Extreme crowding in laying hens during a recurrent smothering outbreak

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Abstract
Background: Piling, a behaviour where hens crowd together, is referred to as smothering if mortalities result. Smothering is a considerable concern for the egg industry, yet is vastly understudied.

Methods: During an outbreak of recurrent smothering, continuous video footage captured a commercial, free-range flock over 35 days. We describe the piling behaviour observed and potential associations with productivity and flock health indicators.

Results: Forty-eight piles were filmed, with a maximum density of 187.93 birds/m² and up to 1204 birds in one pile. Piling occurred in the same house location on 33 of 34 observation days, the first evidence of regularity in piling behaviour. Despite extreme bird densities, we did not find associations between piling extremity and productivity but did find associations with water:feed ratio and temperature range.

Conclusion: This study describes the most extreme level of piling reported in literature and offers new insights into this problem behaviour and its consequences.

1 INTRODUCTION

Smothering, poultry crowding together causing mortality, is a major economic and welfare concern for the egg-laying industry.1-3 We estimate the UK egg industry loses £6.5 million/year due to smothering (based on mortality rates from 1). This figure does not account for the previously unconsidered effects of sublethal injuries or flock stress, such as bone fractures, heat stress, and the stress of physical restraint. Despite this, the smothering literature is lacking of the few published papers investigating smothering, most are preliminary.1-4 No peer-reviewed papers have directly measured smothering in a commercial setting. Piling (birds crowding in high densities), the behaviour underpinning smothering, is poorly understood because it is unpredictable, difficult to induce experimentally, and is disrupted by the presence of an observer.2,3 Only one study has used camera footage to observe piling, capturing 174 piling occurrences over two flock cycles, but no smothering was observed.5

The aim of this study was to describe an outbreak of recurrent smothering (RS) in a commercial flock. RS is one of three smothering categories, characterised by an apparent lack of stimulus and/or observable panic.1-3 RS causes the most deaths, is the most common, and is the most difficult type of smothering to explain or prevent. It is described as recurrent because if flocks smother once, they are likely to repeatedly smother throughout the lay period.1 RS occurs in open spaces, usually the litter, without physical barriers preventing escape or dispersal.1-3 A subsidiary aim was to consider the potential for sublethal effects of piling, such as whether piling is associated with measures of production (Eggs Per Bird [EPB], Floor Eggs, Seconds, Egg Weight) and welfare and environmental measures (water:feed ratio and temperature range). Injured, diseased or immunocompromised birds can be identified by rapid changes in water and feed consumption in the barn,6-8 and temperature fluctuations have been implicated in smothering.1 We hypothesised that any sublethal effects of piling would increase with pile extremity. We predicted that higher pile extremity would be associated with a decrease in production, and an increase in water:feed ratio and temperature range.
2 | METHODOLOGY

Footage was collected between April 23, 2019 and May 27, 2019, from one flat-deck chicken house with a single group of approximately 12,000 free-range hens (for further house layout, see Figure S1). Four agricultural cameras (Agricamera, Barnstable, UK) captured top-down footage in previous locations of smothering, each capturing approximately 13.92 m$^2$ (approximately 30% of the litter area total). BirdBox (www.birdbox.farm), an automated flock management system, was used to gather additional data (see Table 1). Pilot observations revealed that previously used piling definitions, for example, “a minimum of 10 birds pressed against each other for at least 1 min,” were likely to result in type I errors in this commercial flock. Based on pilot observations and industry opinion, piling was defined in this study as >30 tightly packed birds, to the extent that only the head and neck were visible, for 30 min (e.g., a score of 5–8 for >30 min, Figure 1b).

Cases of piling were identified during daylight hours (05:00–21:00) and scored by one observer (GH) on four measures of pile extent (Table 1). Inter-rater reliability was satisfactory: the intraclass correlation coefficient (ICC) was 0.98 for counts of hens a priori based on 14 observations and 224 grid squares counted by two observers; ICC3 was 0.90 for peak pile time; and weighted kappa was 0.70 for the pile rating (∼10% of piling events scored by two observers from videos cropped to the event, 409 data points in total). Associations were explored between a measure of pile extremity (count max as the predictor) and the six BirdBox measures for the matching day and subsequent day for production variables (effects on eggs laid and formed during the pile) as dependent variables (Table 1) using separate linear models. Analysis was carried out using RStudio Version 1.2.1335. The ethics were reviewed and approved by the Animal Welfare Ethical Review Body (Project ID 468).

3 | RESULTS AND DISCUSSION

Forty-eight piles were captured on 33 of 34 observation days resulting in six smothering events and 74 total deaths. With the exception of two piles captured on camera 4, all piles (46 total) were captured by camera 1 and 34 had sufficient footage for further analysis. Piles typically began around midday, the mean start time was 12:41 ± 1 h 15 min (mean ± standard deviation), but start time ranged between 10:30 and 16:02. Piling typically ended in the early afternoon, between 11:45 and 16:50 with a mean of 14:08 ± 1 h 17 min. Piling behaviour lasted 89 ± 52 min (range = 30–213 min). Peak pile time occurred at 13:29 ± 1 h 12 min but ranged between 11:40 and 16:30. Contrary to research describing recurrent piling as unpredictable,1–3,5 piling in this flock occurred at a predictable time. However, this may be an artefact of management. There was a longer period between feeds in the afternoon, and stockpersons who reg-

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**TABLE 1 Definitions of variables recorded from the recurrent smothering flock**

| Measure                  | Definition                                                                 | Number of observations |
|--------------------------|---------------------------------------------------------------------------|------------------------|
| **Video observations**   |                                                                           |                        |
| Duration                 | The length of time between the first and last minute where at least 30 birds are continuously in contact with each other. | 48                     |
| Peak pile time           | The time at which the maximum number of birds appeared in the pile based on visual assessment rather than manual counting of birds. | 48                     |
| Count max                | The view from the camera was divided into 12 virtual grid squares of approximately 1.16 m$^2$ and the number of visible bird combs in each grid was counted at peak pile time. Count max is the highest number of birds counted in any single grid square. | 48                     |
| Bird density             | The number of birds counted in a square metre. Unit given as birds/m$^2$ (b/m$^2$). | 48                     |
| Count total              | The total number of birds on the litter which were part of the pile, based on visible combs at peak pile time. | 48                     |
| Pile rating              | An eight-point visual scoring system for rating the number of birds in a pile grid square (see Figure 1b). | 34                     |
| **BirdBox measures**     |                                                                           |                        |
| Mean pile rating         | The mean pile rating of the litter for the entire focal hour. | 34                     |
| EPB                      | Eggs per bird. The number of eggs laid in one day divided by the number of birds in the flock on that date and the next (to account for lag in egg production). | 34                     |
| Seconds                  | The total number of second quality eggs laid that day and the next. | 34                     |
| Floor                    | The total number of floor eggs laid that day and the next. | 34                     |
| Egg weight               | The mean weight of the eggs laid that day and the next. | 8                      |
| Water:feed               | The ratio of water to food consumed that day and the next. | 34                     |
| Temperature range        | The difference between the lowest and highest temperatures recorded that day and the next. | 34                     |
ularly walk through the house to prevent piling do so more frequently in the morning, which may allow more opportunity for piles to build in the afternoon.

Hens crowded in similar locations repeatedly under camera 1. Hens distributed themselves unevenly across the camera's visual field, with some grid squares consistently containing more birds (see Figure 1a). Further understanding of hen distribution during piling could support management strategies aimed at reducing smothering or elucidate the causes of the behaviour. When divided into 12 virtual grid squares of approximately 1.16 m², there were between 8 and 218 (82 ± 43) birds per grid square or 6.90 × 10^{-8} to 187.93 birds per square metre (b/m²). Pile rating scores1–8 across a focal hour of observation revealed piling behaviour to build to a peak and then dissipate more slowly. In keeping with descriptions of RS1–3, this did not appear to be a panic behaviour. At the peak pile time, 652–1204 hens were counted (989 ± 136) in an area of approximately 13.92 m² of litter. Bird density at peak pile time was 46.84–86.49 b/m² (71.05 m² ± 9.77). The degree of piling reported here is much greater than previously identified in the literature. For example, Campbell et al.5 reported piling of up to 229 birds, although from a group of approximately 800 or 1700, which means the overall proportion of birds piling was higher than that in this study.

We found no support for the prediction that piling would reduce productivity. We found no associations between count max and measures of productivity extracted from BirdBox on the same day: EPB (mean ± SE = 168.59 ± 2.19, F_{1,32} = 1.36, p = 0.252), Seconds (mean ± SE = 0.97 ± 0.01, F_{1,32} = 0.36, p = 0.552), Floor Eggs (mean ± SE = 1.47 ± 0.03, F_{1,32} = 1.44, p = 0.240), Egg Weight (mean ± SE = 64.28 ± 0.02, F_{1,9} = 3.15, p = 0.110); or the next day (EPB F_{1,32} = 1.37, p = 0.251, Seconds F_{1,32} = 0.714, p = 0.404, Floor Eggs F_{1,32} = 0.37, p = 0.545, and Egg Weight F_{1,8} = 0.03, p = 0.870). However, fewer data were available on Egg Weight, and although inaccurate, the effect size indicates this may be worth future investigation. The lack of a relationship found between piling and production measures on the same day could be explained by a lag between when the egg is in the oviduct at the time of a pile and when it is laid.

Comparisons between piling and non-piling flocks are needed to further understand the association with productivity. Piling extremity (count max) was associated with water:feed ratio (mean ± SE = 1.33 ± 0.02, F_{1,32} = 5.41, p = 0.026), and the temperature range (mean ± SE = 6.71 ± 0.32, F_{1,32} = 4.29, p = 0.047). These results are preliminary and only describe a single flock; however, they indicate that unforeseen impacts of smothering on hen welfare need further investigation. It seems plausible that both a wider temperature range and an increase in water:feed ratio are related to birds being exposed to increased temperatures. However, temperature range could also reflect greater heat generated by hens, making it more difficult to control the house temperature. Dispersal of hens is recommended on hot days to reduce heat stress10 and high densities of hens are known to compromise thermoregulation.11 Thus, piling could be expected to result in increased hen, and therefore house temperature and the observed relationship between smothering and temperature range could be a cause or effect of smothering, likewise we cannot infer direct causality with other measures considered here. Maximum and minimum daily house temperatures had respective means (± SD) of 20.86°C (±3.58) and 14.15°C (±2.34). The maximum house temperature recorded was 29.2°C, but this could be much greater in a large pile of hens. When under high temperatures, hens alter their behaviour and internal homeostasis in order to reduce their body temperature, which is considered to negatively impact both productivity and immune response.12,13 It is important that further research into piling and smothering
considers the potential for sublethal impacts, as well as better understanding the aetiology of the behaviour.

4 | CONCLUSIONS

The crowding behaviour described in this study reached more extreme levels than any previously reported, in both frequency and intensity. We highlight the need for future research investigating the consequences of intense piling. This study found associations between piling extent, the water:feed ratio, and the temperature range reported on that day. Novel methods were developed for scoring piling, including a pile rating system, which could be implemented in future research as an alternative to the time-consuming method of counting individual birds.

AUTHOR CONTRIBUTIONS

G. T. Herbert designed the study, collected data, analysed video footage, analysed data, and wrote the first draft of the manuscript. W. D. Redfearn designed the study, collected the data, analysed video footage, and contributed to writing the manuscript. E. Brass designed the study and managed data collection and collected data. H. A. Dalton conceived of and designed the study, and advised on data collection and video analysis. R. Gill, D. Brass, C. Smith, and A. C. Rayner conceived of the study, supported data collection, and contributed commercially relevant information and insight. L. Asher provided oversight for the study, advising on all aspects of the study design, data collection and analysis, and writing the manuscript. All authors read, edited, and approved the manuscript, with G. T. Herbert and L. Asher responsible for overall content.

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CONFLICT OF INTEREST

The authors have declared no conflict of interest.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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