Title – Predicting tail biting from behaviour of pigs prior to outbreaks

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Abstract -

Predicting that an outbreak of tail biting is going to occur in a group of pigs would be a useful tool for farmers. In a prospective longitudinal study, 24 groups of c.30 undocked pigs were followed from birth to slaughter weight. Four groups had to be excluded from the analysis, the remaining groups were classified as having *No Outbreak* (n=6), *Underlying Outbreak* (n=8) or *Severe Outbreak* (n=6) of tail biting. The hypotheses examined were that pigs would be more active, perform more tail-orientated behaviours, or have their tails tucked under their body more in groups that went on to have outbreaks than in those that did not. Direct observations were made at 7, 11, 15 and 19 weeks of age and video recordings were examined for the 4 days prior to an outbreak. All outbreaks occurred after the behavioural observation at

11 weeks of age. Activity levels were significantly higher in *Severe Outbreak* groups in the four days prior to an outbreak, with more pigs *Standing* ($p<0.05$) and significantly fewer pigs *Sitting* ($p<0.05$) or *Lying Inactive* ($p<0.05$) than in matched control groups. Comparisons of the *Severe, Underlying* and *No Outbreak* groups at 7 and 11 weeks of age, prior to any outbreaks, showed no difference in activity levels. However, at these ages, levels of *Tail Interest* were higher in *No Outbreak* groups than in those with *Severe Outbreaks* ($p<0.05$), while the opposite was true for damaging *Tail Biting* ($p<0.05$). Thus high levels of damaging *Tail Biting* may be a good predictor of impending outbreaks, but high levels of *Tail Interest* are not. Tail position also differed between groups at this age, with fewer *Tails Tucked Under* in *No Outbreak* groups ($p<0.01$). Some outbreaks were predicted by multiple variables, while others had no clear predictors. In five outbreaks a small runty pig was tail bitten in the absence of a full outbreak. Whenever this happened, a full tail biting outbreak always went on to take place sometime afterwards. The occurrence of single tail biting events may thus be reliable indicators of future outbreaks. In summary, measurement of pig activity has potential for predicting tail biting outbreaks on commercial farms as do levels of tails tucked under and damaging tail contact. Further work is needed to understand the relationship between different forms of tail contact and tail biting. We highlight the difficulty in predicting all outbreaks from a single measure and conclude that tail biting outbreaks vary considerably. The presence of an ‘indicator pig’ might be a useful sign that an outbreak will occur.

Keywords

Tail biting, pigs, behaviour, welfare

1. Introduction

Most outbreaks of tail biting are detected only once sufficient damage has occurred for there to be blood visible in the pen and an escalation in tail biting behaviour has already occurred (Sambraus, 1985; Fraser, 1987). By this stage, the outbreak has already had a major impact on the welfare of the pigs, and it is difficult to prevent further tail biting in the pen (Zonderland et al., 2008). Therefore, until it is possible to prevent tail biting altogether, an early indication that an outbreak is likely to occur within a group of pigs might help farmers to intervene prior to escalation of tail biting and thus reduce the impact of this damaging behaviour.

One potential indicator for a future outbreak of tail biting is that of increased activity before an outbreak (van Putten, 1969; Fraser and Broom, 2005). Keeling et al. (2004) reported that, when an outbreak was under way, activity levels were higher in pens with outbreaks than in control pens. However, behaviour prior to outbreaks was not recorded, so it is possible that activity levels were raised before damage occurred, or that they increased once the outbreak had started. Interestingly, Svendsen et al. (2006) reported that a single pig that became a tail-biter was more active than its pen-mates in the days prior to an outbreak. Thus raised activity levels prior to an outbreak might occur but there is little direct evidence for this.

Other changes in pig behaviour might also be expected to occur before an outbreak of tail biting. If tail biting develops from non-damaging tail-investigation as previously suggested (van Putten, 1969; Sambraus, 1985; Fraser, 1987; Schrøder-Petersen et al., 2003), tail-orientated behaviours would be likely to be higher in groups which later develop outbreaks, or might become more prevalent before any damage was seen. Fewer curled tails might also be observed, as tails held down (McGlone et al., 1990) and tucked under the body (Bracke, *pers. comm.*, 2005) have been associated with the onset of tail biting. Research on the occurrence of these behaviours before and during tail biting outbreaks would be helpful to ascertain whether they have potential as predictive indicators. Such research is difficult to conduct because it requires observational data before a tail biting outbreak. Due to the unpredictability of outbreaks, these data are in practice, very difficult to acquire.

However, in a detailed longitudinal study of the effects of early experience on the development of tail biting behaviour, we collected data before and during a number of outbreaks, allowing us to investigate whether certain behaviours and behavioural changes were associated with future outbreaks. We hypothesised that pigs would be more active, perform more tail-orientated behaviours and have their tails tucked under more in groups that went on to have an outbreak of tail biting. Our aim was thus to identify whether these changes in behaviour reliably preceded the occurrence of a tail-biting outbreak. This study also investigated whether providing straw at different stages of life affected the occurrence of tail-biting outbreaks and other behaviour. Straw provision treatments might have caused changes in behaviour which then precipitated a tail-biting outbreak. However, the treatments did not have this effect (Statham, 2008).

2. Methods

2.1. Animals and housing

The study was carried out on a commercial farm in the UK with approximately 130 sows. Approximately 700 Large White x Landrace x Pietrain pigs were followed from birth to slaughter. Sows farrowed loose in pens and remained with their piglets until weaning at 25 ± 3 days. At weaning three litters were mixed together in a weaner pen, giving group sizes of 30 ± 9 pigs. Each weaner pen consisted of an open area (2.2m x 4.46m) and a kennel area (2.2m x 4.35m) with heat lamps and an enrichment object (e.g. a wellington boot), and contained a feeder 168cm in length with 8 feeder spaces. At approximately 12 weeks of age each group of pigs was moved, without mixing, into a finisher building where they remained for the last 9 weeks of the study. Finisher pens consisted of a kennel area (3.52m x 3.83m) and an open area (3.52m x 4.4m) with an enrichment object, and included a feeder with three spaces. Creep feed was added daily from 2 weeks of age and after weaning the pigs were fed ad-lib on a commercial pellet diet.

This experiment was part of a large study which intended to examine multiple aspects of tail biting behaviour. One aim of the study was to examine the effect of straw provision and therefore it included four treatment groups with pigs provided with *Straw Throughout life* (ST), *Straw from Weaning* (SW), *Straw in Finishing* (i.e. from 12 weeks) (SF) and *No Straw* (NS). All the pens in the study had solid concrete floors without insulation and thus were designed for use with bedding, so when no straw was provided, wood shaving bedding was present instead. Six replicates of each treatment were made.

2.2. Non-behavioural procedures

Each pig was individually identified with a tattoo at birth and with an ear tag from weaning. At birth piglets' teeth were clipped and an iron injection administered; males were not castrated and tails were not docked. The tails of the pigs were formally examined twice, the first examination at approximately 11 weeks of age and the second at 19 weeks. During each examination, the tails were thoroughly cleaned, measured and details of all damage indicative of tail biting were noted. This involved recording the type of damage (scrapes from teeth, bite marks, chewing damage or severe damage where tail length is reduced) and the position on the tail where it occurred. As well as these checks, tails were examined each week when the pigs identification was re-marked. If any tail damage was noted during a weekly tail examination then an additional formal tail examination was carried out on every pig in the pen.

2.3. Behavioural observations

Video records of behaviour were obtained from two cameras installed over each weaner and finisher pen, one filming the open part of the pen and the other filming the kennel area. The pigs' behaviour was recorded for 10 minutes in every hour throughout each day and night from weaning until the end of the study. Direct behavioural observations of each group were also made at approximately 7, 11, 15 and 19 weeks of age. Two types of observation were made, instantaneous scan sampling and behaviour sampling, with each made at least ten times between the hours of 8am and 6pm.

2.3.1. Instantaneous scan sampling

An ethogram was created by taking elements from various studies of tail biting and enrichment (e.g. Fraser et al., 1991; Beattie et al., 2000; McIntyre, 2003) with the addition of a category for tail interest, after observations of tail biting during a pilot study period. Instantaneous scan observations of each pig in the group were made, recording their posture (*Lying*, *Sitting* or *Standing*), behaviour (see Table 1) and tail position. Tail position was classified as either *Curled Up* (tail forms a loop above the back of the pig), *Tucked Under* (pig is pressing its tail into its body) or *Hanging Down* (tail is neither *Curled Up* nor *Tucked Under*).

2.3.2. Behaviour sampling

All the pigs within each group were observed simultaneously for 10 minutes and the occurrence of the following behaviours was recorded: *Aggression*, *Belly-nosing*, *Tail Interest*, *Tail Interest/Chewing*, *Tail Chewing* and *Tail Biting* (see definitions in Table 1). The frequency and approximate duration of these behaviours was noted, together with which individual pig was performing and receiving the behaviour.

2.4. Analysis

2.4.1. Classification of the severity of tail biting in a group

Each group of pigs was classified as having *No Outbreak* (no confirmed signs of tail biting), an *Underlying Outbreak* (signs of tail biting only detected during formal tail examinations) or a *Severe Outbreak* (‘clinical’ tail biting problem with blood seen in the pen and severe damage on at least two pigs). These three levels of severity were used because it was important to distinguish between those outbreaks that would be readily detected and classified as a clinical problem and those that were likely to be undetected on commercial farms. Of the 24 groups in the study, 4 had to be excluded due to circumstances beyond our control. Of the remaining 20 groups of pigs 14 had tail biting outbreaks. There was no significant difference in the distribution of the outbreaks between straw treatment groups (NS=3, SF=2, SW=4, ST=5). Overall 6 were classified as *Severe Outbreaks*. Intervention was applied as soon as a severe outbreak was detected; both tail-biters and severely bitten pigs were removed from the trial pen and enrichment objects were added.

2.4.2. Video recordings of activity levels during 96h prior to outbreaks

Using video recordings, it was possible to compare the activity levels of each tail biting group in the 96 hours before an outbreak with those of a control (non-biting) group. Each control group was recorded at the same time as a paired 'outbreak group', the pigs were from the same replicate and therefore were the same age, ideally with access to the same type of bedding at that time point and with no tail biting at all throughout the study. Only the six *Severe Outbreak* groups were analysed because these had a clear outbreak time, defined as the point where either farm or project staff observed blood in the pen from damaged tails.

Due to the quality of video recordings it was not possible to identify individuals; therefore one instantaneous scan sample of the behaviour of each member of the group was taken for each of the 96 hours preceding an outbreak. Each pig was recorded as performing one of the mutually exclusive behaviours *Lying Inactive, Lying Active* (performing any behaviour), *Sitting, Standing* and *Locomotion*. These provided a general indication of the activity level of the group. In addition each pig could be recorded as performing *Tail Manipulation* (any contact with a pen mates' tail).

Mean activity levels were compared between tail biting groups and control groups by summing the data for each 24 hour period before the outbreak. This gave four data points for each group: 0-23 hours (TB – 0 days), 24-47 hours (TB –1 day), 48-71 hours (TB –2 days) and 72-95 hours (TB –3 days). The number of times each behaviour occurred within each time period was calculated and then converted to a proportion by dividing it by the total number of pigs that were in view over the whole time period. Having confirmed that the data met the required parametric assumptions of homogeneity of variance and was normally distributed, the proportions of pigs performing each behaviour were analysed using a matched-pairs design repeated measures GLM in SPSS with both group (outbreak vs matched control) and time (days before outbreak) as within-subject factors. Since the comparison was between just two groups the direction of any difference could be ascertained from examining graphs and means for the outbreak and control groups. Where a GLM could not be used, grand means were calculated over the whole 4 day period and the outbreak groups were compared with the control groups using a Wilcoxon test.

2.4.3. Direct behavioural observations at 7, 11, 15 and 19 weeks of age

Comparisons were made to examine whether there were significant differences in pre-outbreak behaviour between groups of pigs which had *Severe*, *Underlying* or *No Outbreaks*. This was done by comparing the amount of tail-orientated behaviour and activity in the first two post-weaning behavioural observations (at 7 and 11 weeks of age) because no outbreaks occurred before these observations.

For the behaviour sampling data the frequency and duration of each of the tail-orientated behaviours during each observation day was calculated for each group of pigs. These were summed and converted to rates of seconds per pig per hour. From the scan observations the postures and tail positions were analysed. The total occurrence of each of these was summed for each group on each observation day and then converted to a proportion of the total number of scans made that day. For all of these behavioural measures, differences over time and between *Severe*, *Underlying* and *No Outbreak* groups were examined. Parametric tests (repeated measure GLMs) were used if the assumptions of normality and homogeneity of variance were satisfied. Significant differences were examined further using the post-hoc testing function in SPSS, which compares the Estimated Marginal Means. To examine interaction effects, those pairs of variables which we were interested in were compared using t-tests. Where assumptions were not met, Kruskal-Wallis tests were used to compare the three groupings at each age and where a significant result was found Mann-Whitney U-tests were used to see where the significant differences lay.

In order to examine changes in behaviour closer to the outbreak each *Severe Outbreak* group was then considered individually, examining behaviours in relation to the point at which the outbreak was detected as explained below. The overall proportion of time spent in each of the tail-orientated behaviours was calculated for each observation period for each group from the behaviour sampling. Finally the proportion of *Tails Tucked Under* was calculated for each observation period from the scan observations. A case-control style comparison was then used with each of the six *Severe Outbreak* groups being matched to one of the six *No Outbreak* groups, matching was first according to replicate and then straw provision. Two observation periods were selected for each pairing, these were the observation before the outbreak (TB-1) and the observation before that (TB-2). For each measure, differences over time and between *Severe* and *No Outbreak* groups were examined. Parametric tests (repeated measure GLMs with both group (outbreak vs matched control) and time relative to outbreak as within-subject factors) were used if the assumptions of normality and homogeneity of variance were satisfied. Where these assumptions were not met, non-parametric Wilcoxon tests were used on a summary measure for the outbreak group vs control.

Finally in order to examine whether any of the behavioural data were consistently associated with the occurrence of tail biting, graphs of changes in tail-orientated behaviour over time for each of the *Severe Outbreak* groups were plotted. These were done for the tail-orientated behaviour data collected in behaviour and scan sampling observations and for the time spent with tails tucked under from the scan observations only. The point at which tail damage was detected was then added to each graph. A summary table was constructed indicating whether the duration of each measure increased in the observation period before the outbreak was detected and also whether the levels of the behaviour were above average level or more than two standard deviations above the mean.

2.4.4. The effects of straw provision treatments

Pigs in the study were exposed to 4 straw provision treatments. Where possible, treatment group or a more relevant variable (e.g. (difference in) time (weeks) that groups had experienced straw prior to outbreaks) was tested as a fixed effect or covariate in the GLM analyses to examine whether these factors influenced behaviours. In all cases, they did not have a significant effect (for all analyses $p>0.156$). Analyses were then repeated without these factors / covariates and are reported below.

3. Results

3.1. Activity during the 96h prior to a tail-biting outbreak

During the 96h prior to a *Severe Outbreak*, the six groups that went on to experience an outbreak had significantly more pigs *Standing* ($F_{(1,5)}=7.744$, $p<0.05$) and significantly fewer pigs *Sitting* ($F_{(1,5)}=12.322$, $p<0.05$) or *Lying Inactive* ($F_{(1,5)}=7.549$, $p<0.05$) than the six matched control groups (Figures 1a-c). However, there was no evidence for a difference in *Tail Manipulation* ($Z=-0.631$, $p>0.05$; a large number of zero values were recorded preventing transformation to normality (Field, 2000)), or in the proportion of pigs engaged in *Lying Active or Locomotion*.

3.2. Direct behavioural observations at 7 and 11 weeks of age

Examination of the time spent *Lying*, *Sitting*, *Standing*, *Inactive* and in *Locomotion* showed there were no significant differences between the activity levels of *No, Underlying* and *Severe Outbreak* groups at 7 and 11 weeks of age. The other scan behaviours investigated were tail postures, and only the proportion of *Tails Tucked Under* at 11 weeks of age differed significantly between groups (χ^2=11.080, df=2, p<0.01). Significantly fewer *Tails Tucked Under* were observed in *No Outbreak* groups than in either *Underlying Outbreak* (U=1.000, p<0.01) or *Severe Outbreak* groups (U=4.000, p<0.05) (Figure 2a).

There were some significant differences in the levels of tail-orientated behaviours between groups with different severities of tail biting. The levels of *Tail Interest* were significantly different overall ($F_{(2,17)}$=3.586, p<0.05) and there was an interaction between age and group ($F_{(2,17)}$=4.933, p<0.05). It was clear from post hoc tests and Figure 2b that levels of *Tail Interest* were significantly higher in *No Outbreak* groups than in *Severe Outbreak* groups (p<0.05). The interaction effect is likely to be explained by the *Underlying Outbreak* group which was significantly lower than the *No Outbreak* group at 7 weeks (p<0.05) but significantly higher than the *Severe Outbreak* group at 11 weeks (p=0.01). There were also significant differences in the levels of *Tail Biting* at 11 weeks of age (χ^2=8.454, df=2, p<0.05). Significantly more *Tail Biting* was seen in *Severe Outbreak* groups than *Underlying Outbreak* (U=9.500, p<0.05) or *No Outbreak* groups (U=6.000, p<0.05) (Figure 2c).

3.2. Pre-outbreak direct behavioural observations

The results for the matched case-control analysis in the two observations prior to an outbreak are shown in Table 2. The only significant differences between groups were in the levels of *Tail Biting* (Z=-2.023, p<0.05) and *Tails Tucked Under* (Z=-2.810, p<0.01). Examination of the means indicated that the levels of *Tail Biting* and *Tails Tucked Under* were significantly higher in the *Severe Outbreak* groups compared with the *No Outbreak* controls.

The next step was to examine each outbreak individually, to investigate whether each measure increased and whether it was above average level or more than two standard deviations above the mean in the last observation point before each outbreak was first detected (Table 3). For one outbreak (2B-NS) all measures were raised to at least above average levels in the observation period before the outbreak, but for another outbreak only one measure was raised above average levels. No one behavioural measure showed a rise above average for *all* of the outbreaks.

During the study it was noted that in five separate cases a solitary pig was tail-bitten some time before a major outbreak occurred. When it was detected, the bitten pig was either removed or treated in the pen, and a full tail examination was carried out on all the pigs in the pen. In each instance no other damage was seen, therefore it could not be classed as an outbreak and the group continued to be monitored. In all these groups, an outbreak went on to occur and in four of the five cases this was a *Severe Outbreak*. There was variation in the timing of the outbreak in relation to when the solitary tail-bitten pig was detected, ranging from 0.5 to 12 weeks later, and also in the level of damage to the indicator pig from a single bite mark to severe chewing of the tail (Table 4). This type of event did not occur in any group where no tail biting occurred.

4. Discussion

If farmers were able to anticipate a tail biting outbreak, they might be able to intervene to try to prevent it. This prospective longitudinal study investigated several possible techniques for predicting outbreaks, the first of which was monitoring activity levels in groups of pigs.

Previous research had suggested that activity levels were raised after an outbreak (Keeling et al., 2004), however it was not clear whether the increased activity was a direct result of the tail biting or whether levels had been raised beforehand. This study offers evidence that the latter might be true, because the time spent *Standing* was higher and levels of *Sitting* and *Lying Inactive* were lower in the 4 days before an outbreak compared with control groups that did not experience an outbreak. Although we showed that activity levels are raised prior to an outbreak being detected, this change is likely to be relatively short-term since no difference was detected at 7 or 11 weeks of age. The change may be attributed to a decrease in the amount of resting within the outbreak groups, since no change was seen in the amount of locomotion. Monitoring general group activity levels (e.g. the levels of *Lying Inactive* or *Standing*) might have some potential to predict an outbreak of tail biting. With advances in technology (e.g. image analysis), such changes could be measured automatically, raising the possibility that a warning system could be developed for use *in situ* on farms.

It was not possible to examine whether tail biting individuals were more active than their pen-mates before tail biting, as had been suggested by Svendsen et al (2006), because video recordings were not of sufficient quality to allow reliable identification of individuals. It would be informative to find out whether the difference in activity levels between groups was driven by particular individuals or a general change in activity level in the whole group.

It was hypothesised that, even early in life, more tail-orientated behaviours would be seen in groups which went on to develop tail biting outbreaks. No significant differences in the levels of *Tail Manipulation* were observed during the four days prior to the outbreak, which may have resulted from the low levels of *Tail Manipulation* detected from video records in this study. From the direct observations, higher levels of *Tail Biting* behaviour were seen at 11 weeks of age in *Severe Outbreak* groups, but the levels of other tail-orientated behaviours were not higher. Indeed for *Tail Interest* the opposite was seen, with higher levels in groups with *No Outbreak* than in those with *Severe Outbreaks*. This means that a high level of manipulating and sniffing tails at a young age was actually associated with groups that did not have a tail biting outbreak later in life. This concurs with work by Ruiterkamp (1985; as cited in Van de Weerd et al., 2006) who reported that the amount of tail-in-mouth behaviour was sometimes higher in groups without outbreaks of tail biting. This contrasts with the theory that non-damaging contact with tails is a pre-cursor to tail biting (van Putten, 1969; Sambraus, 1985; Fraser, 1987; Schrøder-Petersen et al., 2003). Previous studies of tail biting have used this non-damaging behaviour as the outcome indicator of tail biting in the absence of real outbreaks (e.g. Schrøder-Petersen et al., 2003; Beattie et al., 2005) and this might be misleading. Our study suggests that further work is needed to confirm the nature of the relationship between these early non-damaging behaviours and severe tail biting before this assumption can be made. It also emphasises the importance of distinguishing between the different forms of tail contact as their relationship with tail biting appears to differ considerably.

One of the limitations with this analysis was that only the first two behavioural observation periods (at 7 and 11 weeks of age) could be examined. This meant that there was considerable variation in the time gap between the behaviour being studied and the outbreak occurring. Therefore we also considered the two observation periods immediately before the outbreak, using a case-control design. This concurred with the analysis for the early behaviours, where the occurrence of *Tail Biting* was higher in *Severe* relative to *No Outbreak* groups. *Tail Biting* was thus the only tail orientated behaviour that occurred significantly more in groups that went on to experience an outbreak, relative to controls. Higher levels of *Tails Tucked Under* were also seen in groups which went on to have outbreaks in both the early observations (7 and 11 weeks) and in the two observations prior to the outbreaks. This concurs with the work by Bracke (*pers. comm*., 2005) and suggests that high levels of *Tail Tucked Under* may also be indicative of tail biting later in life.

None of the measures recorded in this study increased to above average levels in the observation period before the outbreak for all six of the *Severe Outbreaks*. It is clear from our results that there was a lot of variation between outbreaks, with most measures preceding some outbreaks but not others. This suggests that some outbreaks would be easier to predict than others from observing changes in the amount of tail-orientated behaviours and tail postures, but that no one measure reliably predicts all outbreaks.

Finally, mention should be made of 'indicator pigs'. These pigs were often small runty pigs that were tail-bitten some time before a full outbreak occurred. Whilst this was not a completely accurate indicator in the sense that an indicator pig was not associated with every outbreak of tail biting, it was the case that every time an indicator pig was seen an outbreak followed at some point and thus it could be said to have high-specificity. This is a simple and reasonably reliable indicator that a farmer could use as a sign that intervention might be needed to prevent tail biting occurring at a later point.

Few if any published studies have previously traced the development of tail biting outbreaks in the systematic way done here, even with the effort put into the current study more information of this type is definitely needed to further our understanding of how tail biting outbreaks emerge. This was a labour intensive exercise and, in the current study, only 6 severe outbreaks of tail biting occurred and there are thus limitations to the conclusions that can be drawn. For example, although activity levels tended to be higher in groups with tail biting outbreaks when compared with controls, a much larger number of outbreaks is needed to examine whether a particular threshold or a particular change in activity level could be defined above which the chance of an outbreak occurring exceeds some level of probability (e.g. 80%). Moreover, in this study we only examined video observations for the four days prior to an outbreak and carried out direct observations at four-weekly intervals. It would be interesting to do detailed investigations of behaviour in between these time periods, for example during the fortnight prior to each outbreak to see at what point the differences between tail biting outbreak and control groups develop.

5. Conclusion

We conclude that increased levels of activity, tails tucked under and ‘damaging’ tail contact preceded outbreaks of tail biting on this commercial farm, but ‘non-damaging’ tail contact did not. No one measure was raised prior to all outbreaks, so further work is required to see whether such a predictive measure can be identified. A simple indicator of some outbreaks was the presence of a tail bitten runty pig prior to any other tail damage being seen. This measure was always followed by an outbreak and therefore farmer intervention in groups where an ‘indicator pig’ is seen could reduce levels of tail biting on commercial farms.

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Table 1. Ethogram used for direct behavioural observations.

Behaviour	**Description**
Out of view	The pig cannot be seen
Inactive	Not performing any behaviour
Chewing Other	Chewing (not another pig) with its head raised and away from the feeder
Locomotion	Any movement including walking, running, scampering and rolling, provided that the pig is not investigating the pen or substrate or interacting with another pig at the same time
Rooting	Nosing or rooting in the straw, shavings or muck on the pen floor
Pen Explore	Sniffing, touching, sucking or chewing any object which is part of the pen including the bare floor and the enrichment object
Drinking	Manipulating drinker with or without ingestion of water or drinking water from the floor beneath the drinker
Feeding	Head positioned in the feeder or chewing food having just been displaced from the feeder
Elimination	Defaecating or urinating

Tail Biting	Having the tail of another pig in its mouth and biting or pulling hard enough to cause a reaction from the other pig
Tail Chewing	Having the tail of another pig in its mouth without biting or pulling hard enough to cause a reaction in the other pig
Tail Interest	Sniffing, nosing or manipulating the tail of another pig without taking the tail into its mouth
Tail Interest / Chewing	Alternating between the two behaviours described above rapidly enough that it was not possible to distinguish which was being performed.
Belly-nosing	Repeatedly thrusting snout into the belly of another pig
Agonistic	Head-thrusting, ramming, biting or pushing another pig. This may be mutual or one-way
Other Social	All other social interactions including mounting, head rubbing and nosing parts of the body other than the belly
Other	All other behaviours not listed

Table 2 – Mean time spent in each of the tail orientated behaviours (seconds per pig per hr) and the proportion of Tails Tucked Under for outbreak groups and their controls in the observation prior to an outbreak (TB-1) and the observation prior to that (TB-2). F-values indicate that a Repeated measure GLM was used and Z-values are given for Wilcoxon tests.

		Level of Outbreak		
Behaviour	Time prior to outbreak	Control n=6	Outbreak n=6	Statistical Differences
Tail Interest	TB-2	0.690 (± 0.204)	0.273 (± 0.102)	Time to outbreak ($F=9.027$, $df=1,5$, $p<0.05$)
	TB-1	0.935 (± 0.407)	0.727 (± 0.207)	
Tail Interest / Chewing	TB-2	0.440 (± 0.279)	0.180 (± 0.061)	
	TB-1	0.573 (± 0.505)	0.198 (± 0.105)	
Tail Chewing	TB-2	0.035 (± 0.035)	0.000 (± 0.000)	

	TB-1	0.015 (± 0.015)	0.425 (± 0.243)	
Tail Biting	TB-2	0.000 (± 0.000)	0.193 (± 0.135)	Outbreak level (Z=-2.023, p<0.05)
	TB-1	0.000 (± 0.000)	0.200 (± 0.127)	
Total Tail Contact	TB-2	1.167 (± 0.364)	0.643 (± 0.197)	
	TB-1	1.525 (± 0.584)	1.548 (± 0.545)	
Tails Tucked Under	TB-2	0.007 (± 0.005)	0.025 (± 0.010)	Outbreak level (Z=-2.810, p<0.01)
	TB-1	0.000 (± 0.000)	0.29 (± 0.015)	

Table 3 - Summary of whether behavioural variables could have been used to predict the occurrence of each of the outbreaks. ↑ indicated that the measure increased in the observation before the outbreak relative to the previous observation. >> indicated that for the same observation period the level was more than 2 standard deviations above the mean, whilst > indicates the level was above the average for pigs of that age.

Outbreak	Age of pigs (weeks)	Tail Interest	Tail Chewing / Interest	Tail Chewing	Tail Biting	Total tail contact	Tail Under
2A-SW	11				↑ >>	↑	↑
2B-NS	19	↑ >	↑ >	↑ >>	↑ >	↑ >	↑ >>
2B-ST	19	↑ >		↑ >		↑ >	>
4B-ST	19	↑ >		↑		↑ >	
6A-NS	11	↑	↑	↑ >	↑ >	↑	
6B-ST	15	↑ >					

Table 4 - Summary of the time interval between detection of an 'indicator pig' and the subsequent outbreak, and of the damage seen on indicator pigs

Group	Type of Outbreak	Weeks prior to outbreak	Damage on indicator pig
1A-ST	Underlying	9	Single bite mark
2A-SW	Severe	0.5	Tail severely chewed
2B-NS	Severe	2	Bite mark, red patch and tail tucked under
2B-ST	Severe	2	Tail severely chewed
4B-ST	Severe	12	Bite mark, red patch and tail tucked under

Figures 1a to c - Plots of the mean proportion of scans pigs spent in each of the behaviours against the time to tail-biting outbreak for the 96 hours preceding the outbreaks. These are summary measures for all the six groups combined, with —Δ— representing the outbreak groups and —□— representing the control groups.

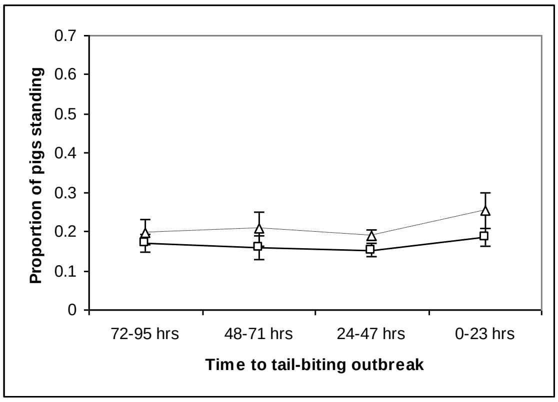

Figure 1a. Proportion of pigs standing

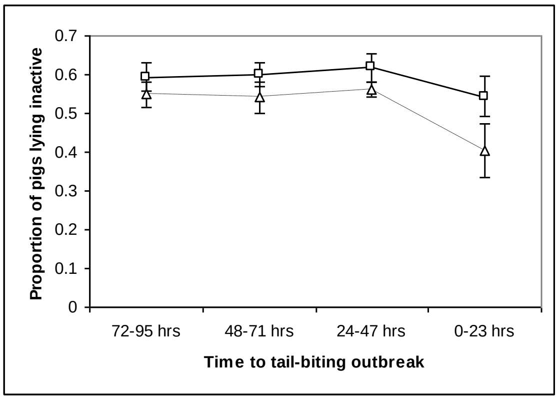

Figure 1b. Proportion of pigs lying inactive

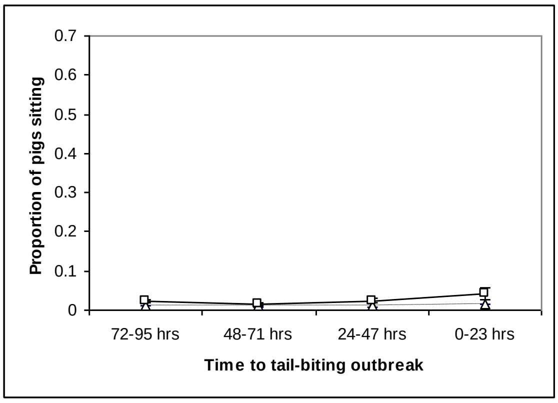

Figure 1c. Proportion of pigs sitting

Figures 2a to c - Plots of the time spent in different behaviours against the age of pigs. These are summary measures with —▲— representing groups with severe outbreaks, – -○- – for groups with underlying outbreaks and ···■·· for those with no outbreak.

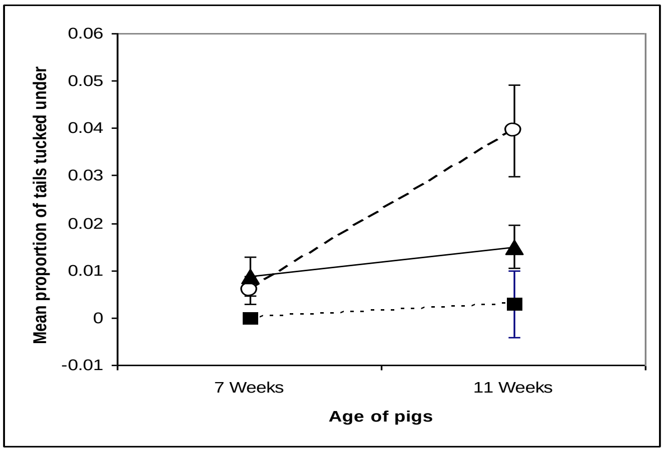

Figure 2a. Changes in levels of tails tucked under

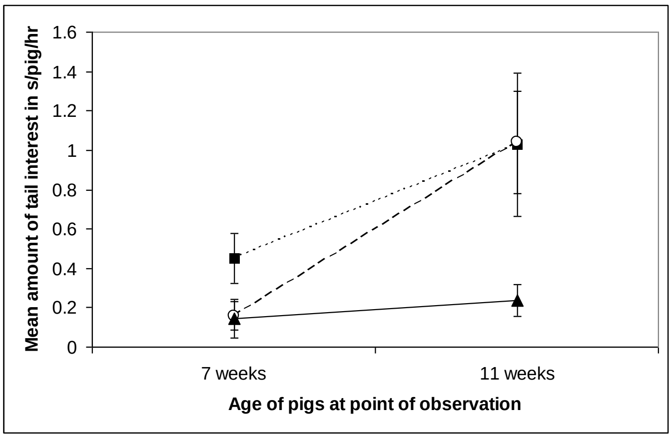

Figure 2b. Changes in levels of tail interest

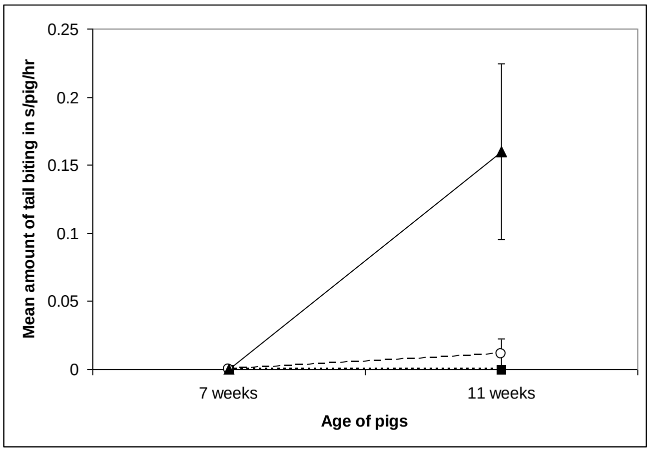

Figure 2c. Changes in levels of tail biting