

VOCALISATIONS AND ACOUSTIC PARAMETERS OF FLOCK NOISE FROM FEATHER PECKING AND NON-FEATHER PECKING FLOCKS

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Ashleigh Bright. VOCALISATIONS AND ACOUSTIC PARAMETERS OF FLOCK NOISE FROM FEATHER PECKING AND NON-FEATHER PECKING FLOCKS. British Poultry Science, 2008, 49 (03), pp.241-249. 10.1080/00071660802094172 . hal-00545329

HAL Id: hal-00545329 https://hal.science/hal-00545329

Submitted on 10 Dec 2010

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British Poultry Science



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Journal:	British Poultry Science
Manuscript ID:	CBPS-2007-155.R2
Manuscript Type:	Original Manuscript
Date Submitted by the Author:	28-Jan-2008
Complete List of Authors:	Bright, Ashleigh; FAI Farms Ltd
Keywords:	Welfare, Laying hens, Feather pecking, Vocalisations





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Vocalisations and acoustic parameters of flock noise from feather pecking and non-

feather pecking flocks

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Running head : VOCALISATIONS OF LAYER FLOCKS

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Accepted for publication 20 February 2008

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2 3	1	Abstr	act.
4 5	2	1	In this study, the colling rates of we colling in sum to indicate distance and
6 7	2	1.	In this study, the calling rates of vocalisations known to indicate distress and
8 9	3		aversive events (Alarm calls, Squawks, Total vocalisations) and acoustic
10 11	4		parameters of flock noise were quantified from feather and non-feather pecking
12 13 14	5		flocks.
15 16	6	2.	One hour of flock noise (background machinery and hen vocalisations) was
17 18	7		recorded from 21 commercial free-range laying hen flocks aged \geq 35 weeks. Ten
19 20 21	8		of the flocks were classified as feather pecking (based on a plumage condition
22 23	9		score) and 11 as non-feather pecking.
24 25	10	3.	Recordings were made using a Sony DAT recorder and Audio-Technica omni-
26 27 28	11		directional microphone, placed in the centre of the house -1.5m from the ground.
29 30	12		Avisoft-SASlab Pro was used to create and analyse audio spectrograms.
31 32	13	4.	There was no effect of flock size or farm on calls/s or acoustic parameters of flock
33 34 35	14		noise. However, strain had an effect on the number of Total vocalisations/s; the
36 37	15		Hebden Black flock made more calls than Lohmann flocks. Feather pecking
38 39	16		flocks gave more Squawks/s and more Total vocalisations/s than non-feather
40 41 42	17		pecking flocks. Feather pecking did not explain variation in alarm call rate or,
43 44	18		intensity (dB) and frequency (Hz) measures of flock noise.
45 46 47	19	5.	The differences between Squawk and Total vocalisation call rates of feather and
48 49	20		non-feather pecking flocks are a new finding. An increase or change in flock
50 51	21		calling rate may be evident before other conventional measures of laying hen
52 53 54 55 56 57	22		welfare such as a drop in egg production or increase in plumage damage, thus

enabling farmers to make management or husbandry changes to prevent an outbreak of feather pecking.

INTRODUCTION

Vocalisation, the generation of sounds with specific organs, is an expression of a
distinctive inner state of an animal (Grandin, 1998). Vocalisations can be recorded noninvasively and their dependence on inner states make them useful indicators of an
animals' state of welfare (Weary and Fraser, 1995). Judgements on welfare require that
the physical and physiological conditions of the vocalising animal can be attributed to its
state of welfare in a given environment (Manteufell *et al.* 2004).

12 Examinations of vocalisations uttered in well-defined situations and during

13 pharmacological studies, have helped clarify which calls may be relevant for the

14 judgment of welfare in domestic fowl (Manteufell *et al.* 2004). For example, during

15 experimental studies, food, water, nest and dust-bath deprivation all elicited gakel calls

16 (sustained sounds with low frequency (Hz) range and lasting more than 4 s (Konishi,

17 1963)) usually uttered pre-laying (Wood-Gush, 1971) from laying hens (Zimmerman and

18 Koene, 1998; Zimmerman *et al.*, 2000). Gakel-calls are thus considered to be an

19 indication of general frustration and possibly impaired welfare in laying hens

20 (Zimmerman et al., 2000). In White Leghorn chicks, distress calls, (high intensity (dB),

21 decreasing frequency (Hz) and call duration of about 0.4s), are almost exclusively uttered

22 when the animal is alone in a sound isolated test box (Marx et al., 2001). That distress

23 calls really do indicate distress is supported by the fact that centrally administered α -

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1	MSH and ACTH, peptides involved in triggering of the stress response, are able to elicit
2	distress calls in domestic chicks. Consequently, a high incidence of distress calls has been
3	considered to indicate impaired welfare in domestic fowl (Panksepp and Abbott, 1990;
4	Panksepp and Normansell, 1990). Total vocalisation rate (sum of all calls per animal/unit
5	of time) in broilers and laying hens is positively correlated with event aversiveness (Jones
6	et al., 1998; Marx et al., 2001). An increase in total vocalisation rate under different
7	conditions or environments is considered an indication of impaired welfare (Jones et al.,
8	1998; Marx <i>et al.</i> , 2001).

9 Feather pecking in laying hens is a behaviour that consists of pecking at, and or, 10 pulling out the feathers of conspecifics (Savory, 1995). Feather pecking may result in 11 poor quality plumage, patches of feather loss and damage to the skin (Savory, 1995). 12 Feather pecking is a welfare problem because pulling out feathers causes pain (Gentle 13 and Hunter, 1990), and damaged birds may be cannibalised (Allen and Perry, 1975). 14 Feather pecking is also an economic problem; it can lead to lowered egg production 15 (Johnsen et al., 1998; El-Lethey et al., 2000), and higher food consumption because birds 16 with little feather cover have poor thermoregulation and consequently greater energy 17 demands than unaffected birds (Leeson and Morrison, 1978; Tauson and Svensson, 1980; 18 Tullett *et al.*, 1980; Peguri and Coon, 1993). Victims of feather pecking show high rates 19 of alarm (high frequency (Hz) sound of ~ 0.3 s duration with a distinct harmonic structure 20 (Konishi, 1963; Collias, 1987)) calling (Rodenburg et al., (2005) and a squawk of 21 startle/pain (short (~ 0.1 s)) with an abrupt onset and ending and covering a wide 22 frequency (Hz) range; Konishi, 1963; Wood-Gush, 1971; Collias, 1987) may be given by 23 a hen suddenly pecked by another (Collias, 1987). Bird lines with a high rate of feather

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1	pecking behaviour made more vocalisations (notes) than birds from a line with a low
2	incidence of feather pecking during individual and social feather pecking tests
3	(Rodenburg and Koene, 2003). Anecdotal evidence suggests that commercial flocks
4	which have a feather pecking problem (see Huber-Eicher and Audigé, 1999; Green et al.
5	2000; Bestman and Wagenaar, 2003; Bright, 2007 for description of what constitutes a
6	feather pecking problem) 'sound different' to non-feather pecking flocks and that this
7	difference is perceivable before any damage to plumage is observed. However, there
8	appears to be no published information on vocalisation differences between commercial
9	feather pecking and non-feather pecking flocks, despite the fact that feather pecking is a
10	major welfare concern for the egg producing industry (Green, et al. 2000) and laying
11	hens are highly vocal animals (Collias and Joos, 1953; Wood-Gush, 1971).
12	A vocalisation/noise difference between feather pecking and non-feather pecking
13	flocks may have important implications for the management of feather pecking in
14	commercial laying hens; a change in specific call rate, intensity (dB) or frequency (Hz)
15	might be an early indication of inadequacy in the housing or management, indicating a
16	problem before physical symptoms of plumage damage are evident. Furthermore,
17	vocalisation rates of specific call types and simple acoustic parameters have the potential
18	to be easily detected by automated monitoring systems (Moshou et al. 2001; Schon et al.
19	2001), thus alleviating the need for manual vocalisation recording and analysis.
20	In this study, 1 h of flock noise from 21 commercial free-range laying hen flocks
21	was recorded in situ. Ten of the flocks were classified as feather pecking and 11 as non-
22	feather pecking (Bright, 2007; Figure 1). The primary aim was to quantify the calling
23	rates of alarm calls, squawks and total vocalisations. As the acoustic parameters of flock

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noise such as maximum intensity (dB), mean frequency (Hz), and frequency bandwidth (Hz), might also reveal differences between feather pecking and non-feather pecking flocks, these were also quantified. **METHODS** A single one-hour sound recording was collected from each of 21 commercial free-range laying hen flocks $(1100 - 10\ 000\ \text{birds})$. The flocks were from 6 farms and were one of 4 commercial free-range laying strains (Table 1) aged \geq 35 weeks. The farms were located in Oxfordshire and Lincolnshire and ranged from single flock to >20 flock/farms. Two hundred birds from each flock (100 in the house and 100 on the range) were scored for plumage damage due to feather pecking immediately after recordings. A co-ordinate grid map of the houses and the range area and random numbers were used to select birds for inspection. If there was more than one bird at a co-ordinate location the observer used a clear sheet of A4 acetate with 5 cm^2 marked squares. The observer stood a few metres back and held up the acetate grid so that it covered most of the section, and selected the bird closest to the square indicated by a pre-determined random number. For all birds, the body was divided (Bilcik and Keeling, 1999) into 5 different regions: neck, back, rump, tail and wing. The neck, back and rump were scored on a 0 (best) to 4 (worst) scale adapted from (Allen and Perry, 1975) (see Bright *et al.*, 2006). Slightly different criteria were used for scoring flight feathers (tail and wing primaries), because of the different types of feathers and damage. The underside of the neck or the breast were not scored as plumage damage from these regions may be attributed to abrasion

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from the feeders and unrelated to damage from other birds (Bilcik and Keeling, 1999), see also Bright *et al.*, (2006) for more information on feather scoring method.

A flock was classified as feather pecking if the combined feather score from birds in the house and on the range averaged ≥4 (that is, a minimum of a plumage damage score of one, from 4 body parts). Ten of the flocks were classified as feather pecking and 11 as non-feather pecking (Figure 1). Two flocks from the same farm were housed under a single roof but were separated by wire partitioning and divided by nest boxes inside and electrical fencing on the range and thus were considered statistically independent.

9 Recordings were made between April 2005 and May 2006 and between ~10.00 h 10 and 14.00 h using a Sony TCD-D10PRO DAT (Sony, Tokyo, Japan) recorder and Audio-11 Technica omni-directional ATM10A microphone (Audio-technica, Tokyo, Japan), placed 12 in the centre of a house, suspended approximately 1.5 m from the ground and at a time 13 when stockpersons did not enter the house for floor egg collections or flock inspections. 14 Recordings were digitalised on to a PC using Avisoft-SASlab Pro software (Avisoft 15 Bioacoustics, Berlin, Germany) and a Sigma-Tel C-major sound card (Sigma-Tel Inc, 16 Austin, USA) at a 22.05 Hz sampling rate, 16-bit precision.

Avisoft-SASlab Pro was used to create and analyse audio spectrograms. From the 1 h recording (starting at 100 s), to allow the experimenter to leave the shed and birds to settle, 60 s spectrograms were created with a 256 FFT at 5 min intervals until the end of the recording. Alarm calls/s, Squawks of startle/pain/s and Total vocalisations per second were determined by visual examination of the spectrograms while listening to the recordings. Alarm calls and Squawks represent a distribution of energy or intensity (dB) over frequency (Hz) and time (s) (Figure 2a and b). Call duration, and energy/ intensity

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]	distribution (represented as grey scale in Figure 2 a and b, the darker the grey scale the
2	2 higher the energy/intensity) were used as criteria for assignment to call types, thus
	3 specification of call types was subjective. Total vocalisations were defined as the sum of
2	all calls per second per flock (Table 2).
4	5 To determine the acoustic parameters of flock noise, power spectrums were
(6 created (logarithmic, rectangle evaluation window), derived from Fourier transformation
-	of the 60 s spectrograms and the following recorded: the intensity of sound (dB),
8	frequency (Hz) at maximum intensity, mean frequency (point at which 50% of the energy
ļ	in the spectrum is below), inter-quartile frequency range (frequency range which contain
1(between 25 and 75% of energy in the spectrum) and frequency bandwidth (difference
11	between maximal frequency and lowest frequency of the spectrum exceeding the -16 dB
12	2 threshold).
13	3 Statistical analysis
13 14	 Statistical analysis The call rates, intensity and frequency measurements were averaged to give a single
13 14 15	 Statistical analysis The call rates, intensity and frequency measurements were averaged to give a single value for each flock. The statistical software used was Minitab for windows (Release 14,
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13 14 15 16 17 18 19 20	 Statistical analysis The call rates, intensity and frequency measurements were averaged to give a single value for each flock. The statistical software used was Minitab for windows (Release 14, Minitab® 2003). Alarm calls/s, Total vocalisations/s and frequency bandwidth datasets were square-root transformed. The inter-quartile frequency range dataset was square transformed. Pearson's correlations were used to test for any associations between Alarm calls/s, Squawks/s and Total vocalisations/s, and also between Alarm calls/s, Squawks/s, Total vocalisations per second and Maximum intensity (dB).
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$ \begin{array}{c} 13\\ 14\\ 15\\ 16\\ 17\\ 18\\ 19\\ 20\\ 22\\ 23\\ 23\\ 23\\ 23\\ 23\\ 23\\ 23\\ 23\\ 23$	 Statistical analysis The call rates, intensity and frequency measurements were averaged to give a single value for each flock. The statistical software used was Minitab for windows (Release 14, Minitab® 2003). Alarm calls/s, Total vocalisations/s and frequency bandwidth datasets were square-root transformed. The inter-quartile frequency range dataset was square transformed. Pearson's correlations were used to test for any associations between Alarm calls/s, Squawks/s and Total vocalisations/s, and also between Alarm calls/s, Squawks/s, Total vocalisations per second and Maximum intensity (dB). General Linear Model (GLM) procedures were used to test for effects of flock size, strain (Hebden Black, Hyline, Lohmann, Oakham Blue), farm (A-F) and feather pecking status (feather pecking, non-feather pecking) on calls/s, intensity and frequency

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1	measures of flock noise. The following GLM was fit for each call/s or flock noise
2	acoustic parameter dataset:
3	$Y = flock \ size + strain + farm (strain) + feather \ pecking \ status$
4	Covariate, flock size
5	Model fit was checked by visual examination of residual plots and the adjusted R^2 values.
6	F-ratios and associated P values were calculated using sequential sums of squares when
7	models were not orthogonal (Grafen and Hails, 2002) and the sequence of variables in the
8	model was rearranged to test the robustness of results. Bonferroni pair-wise comparisons
9	were performed to elucidate statistically significant ($P < 0.05$) differences.
10	
11	RESULTS
12	There were no significant correlations between Alarm calls/s, Squawks/s and Total
13	vocalisations per s (Pearson's correlation $P = >0.164$ for all), or between Alarm calls/s,
14	Squawks/s, Total vocalisations per s and Maximum intensity (dB) (Pearson's correlation
15	P = >0.426 for all).
16	There was no effect of flock size or farm, on Alarm calls/s, Squawks/s or acoustic
17	parameters of flock noise (Table 3). However, strain had an effect ($P < 0.05$) (Table 3);
18	the Hebden Black flock made more Total vocalisations per s than Lohmann flocks
19	(Figure 3).
20	Feather pecking flocks gave significantly more startle/pain Squawks per s and
21	more Total vocalisations per s (Table 3) than non-feather pecking flocks (Figure 4a and b
22	respectively). Flock feather pecking status did not explain variation in Alarm calls per s,

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1	maximum intensity, frequency at maximum intensity, inter-quartile frequency range and
2	frequency bandwidth of flock noise (Table 3).
3	
4	DISCUSSION
5	If the meaning and context of calls and utterances in laying hens are well established,
6	vocalisations are a potentially useful tool for the assessment of welfare because: 1) they
7	can be recorded non-invasively and 2) they may enable detection of a potential welfare
8	problem earlier than conventional measures such as an increase in plumage damage
9	(which requires painstaking and subjective scoring and physical examinations of birds).
10	This study compared the vocalisation rates and acoustic parameters of flock noise in situ
11	from commercial free-range laying hens in feather pecking and non-feather pecking
12	flocks.
13	Strain effects are well documented for a variety of production and personality
14	traits in laying hens (Hughes and Duncan, 1972; Webster and Hurnik, 1990; Zimmerman
15	and Koene, 1998; Hocking et al., 2001; 2003; 2004; Albentosa et al., 2003), so the extent
16	and type of vocalisations might also be expected to vary with strain. In this study, the
17	Hebden Black flock made more Total vocalizations per s than the Lohmann flocks
18	(Figure 4a). However, there were no differences between strains in the vocalisation rate
19	of Squawks, Alarm calls, or intensity and frequency measures of flock noise (Table 3).
20	Alarm calls are usually made in response to mild-moderate disturbances such as
21	passing animals/humans or strange sounds (Collias and Joos, 1953; Konishi, 1963;
22	Wood-Gush, 1971). There was no significant difference in the number of Alarm calls per
23	s from birds in feather and non-feather pecking flocks (Table 3). There may have been no

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1	difference in the incidence of mild-moderate disturbances between feather and non-
2	feather pecking flocks, or at least no difference in the predisposition of birds to utter
3	alarm calls in response to mild-moderate disturbances. In several species of primate, calls
4	associated with more aversive events showed higher pitch, greater frequency range and
5	larger amount of noise (non-harmonic energy) than less aversive events (Gouzoules and
6	Gouzoules. 1989; Fichtel et al., 2001). Examining acoustic parameters (duration,
7	harmonics, and fundamental frequency) of specific laying hen vocalisations such as the
8	Alarm call between feather pecking and non-feather pecking flocks might reveal
9	differences that were not evident from calling rate in this study.
10	The lack of correlation between the Alarm calls, Squawks and Total vocalisations
11	and Alarm calls, Squawks, Total vocalisations and maximum intensity suggests that
12	flocks which are producing more of one particular call type are not simply vocalising
13	more frequently, or are the loudest flocks. Although the number of Squawks per s was
14	relatively low overall compared to Total vocalizations per s (Figure 4a and b), feather
15	pecking flocks had a significantly higher rate of startle/pain Squawks per s than non-
16	feather pecking flocks (Table 3, Figure 4a). There were also more Total vocalizations per
17	s from feather pecking, compared to non-feather pecking flocks (Table 3, Figure 4b).
18	Squawks signify an event aversive to the bird (Collias, 1987) and that the feather pecking
19	flocks in this study were experiencing more of these aversive events. Similarly, total
20	vocalisation rate is correlated with event aversiveness (Jones et al., 1998; Marx et al.,
21	2001) and a high rate of feather pecking behaviour (Rodenburg and Koene, 2003).
22	Communication is when the activities of an individual influence the behaviour of
23	others (Dawkins, 1995). Vocalisations may modulate emotions/behaviour of the receivers

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1	such that welfare may also be affected in conspecifics hearing calls associated with							
2	distress or fear (Manteuffel et al., 2004). For example, aerial- and ground-predator calls							
3	and fear squawks are warning calls associated with the threat of predation, and							
4	presumably heightened fearfulness (Collias and Joos, 1953; Konishi, 1963; Wood-Gush,							
5	1971). Presentation of predator warning calls or fear squawks to battery cage hens							
6	significantly prolonged tonic immobility (an unlearned response to physical restraint							
7	positively related to fear; (Jones, 1986). Similarly, several breeds of laying hen exposed							
8	to 90 dB background noise (background chicken vocalisations and fans) for 1 h, had a							
9	significantly higher heterophil:lymphocyte ratio and longer duration of tonic immobility							
10	than birds exposed to 60 dB background noise (Campo et al., 2005). While this study did							
11	not directly test specific call rate and behaviour of individuals, the comparatively higher							
12	Squawk and Total vocalisation rate in feather pecking flocks may be influencing							
13	fearfulness and distress of birds and thus further contributing to the negative welfare of							
14	the flock and/or enhancing feather pecking behaviour.							
15	Acoustic parameters are frequently measured for specific call types (for example,							
16	for comparisons between individuals (Nakagawa et al., 2001). In this study, acoustic							
17	parameters of flock noise were measured to investigate whether any differences between							
18	feather and non-feather pecking flocks and their general flock noise could be detected.							
19	Higher pitched calls such as 'squawks' have more energy concentrated at higher							
20	frequencies than for example, 'food' calls given by a hen to chicks (Collias, 1987). If							
21	birds in feather pecking flocks are making more startle/pain squawks, the frequency (Hz)							
22	of the flock noise might be different. Furthermore, if flocks are making more							
23	vocalisations, the intensity (dB) of flock noise might also be expected to vary. However,							

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there was no difference between frequency or intensity measures of flock noise between
 feather pecking and non-feather pecking flocks (Table 3).

3 This study measured simple acoustic parameters of commercial flock noise in an 4 attempt to be relevant to industry conditions. In future research, measurements of 5 vocalisation differences between feather pecking and non-feather pecking flocks may 6 need to concentrate on a larger sample size to detect more subtle differences in flock 7 noise than was possible here, and/or investigate differences in acoustic parameters of 8 specific calls rather than differences between general flock noises. Furthermore, 9 vocalisations and acoustic parameters in this study were only recorded in flocks after 10 feather pecking had developed; investigating calls and acoustic parameters of flock noise 11 at an earlier age (such as 1-d-old, age of transfer, onset of lay) and correlated with later 12 feather pecking behaviour would be a valuable area of research. 13 Finally, there is potential to investigate the feasibility of automated monitoring

14 systems for the early detection of welfare problems such as feather pecking. An online 15 monitoring system for pigs has been developed which can detect coughs (indicating 16 presence of a viral infection) and pig stress calls above other calls and farm noise 17 (Moshou et al., 2001; Schon et al., 2001). Similar systems may be possible for poultry 18 units using, for example, the squawk/total vocalisation rate of flock noise in the rearing 19 and laying periods, before other conventional measures of laying hen welfare such as a 20 drop in egg production or increase in plumage damage, thus enabling farmers to make 21 management or husbandry changes to prevent an outbreak of feather pecking.

In conclusion, feather pecking is a serious economic and welfare concern for the egg industry. This is one of the first studies to quantify differences between vocalisations

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and flock noise of feather and non-feather pecking, commercial free-range laying flocks.
Feather pecking flocks had a higher rate of Squawks, of pain/startle and Total
vocalisations than non-feather pecking flocks. The difference between Squawk and Total
vocalisation call rates of feather and non-feather pecking flocks is a new finding. For the
acoustic parameters measured, there were no differences between the general flock noise
of feather and non-feather pecking flocks.

- 7
- 8 Acknowledgments

9 Thanks to J.R. Waas at University of Waikato, Hamilton New Zealand for assistance with
10 sound recordings and advice on sound analysis. M.S. Dawkins, T. A. Jones, K. Drake and

11 an anonymous reviewer commented on and significantly improved earlier drafts of this

12 manuscript. Dean's Foods Ltd (now Noble Foods Ltd) provided a travel and

13 accommodation grant. The Worshipful Company of Poulters' Charitable Trust provided

14 an equipment grant. A. Bright was supported by a Top Achiever Doctoral scholarship

15 from the New Zealand government's Tertiary Education Commission.

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- **Table 1.** *Relationship between farm and strain number of flocks studied is in brackets.*
- 2 For confidentiality, the identity of farms is coded A-F.

4 Table 1

Farm	Strain (n)					
А	Lohmann (2)					
В	Lohmann (2) Hyline (2)					
С	Lohmann (3),					
D	Lohmann (1)					
Е	Lohmann (3)					
F	Hebden Black (1), Hyline (5), Oakh	nam Blue (2)				
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Table 2.	Name and description of vocalisa	tions quantified from 1 h flock recordings.				
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Table 2						
Call		Description				
Alarm call		'Kaah!' – High pitched sound of ~0.3 s duration				
		with a distinct harmonic structure (described after				
		(Konishi 1963: Collias 1987))				
		Alarm calls in laving hens are given in situations of				
		mild to moderate alarm such as strange sounds.				
		disturbance by conspecifics, passing animal or				
		human (Collias, 1987)				
Squawk		'Squawk' – Component notes are short (~ 0.1 s) wit				
oquum		an abrunt onset and ending and cover a wide				
		frequency range. This call is a barsh sound which				
		stresses the higher frequencies (described after				
		(Konishi 1963: Wood-Gush 1971: Collias 1987))				
		(Romsni, 1905, Wood-Gusn, 1971, Comas, 1987))				
		Squawks of startle/pain are associated with being				
		Squawks of startle/pain are associated with being				
		Squawks of startle/pain are associated with being pecked by another hen or suddenly startled (Collias 1087)				
		Squawks of startle/pain are associated with being pecked by another hen or suddenly startled (Collias 1987)				
Total vocali	sations	Squawks of startle/pain are associated with being pecked by another hen or suddenly startled (Collias 1987)				
Total vocali	sations	Squawks of startle/pain are associated with being pecked by another hen or suddenly startled (Collias 1987) Alarm calls + Squawk + all other vocalisations.				
Total vocali	sations	 Squawks of startle/pain are associated with being pecked by another hen or suddenly startled (Collias 1987) Alarm calls + Squawk + all other vocalisations. Other vocalisation may include short duration and highly rapatitive 'context' calls (Collias and Loos) 				
Total vocali	sations	 Squawks of startle/pain are associated with being pecked by another hen or suddenly startled (Collias 1987) Alarm calls + Squawk + all other vocalisations. Other vocalisation may include short duration and highly repetitive 'contact' calls, (Collias and Joos, 1053) 'mogen' and 'threat' calls (Collias and Joos, 				
Total vocali	sations	 Squawks of startle/pain are associated with being pecked by another hen or suddenly startled (Collias 1987) Alarm calls + Squawk + all other vocalisations. Other vocalisation may include short duration and highly repetitive 'contact' calls, (Collias and Joos, 1953) 'moans' and 'threat' calls (Collias and Joos, 1953) end schel ethe (Kerichi 1062) 				
Total vocali	sations	 Squawks of startle/pain are associated with being pecked by another hen or suddenly startled (Collias 1987) Alarm calls + Squawk + all other vocalisations. Other vocalisation may include short duration and highly repetitive 'contact' calls, (Collias and Joos, 1953) 'moans' and 'threat' calls (Collias and Joos, 1953), and gakel calls (Konishi, 1963). 				
Total vocali	sations	Squawks of startle/pain are associated with being pecked by another hen or suddenly startled (Collias 1987) Alarm calls + Squawk + all other vocalisations. Other vocalisation may include short duration and highly repetitive 'contact' calls, (Collias and Joos, 1953) 'moans' and 'threat' calls (Collias and Joos, 1953), and gakel calls (Konishi, 1963).				
Total vocali	sations	 Squawks of startle/pain are associated with being pecked by another hen or suddenly startled (Collias 1987) Alarm calls + Squawk + all other vocalisations. Other vocalisation may include short duration and highly repetitive 'contact' calls, (Collias and Joos, 1953) 'moans' and 'threat' calls (Collias and Joos, 1953), and gakel calls (Konishi, 1963). Total vocalisation rate is positively correlated with 				

al. 1998; Marx *et al*. 2001; Rodenburg and Koene, 2003)

 Table 3. F-ratio and associated P values for GLM's on the effects of flock size, strain

4 (Hebden Black, Hyline, Lohmann, Oakham Blue), farm (A-F) and feather pecking (FP)

5 (feather pecking, non-feather pecking) on calls/s, noise level and frequency measures for

each flock 1 h recording.

8 Table 3

Response	Flock	(P)	Strain	(P)	Farm	(P)	FP	(P)
variable	size				(strain)			
Alarm calls/s	$F_{1,10}=0.56$	(0.471)	$F_{3,10}=0.66$	(0.597)	$F_{5,10}=0.32$	(0.891)	$F_{1,10}=1.38$	(0.268)
Squawks/s	$F_{1,10}=2.79$	(0.126)	F _{3,10} =0.92	(0.466)	$F_{5,10}=1.08$	(0.425)	$F_{1,10}=9.91$	(0.010)
Total vocalisations/s	F _{1,10} =0.37	(0.557)	F _{3,10} =5.11	(0.021)	F _{5,10} =1.25	(0.357)	$F_{1,10}=13.14$	(0.005)
Maximum intensity (dB)	F _{1,10} =0.89	(0.368)	F _{3,10} =0.14	(0.931)	F _{5,10} =0.86	(0.538)	$F_{1,10}=0.70$	(0.423)
Frequency (Hz) at maximum intensity	$F_{1,10}=1.02$	(0.337)	F _{3,10} =0.15	(0.925)	F _{5,10} =0.78	(0.586)	F _{1,10} =0.12	(0.735)
Mean frequency (Hz)	F _{1,10} =0.09	(0.776)	F _{3,10} =0.84	(0.503)	F _{5,10} =0.71	(0.632)	$F_{1,10}=0.07$	(0.793)
Inter-quartile frequency range	F _{1,10} =1.68	(0.224)	F _{3,10} =2.52	(0.117)	F _{5,10} =0.99	(0.474)	$F_{1,10}=0.08$	(0.786)
Frequency bandwidth	F _{1,10} =0.98	(0.344)	F _{3,10} =1.02	(0.423)	F _{5,10} =1.17	(0.387)	$F_{1,10}=0.18$	(0.677)

Figure 1. Total feather score (mean \pm SE) for feather pecking (n = 10) and non-feather pecking (n = 11) flocks. Dashed line represents feather score above which flocks were considered to a feather pecking problem.













