Papers

Continuous monitoring of pop hole usage by commercially housed free-range hens throughout the production cycle

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Free-range laying hens are able to move between the indoor house and range through exits termed pop holes. The aim of this study was to examine the proportion of the flock that used the pop holes and to identify patterns of movement throughout the flock cycle. Four flocks of free-range hens each of 1500 birds were studied. Ten per cent of each flock were tagged with RFID (radio-frequency identification) transponders and their pop hole activity studied throughout the production cycle. Within two weeks of tagging at 25, 35, 45, 55 and 65 weeks of age, approximately 80 per cent of the tagged birds were seen in the pop holes and 50 per cent of the tagged birds were seen on 80 per cent of the days available to them after tagging. Within the flock, subpopulations of birds could be identified: those that never ventured to the pop holes (approximately 8 per cent), those that used the pop holes very infrequently (approximately 8 per cent), those that sat in the pop holes (approximately 4 per cent), and those that used the pop holes frequently (approximately 80 per cent). There was an effect of age of the birds, time of day and daily mean temperature on pop hole usage. Additional factors affecting activity on particular days were wind speed, rainfall and hours of sunshine. The findings show that a significant proportion of the flock accesses the pop holes on a regular basis with only a very small proportion preferring to stay in the house.

THERE is growing demand by consumers for eggs produced by birds housed in non-cage systems with the majority of non-cage eggs in the UK being produced using free-range systems. This change in buying preference, in parallel with an increased awareness of the restrictive nature of the traditional battery cage and the impending ban on such housing within the European Union in 2012, will see a dramatic fall in numbers of eggs produced using cage systems. The development of furnished, colony cages, considered to be superior on welfare grounds to the traditional cage (Pohle and Cheng 2009, Sherwin and others 2010) will provide an alternative, albeit one that involves considerable installation costs. Consequently, it is anticipated that the major growth will be in extensive, free-range housing.

The common feature of all free-range systems is that they allow birds to have continuous daytime access to outdoor runs which are ideally covered with vegetation and which are subject to stocking density restrictions. Consumer perception is that these systems are of higher welfare (Harper and Makatouni 2002) as birds are able to perform their normal repertoire of behaviours such as pecking, scratching and dust-bathing in a more natural environment on the range (Zeltner and Hirt 2008). While access to the outdoor range is assumed to be of great benefit, the modern hen, after spending 20 weeks inside during rearing and early placement before the pop holes are opened, has been reported as being disinclined to range outside (Bubier and Bradshaw 1998, Hegelund and others 2005, Hartlander-Matauschek and others 2006). From a welfare perspective, the birds are depriving themselves of being able to engage in a range of natural behaviours which might result in redirection to behaviours associated with aggression and feather pecking (Blokhuis and Arkes 1984, Vestergaard and others 1993). Indeed it is known that increased flock ranging is associated with a reduced risk of feather pecking (Nicol and others 2003, Lambton and others 2010). This reported reluctance to range outside is not readily explained based on the information currently available. The modern laying hen or domestic fowl is descended from the Red Jungle fowl (*Gallus gallus*) which inhabited tropical and subtropical forest edges and spent its life in the open, scratching in the undergrowth for food, building a nest, dust-bathing and roosting above the forest floor for safety. Despite centuries of domestication, the laying hen is thought to retain the natural behaviours shown by its wild ancestors (Schutz and Jensen 2001). However, genetic selection over many generations has produced a relatively small, modern hybrid capable of producing 300 eggs or more in a single laying cycle, which is particularly appropriate for cage egg production, within a carefully controlled indoor environment.

Previous studies with laying hens have monitored range use by use of individually identified, manually observed birds but only in relatively small scale or experimental systems, and some for only a limited

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period within the laying cycle (Grigor and others 1995, Mahboub and others 2004). Some recent work has been carried out using newer technologies, for example on broilers using GPS (global positioning system) (Castellini and others 2009) and small scale experiments on hens using RFID (radio-frequency identification) (Thurner and Wendl 2008, Gebhardt-Henrich and Frohlich 2010). Current research has suggested that in free-range flocks only a small proportion of the flock is outside at any given time (Hirt and others 2000) and additionally, that the use of the ranging area is highly dependent upon weather conditions and time of day (Keeling and others 1988, Hegelund and others 2005). The purpose of this study was to address the fundamental question of what proportion of a commercial flock uses the pop holes, how frequently they use the pop hole daily and how this distribution changes during the lifetime of the flock and under different weather conditions.

Materials and methods

The approach adopted used an automatic identification technology whereby digital data encoded in an RFID transponder/tag or 'smart label' was captured by an antenna and reader positioned in the pop holes and over which the hens had to pass to enter or leave the house. The system was able to individually identify the birds which were using the pop holes and also record the date, time and which pop hole was used.

The RFID system was designed and constructed to order (Dorset ID), and was installed into four self-contained, large pens, within one half of a production unit on a commercial free-range farm. Each pen held 1500 birds and allowed access to its own outside range, enclosed by electric fencing. Each pen within the house contained two pop holes. Each pop hole was 2 m long and 0.45 m high and allowed 12–15 birds to access the pop hole at any one time. Two antennae were installed within each pop hole. Pairs of antennae were 'tuned' to prevent interference between the magnetic fields which they generate.

The antennae were able to activate and read transponders to a reading distance of approximately 3 cm, which allowed the RFID transponders to be attached to leg tags fixed to the birds. The transponders within the leg tags had to be orientated perpendicular to the antenna for a reading to be taken as the transponders are passive devices, containing no battery, but are powered by inductance when within the field generated by an antenna. Each antenna was connected to a decoder which was able to interpret the transponder signal and relay information to a data logger with a time/date stamp and antenna number for recording. The decoders were programmed to read a tag and then ignore it for 10 seconds before reading again. There were 16 antenna and 16 decoders in the array. Data were converted via a Moxa A52/A53 RS232-RS485 converter to produce signals for a removable 'compact flash' data logger which was downloaded every eight weeks. An uninterruptable power source was installed to reduce problems with interruptions and spikes in the mains supply.

Before being fitted, transponders were read using a hand-held RFID reader (Trovan LID57 series) and placed in specially designed leg tags (Roxan iD) and secured with silicone glue. The tags were then secured on the birds' legs and to prevent them either coming undone or tightening further they were secured with a spot of super glue.

Birds were a standard commercial breed, Lohmann Brown, reared in a single shed and all transported to the laying house on the same day. The birds were 16 weeks of age at the start of the trial. The laying house and range area conformed to Freedom Food standards for free-range birds. The four trial flocks consisted of 1500 birds in each flock, with a total of 12,000 birds in the house. The house was 60 m long by 24 m wide. One side of the house contained the four experimental pens; each pen was 15 m long by 12 m wide which included nest boxes, slats and litter. The individual ranges for the experimental flocks were very similar and were each separated by electric fencing. A range consisted of small stones was immediately outside the pop holes with grass, trees and additional fabricated shelters throughout its length. There was also access to additional fields to allow a stocking density of 1000 birds/10,000 m^2. The trial took place between June 2009 and July 2010. Birds were fed a standard commercial diet throughout the laying period. At 25, 45, 55 and 65 weeks of age, 25 transponder leg tags were placed on randomly selected birds caught within the house before the pop holes were opened in the morning. As birds were continually moving within the house because of our presence, we did not record the areas (litter, slats or nest boxes) that they were caught from. At 35 weeks, 50 birds from each flock were similarly tagged. Thus, a total of 150 birds (10 per cent) from each of the four flocks were tagged. Throughout lay, the pop holes were normally opened at 09.00 and shut at dusk.

TABLE 1: The percentage of birds using the pop holes for 50 or 80 per cent of the days available after tagging, at different ages

Age at tagging	50% of days available (% of birds)	80% of days available (% of birds)	Days available
25 weeks (n=27*)	79	40	242**
35 weeks (n=143*)	67	44	237
45 weeks (n=66*)	77	51	177
55 weeks (n=69*)	77	53	102
65 weeks (n=78*)	89	57	22

* Number of birds found at the initial tagging age with still functioning leg tags at end of lay
** Days available are only 242 instead of 300 because of initial problems with the RFID (radio-frequency identification) recording equipment

Weather data were collected from a local meteorological recording station providing information on daily temperature, day length, hours of sunshine, wind direction and speed as well as the amount of rainfall.

At the end of the laying cycle all birds still wearing a transponder were collected and the tag number recorded.

A complete data set was only available from week 34 because of initial problems with the RFID recording equipment and data before this point were discarded.

The experiment was carried out in one half of a production unit on a commercial free-range farm following approval from the University of Bristol Ethical Review Committee.

Statistical analysis

Data were reduced to a count of the frequency with which an individually tagged bird was registered at a pop hole each day for both the morning (09.00 to 13.00) period and the afternoon (13.00 to 17.00) period. The duration of data collection from a bird was considered to start from the day on which it was first registered at a pop hole until the last day on which it registered. The data set was constructed so that any intervening morning or afternoon on which the bird did not register was recorded as a zero count. Statistical models were built to identify the effect of morning/afternoon, time of year (count of the days of the study (week 34 to week 69, a total of 242 days) centred about day 121 and as a squared term; the squared term is used to account for the curvilinear effect of season) and differing weather conditions on the response variable 'mean pop hole activity per bird per hour', with the basic statistical unit being the mean of the morning or afternoon count. The models were built using the multilevel software MLwiN v2.22 (Rasbash and others 2010) which allowed specification of the underlying data structure of repeated measures on morning/afternoon for each day for each bird within a pen.

Results

An initial test of between pen differences of pop hole activity was carried out and no significant differences between pens were found.

During the laying cycle 600 birds were fitted with RFID leg tags and at the end of lay 415 birds were found with functioning leg tags. Retention of the tags was improved at week 35 by the addition of super glue to the end of the fastening clip, which increased retention rate to end of lay from 29 per cent for tags fitted at 25 weeks to greater than 70 per cent at subsequent ages. In total, 509 of the 600 birds tagged were recorded by the RFID system at some point during the study. Some tags will have also been lost from the study due to bird mortality, but this was not recorded.

Of the 415 tagged birds seen at the end of lay, 32 (7.7 per cent) never registered at a pop hole. Of these 32 birds, one was tagged at

TABLE 2: The parameter estimates, their standard errors and significance for the model of mean pop hole activity

	Variable type	Parameter estimate	SE	P-value
Constant		0.68433	0.01524	<0.001
Temperature (°C)	Continuous	0.04182	0.00217	<0.001
Daily rainfall (mm)	Continuous	−0.00861	0.00222	<0.001
Wind speed (knots)	Continuous	−0.01905	0.0015	<0.001
Hours sunshine (hours)	Continuous	0.01231	0.00281	<0.001
Time of year (day) (centred*)	Continuous	−0.00081	0.00001	<0.001
Time of year squared (day^2) (centred*)	Continuous	0.000026	0.000002	<0.001
Temperature °C x hours sunshine	Continuous	−0.0000078	0.00024	<0.001
Daily rainfall x wind speed	Continuous	−0.00072	0.00029	0.006
Morning/afternoon	Categorical	−0.14102	0.0065	<0.001

*Time of year centred on 121 days

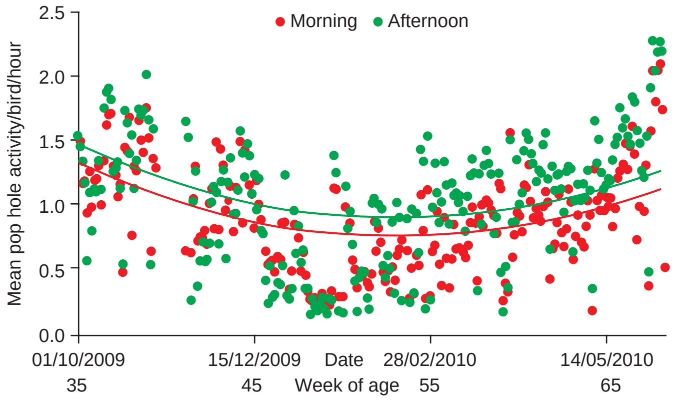

FIG 1: Predicted pop hole activity by morning and afternoon periods throughout the study. The age of the birds is given on the x-axis and the raw data are also shown

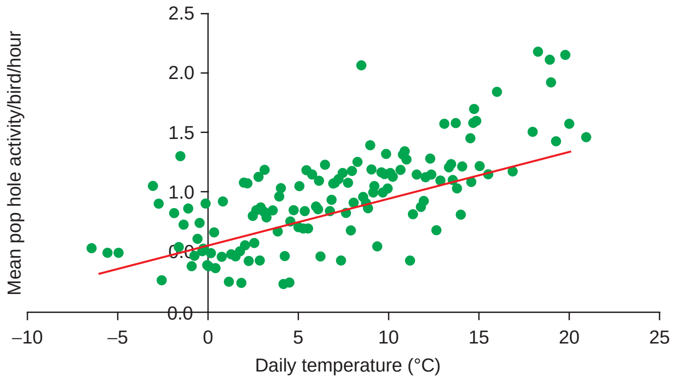

FIG 2: The relationship between mean daily temperature and predicted pop hole activity of tagged birds/hour. The raw data are also shown

25 weeks, 11 at 35 weeks, six at 45 weeks, seven at 55 weeks and seven at 65 weeks. Thirty-three (7.9 per cent) were seen only once or twice throughout the cycle and 16 (3.8 per cent) had very high sequential RFID counts indicating that they were sitting in the pop holes. For later analysis to reduce the impact of multiple recording events (>7 events/bird/minute), data generated by each bird were restricted to a maximum of one count every minute.

There was a big variation between the frequency that birds were accessing the pop holes. The majority of birds were seen 1–30 times a day, but some (most likely sitting in the pop holes) were recorded up to 200 times a day, equating to almost 200 minutes.

An overview of pop hole usage following tagging is summarised in Table 1. Nearly 75 per cent of the birds tagged, regardless of age, used the pop holes on 50 per cent of the days available to them after tagging and approximately 50 per cent of the birds used the pop holes on 80 per cent of the available days after tagging. There was only a small percentage of birds (approximately 8 per cent) that used the pop holes for less than 10 per cent of the available days.

At each age of tagging, the number of newly tagged birds recorded using the pop holes within two weeks of tagging was monitored. Because of problems with the equipment, the 25-week data corresponding to birds tagged at 25 weeks were not available. There were no significant differences in the percentage of birds seen at the different tagging ages (77, 77, 86 and 87 per cent, respectively), but the percentage was slightly higher at weeks 55 and 65, which corresponded with warmer weather in May and June.

The parameter estimates from the modelling exercise to identify predictors of pop hole activity based recorded usage are shown in Table 2. The dependant variable was the mean count per hour for an individual bird for each morning/afternoon period.

The parameter estimates give the change in mean pop hole activity for a unit change of each variable. Positive parameters indicate that an increase in the value of a variable is associated with an increase in mean pop hole activity and negative parameter estimates, a decrease. When looking at the categorical parameter morning/afternoon, a negative parameter estimate means that there is less activity in the morning than in the afternoon.

The mean pop hole activity was modelled in terms of the weather variables, morning/afternoon and time of year as predictors of activity. Time of year was fitted to the model as a count of the days of the study (week 34 to week 69, a total of 242 days) centred about day 121 and as a squared term. The squared term is used to account for the curvilinear effect of season. The parameter estimates are shown in Table 2, and Fig 1 shows the estimated effect of morning/afternoon and the time of year effect on predicted activity, superimposed upon the raw data.

There were significant effects of all the key weather variables on birds' usage of the pop holes (Table 2). Daily temperature had a large effect on the activity of birds (Fig 2) with an increase in pop hole use of 0.0418 for every degree rise in temperature when all the other parameters were held constant and there were zero hours of sunshine.

Significant effects on pop hole usage were also seen for wind speed and rainfall. Increasing wind and rain both led to a reduction in pop hole use, but there was an increase in activity with longer periods of sunshine. There were significant interaction effects between temperature and the amount of sunshine and between daily rainfall and wind speed. At lower temperatures, as the hours of sunshine increased, the pop hole activity increased. But at higher temperatures above 20°C, the hours of sunshine had little effect on pop hole activity when other parameters were held constant. Figure 3 shows the interaction effect of hours of sunshine and temperature displayed as a percentage change in pop hole activity for each change in hours of sunshine relative to activity at zero hours of sunshine. The data have been presented in this form because the change in activity is relatively small compared with the effect of temperature.

As both rainfall and wind speed increased together, there was a corresponding reduction in pop hole activity, both with similar strength of effect, but this reduction was significantly increased (Table 2, $P<0.001$) such that if, for example, there was rainfall of 20 mm and a wind speed of 20 knots, there was a 75 per cent reduction in pop hole activity when compared to either wind or rain alone at those levels. The modelled interaction effects of daily rainfall and wind speed are shown in Fig 4a, b.

Discussion

The opportunity for hens to carry out their full repertoire of natural behaviours has long been an emotive issue in poultry husbandry and has led to the impending EU ban on the use of conventional cage systems. The introduction of alternative, non-cage systems permits birds access to range and enables them to carry out normal behaviours such as dust-bathing, scratching and foraging. However, preliminary observations of many flocks have indicated that for most of the day

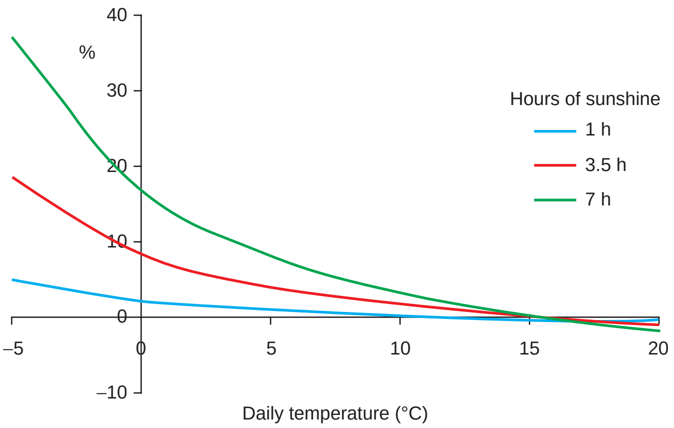

FIG 3: The interaction effect of temperature and hours of sunshine on the per cent change in predicted mean pop hole activity/bird/hour

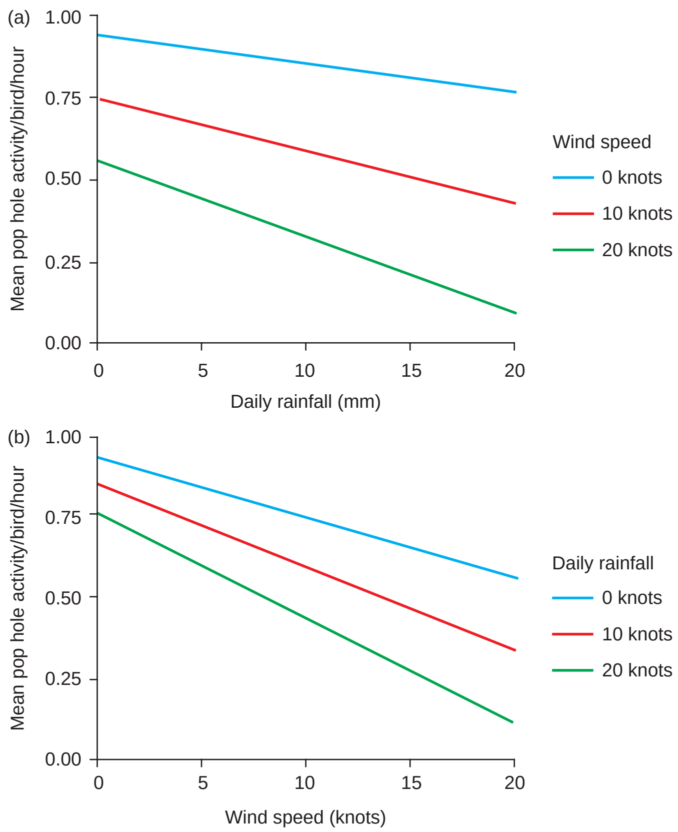

FIG 4: Interaction effects of (a) daily rainfall and (b) wind speed on the predicted mean pop hole activity/bird/hour

only a small proportion of the flock is outside (Hirt and others 2000). Similarly, it has been thought that it is the same birds that use the range each day and that a large proportion of the population remains inside. The present study has moved away from the limits of manual observation and using RFID technology has allowed us to identify individual bird activity throughout the flock cycle regarding use of the pop holes. RFID technology is relatively new and only limited studies have been published describing its use in poultry, for example Gebhardt-Henrich and Frohlich (2010) and Thurner and Wendl (2008).

Throughout the whole production cycle, approximately 85 per cent of the birds tagged were seen to use the pop holes at least once and a large proportion of these (approximately 80 per cent) were seen within two weeks of the tag being applied at various tagging ages, with slightly more birds seen immediately following the 55 and 65 week application dates. However, these later application weeks did correspond with warmer months of the year which may have accounted for the slightly higher activity. The number of days that birds accessed the pop holes was highly variable across birds, with some being registered only once or twice in total and others being registered almost every day. Nevertheless, approximately half of all tagged birds were recorded on 80 per cent of the days available and three-quarters were recorded within the pop holes on at least 50 per cent of the days available to them. These figures indicate that a much larger proportion of birds access pop holes than has previously been reported (Hegelund and others 2005, Hartlander-Matauschek and others 2006). It has been suggested that some birds enjoy the security of the pop holes because of the cover provided by the house and perceive the ranges to be not as safe as the building (Hartlander-Matauschek and others 2006). This may have been the case in the present experiment. Some birds were identified as sitting in the pop holes for extended times by the very high number of counts on the RFID recording system which would record the same bird every 10 seconds until it moved from the pop hole. This is a potential flaw with the system in that, while identifying and recording the presence of individually tagged birds within the pop holes, it does not readily distinguish between birds passing across the antenna and birds which choose to remain within the pop hole without accessing the range. To overcome this, the data generated by each bird were restricted to one reading every minute to reduce the disproportionate contribution of these birds to the total activity recorded. The proportion of birds sitting in the pop holes regularly (>3 times/bird/hour adjusted to one reading every minute) was quite variable but overall approximated to 4 per cent. This inevitably leads to the problem that we are only able to report pop hole activity and not time that birds actually spend on the range and the frequency that they go in or out. However, over the period of the whole flock cycle it gives a good insight into whether the hens are accessing the pop holes.

The relationship between pop hole use and mean daily temperature was highly significant with, as expected, the winter months showing reduced use as a consequence of the negative influence of bad weather coupled with shorter day lengths (Hegland and others 2005). During the winter when the temperature was below 0°C, access to the pop holes was less than 0.56 times/bird/hour but in the height of summer more than 1.33 times/bird/hour. Even when temperatures were below freezing with snow on the ground, birds were still seen to be frequently registered at the pop holes.

Additional, detailed atmospheric data such as mean daily rainfall, wind direction and speed, as well as hours of sunshine were modelled. The models showed that all these climatic factors except wind direction were extremely important in pop hole usage for the birds. Wind speed and rainfall both caused a reduction in pop hole activity, but this reduction was significantly higher when there was both heavy rain and high winds, reducing usage by as much as 75 per cent (Fig 4a, b). As already described, as temperature increased so did pop hole usage and additionally as hours of sunshine increase so did usage. However, there was a significant interaction between temperature and hours of sunshine on resultant pop hole usage. At very low temperatures, as the amount of sunshine increased so did usage (Fig 3), probably the result of the warming effect of sunlight on the birds. However, surprisingly, at temperatures above 20°C the amount of sunshine had no effect, although the actual pop hole usage was quite high. The relative reduction in increasing pop hole use during combined high temperatures and long periods of sunshine and the reduced numbers of birds using the pop holes during heavy rain and high winds possibly indicate the birds' requirement for shade and cover. If this was provided, possibly in the form of verandas or extended roofs, it might limit the impact of heavy rain, high winds and long hours of hot sun on the bird's reluctance to exit the house more frequently and for longer periods.

The model indicates that birds were more active throughout the flock cycle during the afternoons compared with the mornings. This may be because the majority of birds are laying their eggs in the morning and therefore restrict their movements to locations near the nest boxes. Birds are encouraged to lay in the 8-hour period after lights on (05.00) by manipulation of the lighting regimes (Lewis and others 2007).

The findings also suggest that there are possibly several subgroups of birds that develop and are maintained within the flock throughout lay: birds that do not go outside (approximately 8 per cent) and which were not seen throughout the production cycle, those that probably use the litter/slats and only infrequently access the pop holes, perhaps accidentally as a result of panic or other unusual activity in the house (approximately 8 per cent), those that spend long periods sitting in the pop holes (approximately 4 per cent) and, finally, those that probably frequent the range on a regular basis. This latter group comprises 80 per cent of the birds in the flock. What is not clear and was not examined in this study was whether there are differences in specific behaviours of the four subgroups perhaps as a consequence of differences in fearfulness (Mahboub and others 2004), health, size or position within the pecking order and whether those differences are responsible for the differing preferences to range.

Conclusions

Overall, a large proportion of the flock accessed the pop holes during the cycle, some birds many times a day. However, the number accessing the range at any given time appears to be small and does not reflect the overall usage on a flock basis. This would explain previously reported low estimates of range use, as they were generally based on single direct observations of the number of birds using the range at any given time. What is apparent is that pop hole usage is affected by the weather conditions prevailing on the day and modifications to pop hole design in combination with changes to the range layout might improve range use on days with poorer weather conditions. There is a small proportion (8–16 per cent) of birds that do not go outside, or which access the pop holes very infrequently, and further research is required to discover why these prefer the house to the range.

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