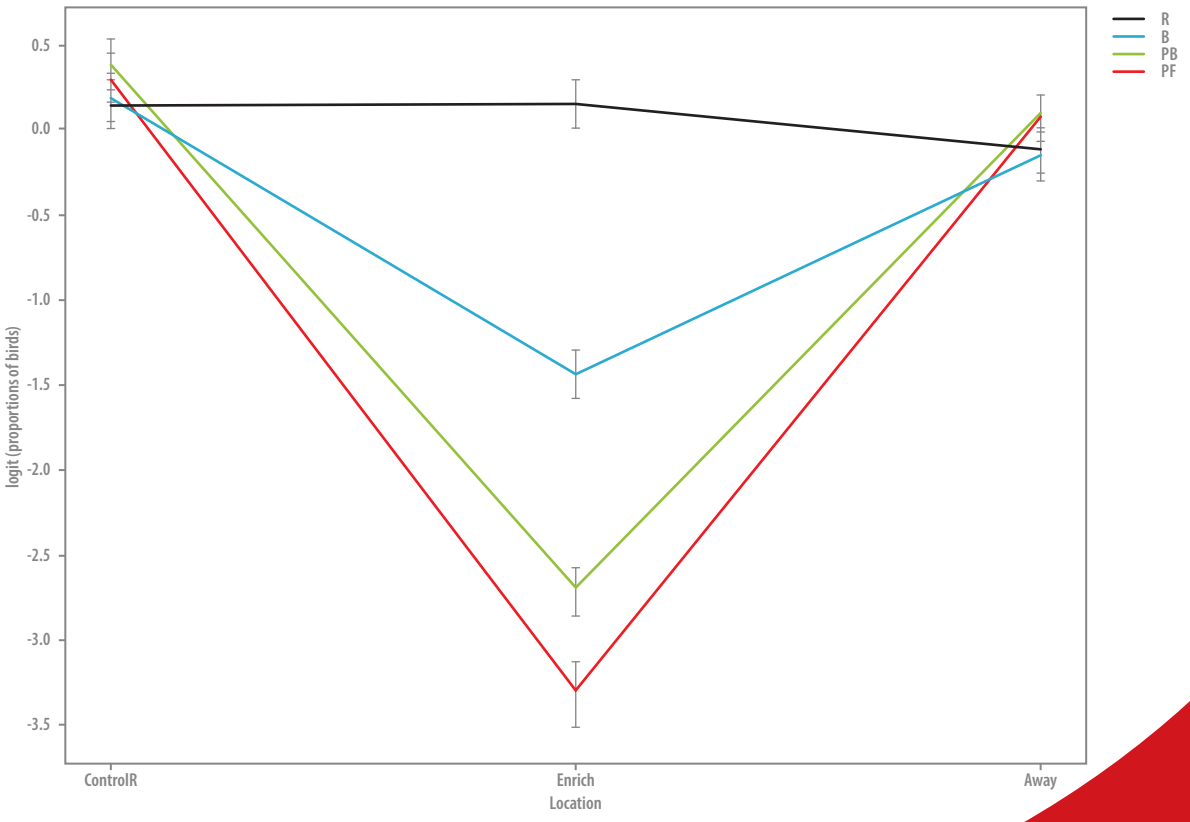


BEHAVIOUR

STAND/SIT

There were some marginally significant three-way interactions on stand/sit behaviour which were largely due to hens in PF treatment at location Enrich: the proportion of PF Enrich birds observed in stand/sit was both greatest at time ≥1 (time.location.treatment, $Wald_{12}$/ndf=1.92 by GLMM; P=0.027) and lowest at age 34 weeks (age.location.treatment, $Wald_{12}$/ndf=2.15 by GLMM; P=0.012) (data not shown). Averaged over other fixed effects, the proportion of birds observed in stand/sit behaviour increased with age (predicted means ± SE logit (back transformed proportions) 34 weeks -0.80 ± 0.09 (0.31), 52 weeks -0.53 ± 0.10 (0.37), 70 weeks -0.28 ± 0.12 (0.43); $Wald_2$/ndf=8.69 by GLMM; P<0.001). There was a highly significant interaction of location.treatment on proportion of birds observed in stand/sit behaviour ($Wald_6$/ndf=34.94 by GLMM; P<0.001): the greatest proportions of hens standing/sitting were seen in those locations where there were no enrichments (i.e. Away) or only rope enrichments (i.e. location ControlR, and treatment R in Enrich); however PF, PB and B showed significantly less hens standing/sitting at location Enrich (Figure 6).

Figure 6
Mean ± SE logit(proportions of birds) observed in stand/sit behaviour, according to location (ControlR, Enrich, Away) and treatment (R, B, PB, PF), estimated from GLMM.

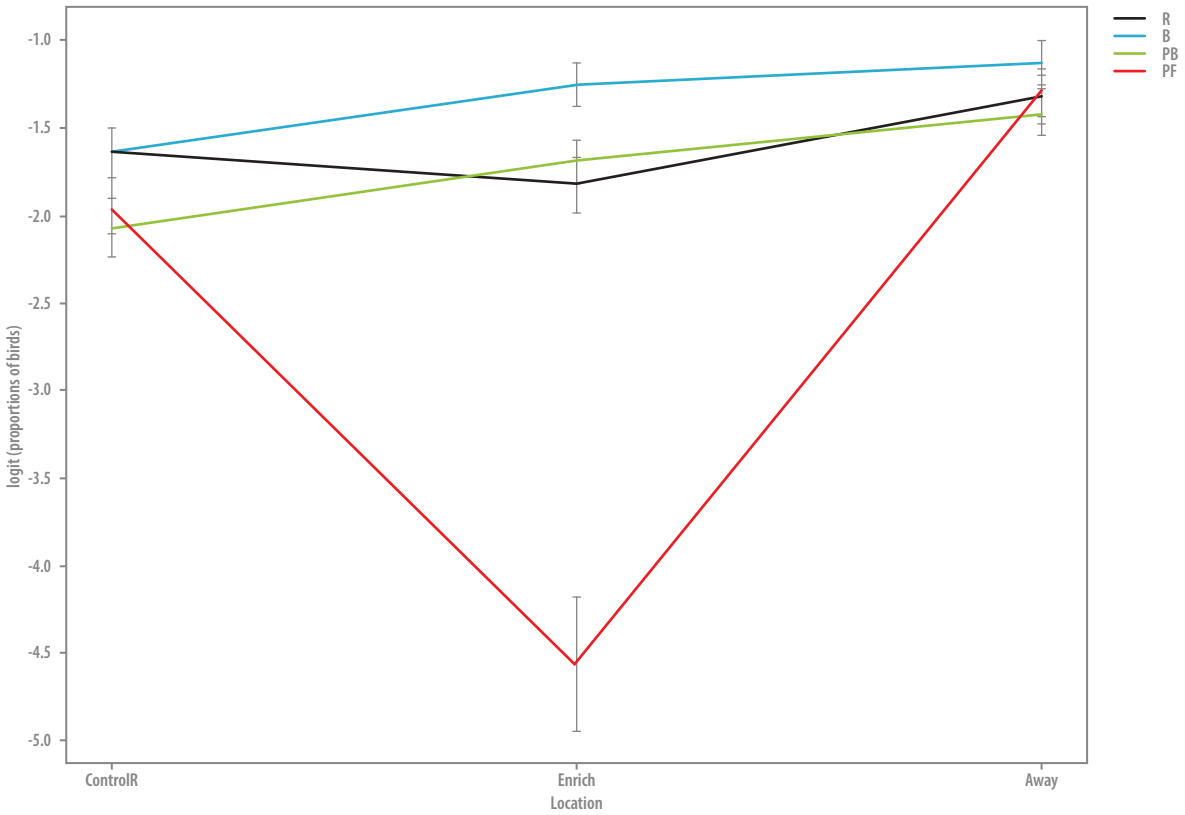


BEHAVIOUR

FORAGE

There was a weak 3-way interaction of time.location.treatment on the proportion of birds observed foraging (excluding the PF scatter area) ($Wald_{12}$/ndf=1.81 by GLMM; P=0.041) which was solely due to a decrease in PF birds foraging at litter (other than where feed was scattered) at time 0 in the Enrich location but this is merely due to no birds foraging on anything other than PF scattered at this time (data not shown). There was a highly significant location.treatment interaction on the proportion of birds foraging ($Wald_6$/ndf=9.49 by GLMM; P<0.001), again due to a decrease in PF birds foraging at litter (other than where feed was scattered) at time 0 (Figure 7). Foraging decreased with bird age (predicted means ± SE logit (back transformed proportions) 34 weeks -1.64±0.10 (0.16), 52 weeks -1.72±0.10 (0.15), 70 weeks -2.09±0.13 (0.11); $Wald_2$/ndf=8.42 by GLMM; P<0.001).

Figure 7
Mean ± SE logit(proportions of birds) observed in foraging behaviour, according to location (ControlR, Enrich, Away) and treatment (R, B, PB, PF), estimated from GLMM.



BEHAVIOUR

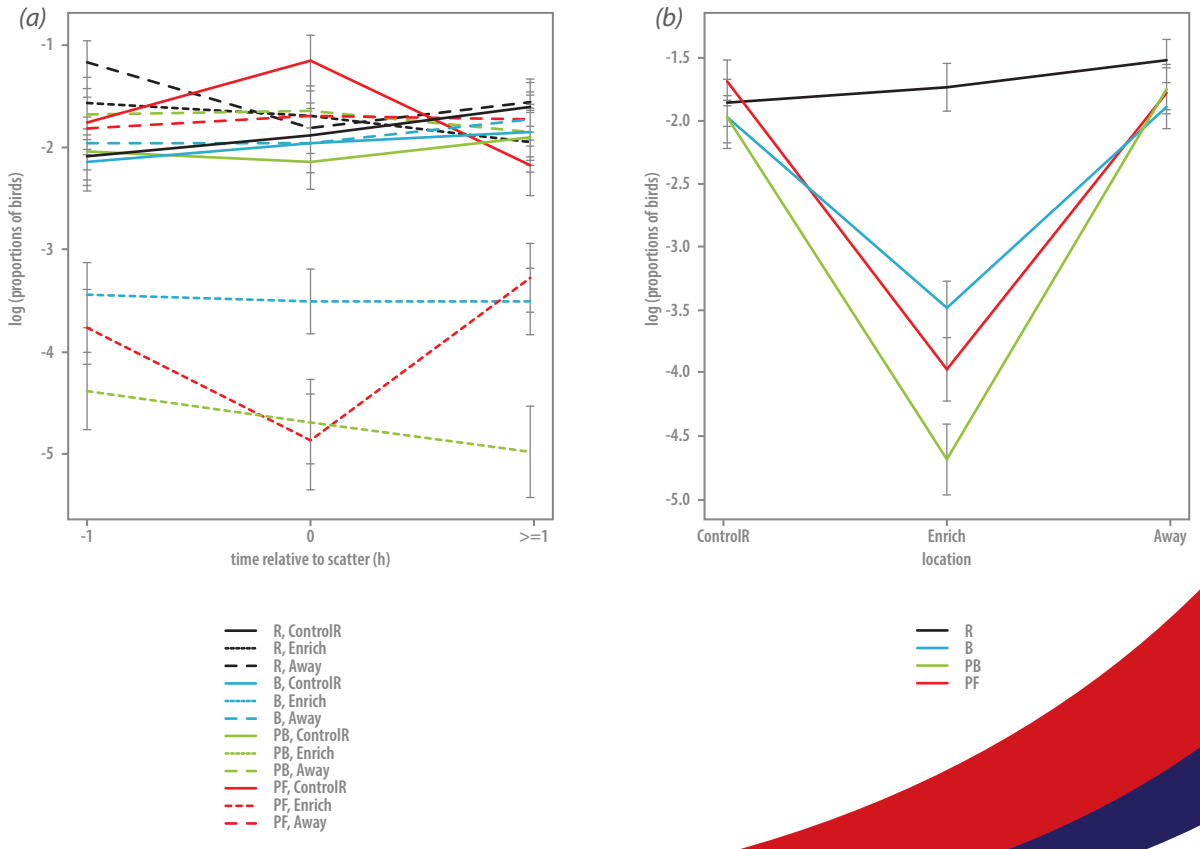
WALK/RUN

The proportion of birds observed in walk / run behaviours was marginally affected by the interaction of time.location.treatment ($Wald_{12}$/ndf=2.10 by GLMM; P=0.014) largely due to the influence of PF and time relative to scatter, for which walking / running declined then increased at the enrichment and commensurately increased then declined at ControlR, whilst for the other treatments behaviour remained broadly steady with the times observed relative to scatter (Figure 8a). There was a highly significant location / treatment interaction on the proportion of birds observed in walk / run behaviour, where birds were observed walking / running least in the Enrich area with all treatments except R, while hens seen in treatment R, and at all treatments in locations ControlR and Away were all similar ($Wald_6$/ndf=13.20 by GLMM; P<0.001) (Figure 8b). Walking / running decreased marginally with bird age (predicted means ± SE logit (back transformed proportions) 34 weeks -2.10±0.09 (0.11), 52 weeks -2.38±0.11 (0.08), 70 weeks -2.59±0.13 (0.07); $Wald_2$/ndf=4.47 by GLMM; P=0.011).

There were very few counts of birds seen dustbathing, feather pecking, aggressive pecking, perching, or in 'other' behaviours, so these are not reported further.

Figure 8
(a) Mean ± SE logit(proportions of birds) observed in walk/run behaviour, according to time (-1, 0, >1), location (ControlR, Enrich, Away) and treatment (R, B, PB, PF), estimated from GLMM.

(b) Mean ±SE logit(proportions of birds) observed in walk/run behaviour, according to location (ControlR, Enrich, Away) and treatment (R, B, PB, PF), estimated from GLMM.



FEATHER SCORES

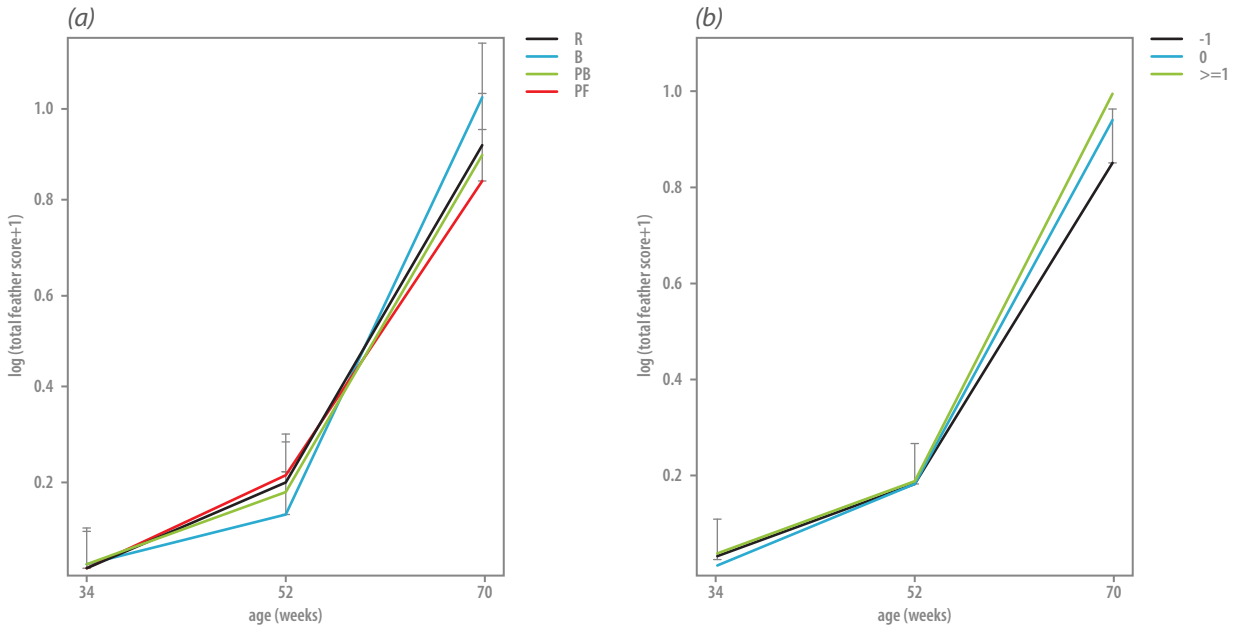
Feather scores were low (i.e. little damage) at bird ages 34 and 52 weeks, with only tails having some damage (Table 6). Feather scores were highest at 70 weeks with mean total feather score of 2, but mean feather scores at each body site were each less than 1. The prevailing effects on feather score were due to age and (when examining the individual scores) from the tails (where scores were highest; scores were lowest at breast, and in between for neck, back, wings) (site.bird age interaction, $Wald_8/ndf=15.42$ by LMM; $P<0.001$). Many interactions would not converge due to sparse data or were not significant ($P>0.05$) in the GLMMs applied to individual sites data, so this is not reported further.

Table 6
Mean ± SD feather score by bird age and body location (overall treatments and flocks) and mean ± SD total feather score (FS).

	34 weeks	52 weeks	70 weeks
Neck	0.000 ± 0.000	0.003 ± 0.053	0.398 ± 0.536
Back	0.000 ± 0.000	0.001 ± 0.037	0.362 ± 0.520
Tail	0.024 ± 0.153	0.257 ± 0.444	0.664 ± 0.495
Breast	0.000 ± 0.000	0.000 ± 0.000	0.145 ± 0.358
Wings	0.000 ± 0.000	0.000 ± 0.000	0.436 ± 0.580
Total FS	**0.024** ± 0.153	**0.261** ± 0.452	**2.004** ± 1.790

Figure 9
(a) Mean ± SE log(total feather score + 1) by age (34, 52, 70) and treatment (R, B, PB, PF), estimated from LMM.

(b) Mean ± SE log(total feather score) by age (34, 52, 70) and time relative to scatter (-0, 0, >1)), estimated from LMM.



Total mean feather scores were significantly affected by the interaction of treatment and age, whereby feather scores were lowest for B hens at 52 weeks of age, but were higher than PF at 72 weeks of age ($F_{6,43}$=3.8 by LMM; P=0.004) (Figure 9a), but in reality these differences were small (back transformed means: age 52 weeks, B 0.14 versus other treatments (range) 0.19-0.24; age 70 weeks, B 1.80 versus PF 1.33), and, furthermore, the difference between 52 and 70 weeks may have been influenced by the lack of data from four out of eight flocks at age 70 weeks. There was a further interaction with age and time (Figure 9b), with no differences between times at ages 34 or 52 weeks, but with more hens seen with poorer feather scores at time ≥1 compared to time -1 at 72 weeks ($F_{4,2058}$=4.7 by LMM; P=0.001), but again in reality differences were small (back transformed means age 72 weeks: 1.35-1.69) and may have been influenced by missing data from half of the flocks at age 70 weeks.

REPLACEMENT FREQUENCY AND COST

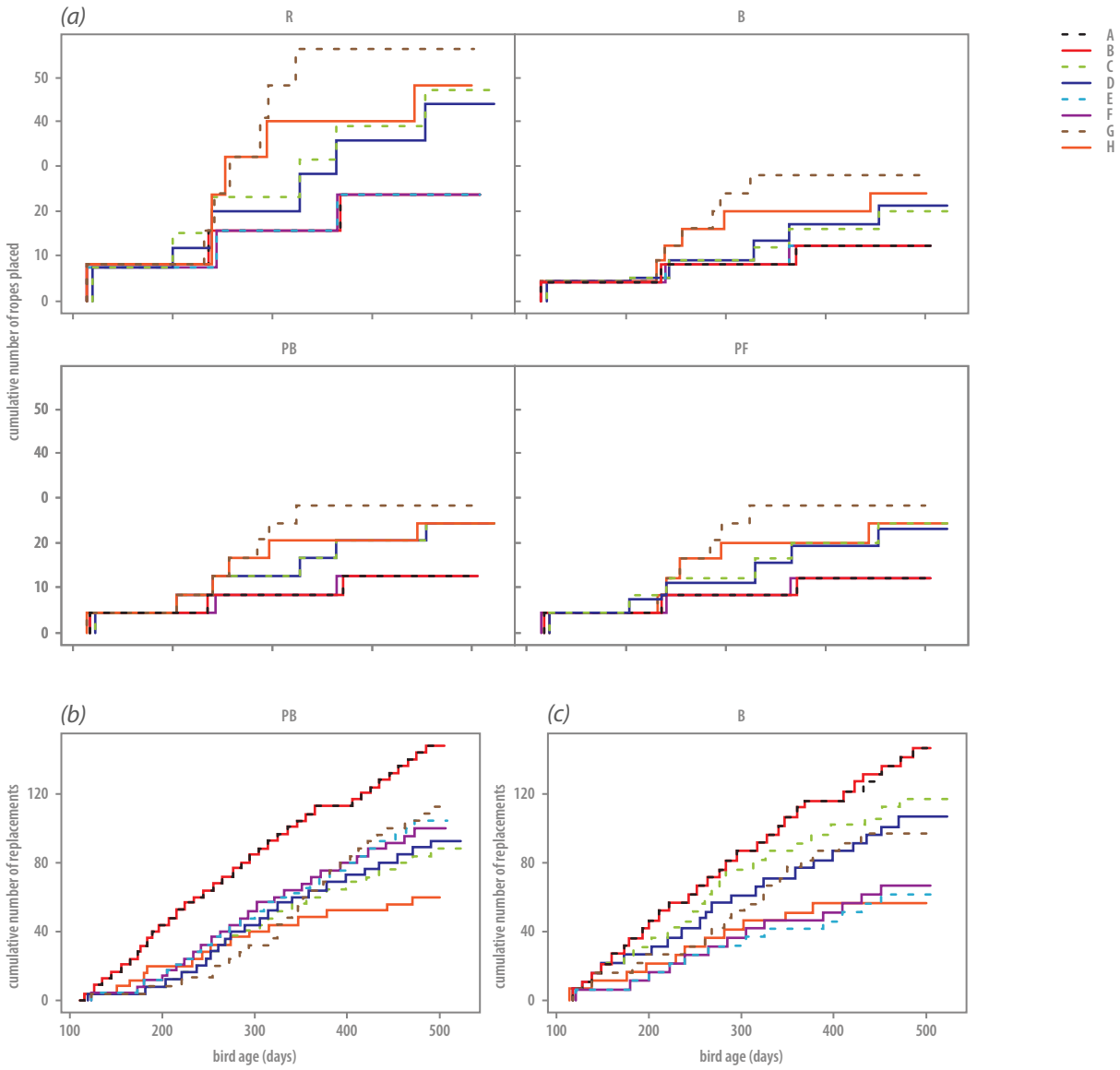
Enrichments were replaced regularly by the farms based on their judgement of depletion. As a result, rates of replacement varied widely from flock to flock (Figure 10) apart from with PF which was scattered twice a day in every flock (not shown). For example, replacement of PB pairs was highest in flocks A and B (which were on the same farm). Replacement of ropes was understandably higher in the treatment R, where there were twice as many ropes as in B, PB, or PF, but was lowest in flocks A and B in all quarters. When covariates on days since last replacement and the cumulative amounts of enrichments replaced were tested last in the above reported statistical models of behaviour data, as would be expected, the more recently items had been replaced, the more interest was shown by the birds. These covariates were often statistically significant with estimated coefficients in the expected direction, but no further details of this modelling are reported as these covariates were observational and the full range of their scales was only sparsely represented in the data.

Figure 10
The cumulative number of enrichments replaced in each flock (A-H) over bird age (days).

(a) replacement of ropes (in all treatments);

(b) replacement of pecking block pairs (PB);

and (c) replacement of hay bales (B).).



The estimated and actual rates of enrichment replacements, and the total costs for use, are shown in Table 7. Flocks studied here were followed to 70+ weeks of age, however flocks are likely to be housed for longer than this, depending on production. Therefore, the following cost estimates are based on the actual mean rate of replacement shown, in 16,000-hen flocks housed from 16 to 80 weeks (ignoring varying rates in mortality), thus needing enrichments for 64 weeks. Note that flocks are often expected to be given a variety of enrichment. Here we estimate the costs based on providing each enrichment per 16,000 hens. However, where required (by accreditation schemes or other), flock managers would have to choose combinations of the enrichments shown to get the total cost per flock. For example, RSPCA Assured require two items of permanent, destructible enrichment for every 1,000 hens[4], so two items below would have to be added together (and pelleted feed might not be permitted, if not considered permanent, despite it being of greater interest than ropes).

With all enrichments used, the mean replacement rate varied widely from flock-to-flock: standard deviation values were 33-40% of the mean values. However, it is still clear that while Lucerne bales, pecking blocks, and pelleted feed generated the most interest in hens, ropes were by far the cheapest enrichment to provide. The most expensive was pecking blocks, followed by pelleted feed, then bales.

** = with enrichment; NA = not applicable, because there are no enrichments to interact with*

Table 7
The estimated and actual mean rate of replacement for the four enrichments in 8 flocks, with standard deviation (SD) given, and the total cost of using each enrichment in a flock of 16,000 hens, housed for 64 weeks (16-80 weeks of age), based on the actual mean rate of replacement seen here. Costs do not include local taxes or shipping.

	Bales	Pecking blocks	Pelleted feed	Rope
Estimated replacement	21 days	10 days	Twice a day	180 days
Mean replacement (n=8)	21.9 days	14.9 days	Twice a day	96.6 days
SD (n=8)	8.8	4.9	0	36.3
Cost of 1 item	6.50/bale	£7.00/block	£8.38/20 kg bag (£419/tonne)	8.295 p/30 cm (£27.65/100 m reel)
No. required (for 16,000 hens)	16	32	16 kg	16
Cost as 1 enrichment for 16,000 hens	£104.00	£224	£6.70	£1.33
Number of times item would need replacing in 64 weeks	20	30	448	5
Total cost (to nearest £)	£2,080	£6,720	£3,008*	£6.64

** Only 7168 kg needed, but feed can only be bought in bags of 20 kg, so 7080 kg = £3008.*

4. DISCUSSION

A high proportion of hens were seen in standing/sitting in both ControlR and Away locations with all treatments, but this was significantly lower with B, PB and PF compared to R in Enrich, probably related to the commensurate increase of birds interacting with enrichments (other than R) in Enrich, which occupied 0.370-0.599 of the mean proportion of hens observed. This suggests that, of the four enrichments studied, ropes are least favoured by hens (and in fact no more attractive to hens than no enrichment at all). This is corroborated by the analysis, where interacting directly with the enrichments was significantly greater with PB and B at all observation times, while with PF interaction peaked at feed scatter (with concurrent decline in hens in the vicinity of, but not engaging with, the PF enrichment), but declined within an hour, probably because most pellets had been consumed by then, but hens were still showing an interest in PF at other times (-1, ≥1) compared to R or areas where there were no enrichments. R elicited the least interaction from the hens, suggesting that of the four enrichments studied here, they were the least useful to hens, or perhaps not enough were provided. In contrast to the other enrichments studied, ropes are the smallest item (in terms of surface area), so many more of them may be needed to increase interaction. But, given the lack of interest around ropes shown here, there is little supporting evidence to suggest that increasing the number of rope bundles would bring any benefit to hen behaviour.

The mean counts of birds seen in any location, engaged in all behaviours, ranged from 6.8-17.2 birds. Given that the observation locations of 1 m diameter each provided an area of 7850 cm^2, then on the

basis of stocking density for hens in free-range systems of 9 hens/m^2 (equivalent to 1111 cm^2 per hen), this would have comfortably allowed space for 7 hens. In locations where there were ropes (all treatments in ControlR, and treatment R in Enrich) or no enrichments (Away) there were on average about the number of hens expected based on this stocking density, with 6.8-8.7 hens seen. In contrast, where there were B, PB, or PF enrichments (in location Enrich), we observed on average 10.8-17.2 hens, suggesting that birds were attracted to these enrichments. Bird attraction to the area was highest (and consistent) with PB then B, whereas PF showed a decline in attraction outside of scattering, presumably because scattered feed was depleted. However, PF interest was still higher than that around ropes, suggesting that scattering of feed has long-lasting effects.

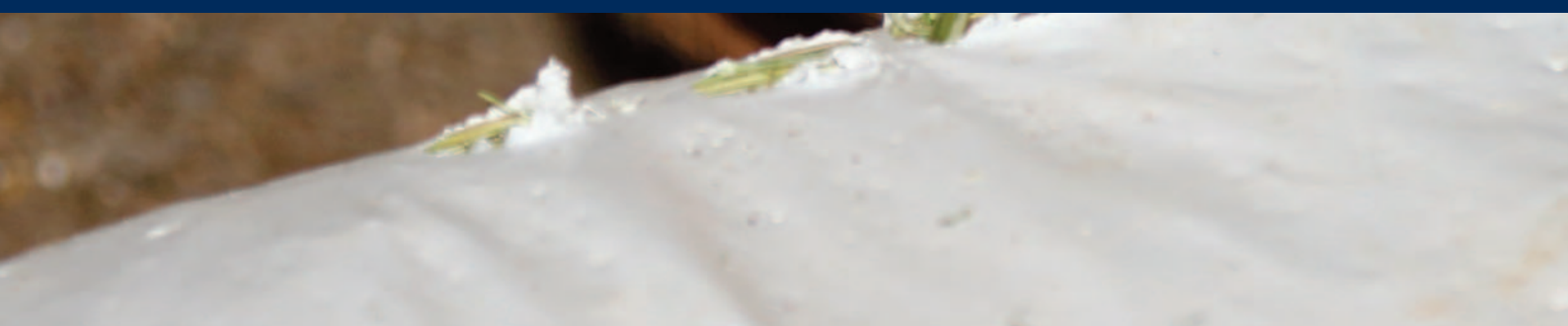
With bird age, the attraction of the enrichments appeared to wane, but the drop in bird numbers was least with PB, followed by B and PF. The numbers of birds reduced the most over age with R. It is worth noting that there is an overall drop in the number of hens seen in the three locations with age, regardless of treatment.

The expected benefits of providing destructible enrichments are to encourage birds to direct pecking behaviours away from other hens, to fulfil natural behaviour, and improve feather cover. In this study, we have to consider both interacting with the enrichments (which are used for pecking and pulling at) plus foraging behaviour in the litter (which excluded the PF scatter area in that treatment). While foraging behaviour alone showed little differences between treatments, apart from a drop in foraging with

PF as hens were drawn to the scattered feed area, all the non-rope enrichments achieved the desired goal of encouraging interaction at the enrichments, which would hopefully benefit feather cover. However, feather cover responses were unclear and were probably exacerbated by the loss of data, plus hens were able to move out of popholes in one quarter, and re-enter the shed at another quarter, thus potentially mixing birds throughout the treatments. Feather cover did worsen with age, as expected, but feather cover was generally good (overall scores on average of 2 or less), which is highly desirable. It may be that since evidence of feather pecking (via feather scores) was low in these flocks, there were only small differences gained from different enrichments, and a better comparator would be to have a treatment with no enrichments at all. However, that was not possible in commercial flocks.

Providing enrichments comes at a cost to the producer, which must be balanced against benefits to the birds and their effects on finances. While using rope was the cheapest enrichment by far over the lifetime of flocks, it was also the least effective in terms of effects on behaviour, and indistinguishable from behaviour away from all enrichments in this study. In all shed quarters tested here, we tested rope + another enrichment (or rope + rope for control), but we did not test all combinations of the four treatments (e.g. B + PF, PB + PF etc.) It may be that such combinations would have further benefits on behaviour and feather scores, but it is likely that the costs of these would be prohibitive to many producers. Therefore, given the requirements of some accreditation schemes for 2 different enrichments, rope + another is potentially a good compromise between interest for hens and reasonable costs.

ACKNOWLEDGEMENTS



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