THE USE OF NOSE-RINGS IN PIGS: CONSEQUENCES FOR ROOTING, OTHER FUNCTIONAL ACTIVITIES, AND WELFARE

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Abstract *Animal Welfare 2001,* ***10:*** 3-22

Commercial pigs kept outdoors are often given nose-rings, to inhibit rooting and minimize pasture damage. If rooting is a 'behavioural need' in the pig, and ringing is effective because it renders rooting painful, nose-ringing may be a threat to welfare. Thirty gestating sows were assigned to one of three conditions: unringed controls (UR); sows ringed with three, wire 'clip' rings through the snout rim (CR); or sows with one, rigid 'bull' ring (BR). They were observed on grass for 7h day^{-1} at intervals over 6 months. Ringing almost totally abolished penetration of the ground by rooting during the month after ringing (UR, CR and BR sows respectively spent 5.6%, 0.1% and 0.1 % of scan observations dig-rooting during this month; $P < 0.001$). These differences in recorded rooting were reflected in a much greater extent of pasture damage in paddocks containing UR sows. Rooting remained largely suppressed throughout the 6 months of observations in BR sows; but substantial recovery of this function occurred in CR sows by the sixth month, although much of this may be attributed to the fact that most sows lost at least some of their rings. Ringing also partially inhibited grazing (which accounted for 26.2%, 27.1% and 21.9 % of scans over the whole project in UR, CR and BR sows respectively; $P < 0.05$), nosing in straw, digging out wallows and stone-chewing (18.3%, 9.5% and 9.2 % respectively of all scans in UR, CR and BR sows; $P < 0.001$). Ringed sows spent more time standing but otherwise inactive than did controls (0.8%, 1.7% and 4.0 % of all scans in UR, CR and BR sows respectively; $P < 0.001$), and displayed more straw-chewing, vacuum-chewing and digging at soil with the forepaw. We conclude that nose-ringing in pigs inhibited a range of functional activities, as well as rooting, and elicited more behaviours that suggest a degree of reduced welfare. BR sows displayed more of these effects than did CR ones, although these differences may be largely, but not entirely, due to a loss of clip rings over time.

Keywords: *animal welfare, behavioural needs, nose-rings, pasture damage, rooting*

Introduction

In natural conditions, pigs spend 20 per cent to 30 per cent of their waking hours engaged in rooting in one form or another (Stolba & Wood-Gush 1989). Rooting is the means by which they search for, locate and harvest food. It is a complex activity involving two sensory systems and an effector action. They sniff close to the surface of the ground, palpate surfaces or potential food items with the nasal plate (the flat end of the snout), and dig into the ground with the front edge of the snout, often with considerable force.

Although its primary purpose is to locate and extract food from underground, pigs in intensive conditions continue to root, even when fed *ad libitum* and housed on wire-mesh or concrete floors, where they have no need of food and no prospect of digging successfully (Algers 1984; Horrell 1992). Moreover, they take advantage of the provision of earth-filled rooting trays to increase the time spent rooting (Wood-Gush & Beilharz 1983) and early weaners given the opportunity to root in peat-filled rooting trays reduced their tendency to engage in vices such as 'belly-nosing' and ear- and tail-biting (Horrell & A'Ness 1995). These facts are consistent with the conclusion that rooting is a 'behavioural need' (Hughes & Duncan 1988).

A consequence of the strong urge to root is that pigs kept outdoors root a great deal and dig up considerable quantities of soil. When they are maintained on pasture of any quality, the economic cost of pasture destruction may be substantial. As a result, pigs kept outdoors on grass are often fitted with nose-rings with the specific purpose of preventing rooting. Rings fall into two broad types: i) rigid stainless-steel rings, which are fixed, one per snout, through the nasal septum, in very much the same manner as a 'bull' ring; and ii) smaller rings of flexible steel or copper wire, which are clipped in multiples of 3–9 through the upper rim or edge of the snout.

In so far as ringing reduces or prevents rooting, it does so by making it painful to press the snout against the ground. In addition, if rooting itself really is a behavioural need, which pigs have a strong urge to perform independently of its function in finding and harvesting food, ringing prevents pigs from satisfying one of their basic motivations. Nose-ringing, therefore, threatens the welfare of the pig from two different perspectives.

If an animal is prevented from carrying out a behavioural need, we expect it to display its frustration by performing a variety of abnormal behaviours (Mench & Mason 1997), such as the stereotypies seen in gestating sows on concrete floors and constrained by tethers (Rushen 1985; Mason 1991; Terlouw *et al* 1991). We have circumstantial evidence that preventing early weaned pigs from rooting increases the incidence of 'belly-nosing' (Horrell & A'Ness 1995). Furthermore, the rooting action is used for a number of other functions, such as digging wallows, nestbuilding and general exploration. This project was designed to determine the impact of nose-ringing in gestating sows, ringed by each of the two methods, on rooting, other related functional actions, and behavioural indicators of welfare.

Methods

All procedures were approved by the Animal Experiments Committee of the Scottish Agricultural College.

Animals and conditions

Observations were made on gestating Landrace/Large-White/Duroc derived sows (PIC™ Cambrough, strain 12), which had been maintained in the same herd on grass throughout their breeding lives. Thirty sows, ranging in parity from two to seven, were assigned to six groups of five in relation to their predicted farrowing date; most could, therefore, be assumed to have been familiar with one another from previous breeding cycles. Two groups were assigned to each of three treatments, with their farrowing dates arranged in a counterbalanced fashion in such a way as to ensure that the median stage of pregnancy was approximately equal for each treatment.

Ringing was carried out by a veterinary surgeon while the sows were penned in an individual feeding crate indoors. The three treatments were as follows:

i) Control group (UR): put through the penning procedures but no nose-ring fitted.
ii) Clip ring (CR): fitted with three, copper wire clip rings, one centrally placed and the other two approximately 2cm to either side, through the upper rim of the snout.
iii) Bull ring (BR): a single, rigid stainless-steel ring fixed through the nasal septum.

Immediately after ringing, each group of sows was transported in a pig trailer and released into the observation paddocks.

The sows were then observed over five observation periods, each of 2 days, distributed over the next 6 months. They were maintained over the first three observation periods in two rows of three adjacent grass paddocks (each measuring 28x60 m), giving an overall stocking density of 30 sows ha^{-1}. The paddocks had recently had hay cut from them and were, therefore, of regular grass length. After their next farrowing and mating (well before the fourth and fifth observation periods), the sows were put back into a different set of paddocks of similar size. Each paddock had a 3.6x2.1 m ark, large enough to accommodate five lying sows. Sows were fed their normal daily diet of 3kg roll nuts (ie animal feed compacted into solid cylinders, approximately 1cm in diameter and broken into lengths ranging from approximately 1–4 cm), specifically formulated for gestating sows (Hipeak™ dry sow nuts: providing 13MJ DE kg^{-1}, 16% protein and 5% fibre as fed air-dried). The animals were fed at 0730h each day, with the nuts spread in a line of approximately 15m on the ground at one end of each paddock.

Observations

Each group of five sows was recorded by a hand-held, VHS video recorder (Panasonic ™ M.40; Matsushita Electric Industrial Co Ltd, Osaka, Japan) at first introduction into the paddock, immediately after ringing. The whole group was recorded as it left the trailer, then each sow in turn was recorded as a focal animal for 1min, with the sequence repeated to give 10 x 1min focal samples. The videotapes were subsequently viewed and the time (to the nearest second) spent in each bout of activity transcribed, from which mean time per min was derived for each of a range of activities.

Thereafter, systematic observations were made for 3.5h in the mornings and another 3.5h in the afternoons of the first and second complete days after ringing (in June), on two successive days during each of the third and fourth weeks (early July), and in the 22nd and 23rd weeks (November) after ringing. Observations started 30min after feeding and were made by two observers operating in tandem, each observing three paddocks (one under each condition), using a mixed focal-animal and time-sampled scanning strategy. All six pens were scanned every 15min, to record the location and activity of each sow; in the period between scans, a designated sow in one of the pens was recorded continuously for 10min.

At scans, observers recorded how many sows in each paddock were in the ark, adjacent to it, at the feed area, the drinking trough, the wallow, or anywhere else in the paddock except at those locations. In each case, they recorded whether they were standing, lying, or engaged in any of a range of specified activities, with the substrate involved (concentrate, grass, straw, soil, stones) noted in the case of chewing or rooting. Other activities, such as vacuum-chewing or scraping at the ground with foreleg, were noted when evident. The complex of actions involved in rooting was classified into three component forms: dig-rooting, palpate-rooting, and sniff-investigating. During focal sampling, the same behaviours were coded, plus transient events such as social interactions, nosing or carrying objects, and body rubbing (scraping), with time of initiation and duration of each bout recorded. A full list of behaviours and activities, and their definitions is given in Table 1.

Table 1 Definitions of behaviours identified and recorded at the time-scans.

Activity	Definition	Possible qualifiers
Standing inactive	On four feet, not walking and not engaged in any other activity	
Lying but active	Lying but engaged at the same time in one of the other activities listed below	The second activity
Lying inactive	Not engaged in any other activity	
Walking	Moving across the ground but not engaged in other activities listed	
Feeding	Picking up, chewing or ingesting roll nuts	
Drinking	Clearly imbibing	
Dig-rooting	Snout applied to the surface of the ground in a reciprocating action with apparent force and clearly penetrating it, excavating some soil from below the surface	
Palpate-rooting	Snout being passed across the surface of the ground, making clear contact but not penetrating the surface	
Sniff-investigating[1]	Snout passing over the ground within 5cm of the surface in a similar 'searching' reciprocating action without making physical contact	
Wallowing	Lying in, or rolling around in, mud or water	
Grazing	Biting, chewing and swallowing grass	
Chewing	Chewing with the teeth without swallowing	The substrate, most commonly stones, straw or other vegetation
Vacuum-chewing	Chewing with no extraneous object or material in the mouth; this may involve chewing of the tongue	
Scratching	Rubbing the body against an object	The object, most commonly the ark
Scraping	Dragging a foreleg backwards over the surface of the ground	
Carrying	Moving around with objects or materials in the mouth	The object or material

[1] The alternative term 'sniff-rooting' emphasizes the character of the action and avoids the interpretative 'investigation'.

This schedule enabled each observer to record 12 focal samples (four sows from each ring condition) and 14 scans of all three pens during each 3.5-h observation session, with a brief break in the middle. Successive focal samples were taken in pens with different ring conditions, with the conditions in counterbalanced order and the two observers working through conditions in the opposite order. The individual focal sows from each pen were selected to follow a regularly repeated order, ensuring an equal number of observations on each sow.

In addition, on the first 2 days after ringing only, all paddocks were observed for 30min at the daily feeding time (before the main observations started). The herdsman spread the roll nuts in a 10m line along the ground, in successive paddocks, 1min apart. The observers spent 1min on each pen in turn in a repeating cycle. This enabled the number of sows in each paddock engaged in feeding and other activities to be counted at 4-min intervals, and each to be continuously scanned for 1min in every 4 in order to count the number of agonistic events.

Soil damage assessment

Independently of work on the same pigs reported elsewhere (Edwards *et al* 1996), an estimate was made of pasture damage 17 and 23 days after ringing, with one paddock of each ring type measured on the first occasion and the other three paddocks on the second. Five markers were placed equidistantly along the ends of each paddock. A tape measure was then laid out in a straight 60m line between each pair of opposing markers. Each section of damaged pasture was then measured (to the nearest cm), and assigned to one of two classes: i) bare soil with no grass; and ii) soil surface unequivocally dug up, to a depth of at least 2cm. This gave the total distance (along each line over the length of the paddock) of damaged pasture in each class. In addition, the depth of the hollow at the deepest point was measured in each of five standard dug over areas: the feeding area, the doorway of the ark, the wallow, in front of the drinking trough, and the deepest digging in the open paddock. Although a basic wallow was dug out by a tractor with fore-end bucket to ensure the existence of a good wallow (thus giving an exaggerated measure for the ringed conditions and, hence, reducing the apparent differences between conditions), the depth of the wallow was included as the sows still rooted it out to a much greater depth.

Statistical analyses

Observations

For analysis of the data at initial entry into the paddock immediately after ringing, the mean time spent in each activity over each of the (separate) 2min recorded for each sow was used as raw data. Where valid, a one-way analysis of variance (ANOVA) for independent samples was used to compare conditions. In cases where (because of a skewed distribution, with a number of zeros) this was not appropriate, a Kruskal-Wallis ANOVA was used to examine the three conditions together; and the Binomial test or a Mann-Whitney *U* test for comparisons between two conditions.

For the main observations on all days subsequent to the day of ringing, the total number of events in each category over the 14 scans at each 3.5h observation session formed the raw data used for both descriptive and inferential statistical purposes for the time-scan data; thus, the maximum possible number of scan observations was 140 (14 scans x 2 groups of 5 sows). For the focal animal observations, the total time spent in each activity by all four focal animals observed in each ring condition during the session was analysed. Over the entire course of the observations, a number of sows lost some or all of their rings (see, *Results*). Where this occurred, data from the BR sows which lost their rings and from any CR sows that lost more than one ring were excluded and the data for the session corrected by appropriate proportional multiplication. For descriptive purposes, the mean of the four such units derived from each block of 2 days' observations are given in the Tables, except where otherwise indicated. Since these data can only safely be regarded as ordinal and a significant proportion of the entries in any cell of a data set were zero, non-parametric methods were used for inferential statistics. For an overall evaluation of whether there were reliable differences between ring conditions, the Friedman two-way ANOVA was employed; for comparisons between two specific conditions, Wilcoxon matched pairs tests were used. In both cases, matching of data was on the basis of the observation session, with the data from different conditions recorded at the same session being regarded as equivalent. (On the few occasions where other tests were used, these are specified in the text.)

Soil damage

The data for each class of soil damage were separately analysed using either an ANOVA or Student's *t*-test and a matched samples assumption (based on which of the two groups of three paddocks and which strip in sequence across the paddock the data referred to).

Results

Initial entry after ringing

Data on the behaviour of the sows during the 10min of observation on initial entry into the paddock immediately after ringing are given in Table 2. During this period, dig-rooting was never recorded in ringed animals, while this activity occupied over 15 per cent of the time in UR sows. Instead of rooting, both CR and BR sows spent significantly more time with snouts held a few centimetres above the ground, apparently sniff-investigating it, but avoiding any contact ($F_{2,18} = 5.06$, $P = 0.014$). Grazing was also inhibited to a significant extent in ringed sows ($F_{2,18} = 5.43$, $P = 0.01$), while they spent more time walking (not significant) or, perhaps most tellingly, simply standing still, but engaged in no overt activity at all ($H = 9.54$, $df = 2$, $P < 0.01$): BR sows spent almost 18 per cent of the time standing doing nothing. All of these effects were greater in BR than CR sows. These quantitative data give objective substance to the vivid subjective impression gained by observers when the sows were first introduced into the paddocks. The UR sows came running out, walked or ran round the paddock, started rooting and exploring immediately, and generally appeared full of the joys of release. One group immediately set out to dig a wallow in a soft patch and many were wallowing in mud by the end of the 10-min observation period. Ringed sows, on the other hand, were quiet and seemed listless, many stood around staring into space, or poked their snouts gingerly at the ground, usually without making contact, and gave the appearance of being in a state of shocked inertia. These differences appeared to persist throughout the day of ringing.

Table 2 Mean time (s min^{-1}) sows spent in various specified activities during the first 10min on return to pasture following ringing. See text for details of statistical analyses. ($P < 0.01$; ***$P < 0.001$; ns – not significant.)**

	Control (UR)	Clip ring (CR)	Bull ring (BR)	Significance
Dig-rooting	9.1	0	0	***[1]
Sniff-investigating (with snout)	12.7	20.4	27.9	**
Grazing	11.2	6.9	1.6	**
Chewing grass	13.0	14.4[a]	6.2[b]	$P = 0.06$, for [a/b] comparison
Walking (not engaged in other activities)	7.6	10.8	11.7	ns
Standing inactive	0.4	4.7	10.6	**

[1] Sign test.

Rooting

Dig-rooting, was almost eliminated in ringed sows, over the first month after ringing, and still strongly suppressed 5 months later. Tables 3 and 4 show the data on the amount of rooting and exploration of the ground, in each of the three categories of such activity. Whether using the results of the 15-min interval scans of the whole population (Table 3) or the focal animal data (Table 4), it is evident that dig-rooting was almost totally abolished over the first month after ringing by either the clip ring or bull ring methods: the overall influence of ringing condition was highly significant ($F_r = 15.13$, $df = 2$, $P < 0.0005$), but there was no significant difference between CR and BR sows. By weeks 22-23 (ie 5 months later, in November, when the ground was much softer), dig-rooting had recovered to a considerable extent in CR sows, even when restricting the data used to those with at least two rings still in place. However, there were still significantly fewer CR than UR sows dig-rooting: the frequency of CRs found dig-rooting was only 64 per cent that of URs over the two weeks in November ($z = 2.10$, $P < 0.05$), and BR sows showed very little recovery, now being significantly less likely to dig-root than CRs and rooting with only 9 per cent of the frequency of URs ($z = 2.2$, $P < 0.05$).

Table 3 Mean number of pigs observed dig-rooting, palpate-rooting or sniff-investigating per 3.5h scan sampling session for each week of observations (maximum = 140). Summary means and the results of their statistical comparisons are shown (in bold) for observations over the first month (weeks 1-4), over two weeks at 5 months after the ringing (weeks 22-23) and over the whole observation period. See text for details of statistical analyses (*P < 0.05; **P < 0.01; ***P < 0.001; ns – not significant).

Weeks	1	3	4	1-4 (Mean)	22	23	22-23 (Mean)	Overall (Mean)
Dig-rooting								
Control (UR)	12.5	3.8	7.3	**7.9[a]**	8.0	5.8	**6.9[a]**	**7.5[a]**
Clip ring (CR)	0	0.3	0	**0.1[b]**	5.0	3.8	**4.4[b]**	**1.8[b]**
Bull ring (BR)	0.5	0	0	**0.2[b]**	0.9	0.3	**0.6[c]**	**0.3[c]**
	F			*******			*******	*******
Palpate-rooting								
Control (UR)	0.8	5.3	7.0	**4.4[a]**	6.5	10.0	**8.3**	**5.9**
Clip ring (CR)	2.8	2.8	1.8	**2.5[a]**	6.3	10.6	**8.5**	**4.9**
Bull ring (BR)	0.8	1.5	1.3	**1.2[b]**	8.6	11.3	**10.0**	**4.7**
	F			*****			**ns**	**ns**
Sniff-investigating								
Control (UR)	0.8	3.0	1.8	**1.9**	1.0	1.3	**1.2[a]**	**1.6[a]**
Clip ring (CR)	0.5	0.3	2.5	**1.1**	3.1	2.5	**2.8[a]**	**1.8[a]**
Bull ring (BR)	1.5	1.8	2.8	**2.0**	5.0	4.1	**4.6[b]**	**3.0[b]**
	F			**ns**			**ns**	***P* < 0.1**

Means within a column lacking a common superscript letter were significantly different in individual comparisons using Wilcoxon matched pairs tests ($P < 0.05$).

Palpate-rooting was also inhibited to a modest extent during the first month after ringing, although the effect was only significant in the time-scan data, where CR sows palpate-rooted at 56 per cent of the frequency of URs, but the BRs with only 28 per cent of their frequency ($F_r = 6.29$, $df = 2$, $P < 0.05$; Table 3). There was no significant difference between conditions by 5 months after ringing. There was a very high variance in the focal data, with some sows rooting for much of their focal period and others lying or grazing throughout, making statistical significance unlikely to be achieved in focal data in general. The distinct tendency for BR sows to be more inhibited than CRs was not significant for either type of data.

On the other hand, sniff-investigating (sniff-rooting) actually increased in BR sows in the later stages of observations, compared to both URs and CRs (Tables 3 and 4). Over the first month, the overall effect of ring condition was slight and not significant ($F_r = 3.88$, $df = 2$, ns). However, during weeks 22 and 23 (in the fifth month after ringing), the BR sows were almost four times as likely to be found sniff-investigating as the URs ($z = 2.20$, $P < 0.05$), and 1.6 times as likely as CRs (Table 3). The trend shown by BR sows, to increase the amount of exploratory sniffing with time since ringing, so that it became much more frequent than dig-rooting (unlike in CRs), is represented in Figure 1. Thus, there seemed to be a developing reciprocal relationship between rooting and non-contact exploration with the snout: excavation was heavily suppressed in ringed sows, especially BRs, but they tended to search over the surface of the ground more, especially after they had recovered fully from the ringing.

Table 4 Mean time (s h^{-1}) focal pigs engaged in various categories of rooting and exploration with the snout. Summary means and the results of their statistical comparisons are shown (in bold) for observations over the first month (weeks 1-4), over two weeks at 5 months after the ringing (weeks 22-23) and over the whole observation period. See text for details of statistical analyses (*P < 0.05; **P < 0.01; ***P < 0.001; ns – not significant).

Weeks	1	3	4	1-4 (Mean)	22	23	22-23 (Mean)	Overall (Mean)
Dig-rooting								
Control (UR)	238.3	11.3	14.8	**88.1[a]**	63.4	19.7	**41.6**	**69.5[a]**
Clip ring (CR)	0	0	5.4	**1.8[b]**	15.4	31.0	**23.2**	**10.4[b]**
Bull ring (BR)	0	0	0	**0[b]**	9.8	0	**4.9**	**2.0[b]**
	F			**			**ns**	**
Palpate-rooting								
Control (UR)	46.1	129.9	87.8	**87.9**	213.2	203.4	**208.3**	**136.1**
Clip ring (CR)	16.9	8.6	96.4	**40.6**	210.9	96.5	**153.7**	**85.7**
Bull ring (BR)	0	51.9	3.4	**18.4**	40.7	215.4	**128.1**	**62.3**
	F			**ns**			**ns**	**ns**
Sniff-investigating								
Control (UR)	17.8	111.9	0	**43.2**	33.8	59.3	**46.6[b]**	**44.6[b]**
Clip ring (CR)	10.9	25.3	49.9	**28.7**	7.9	2.5	**5.2[a]**	**19.3[a]**
Bull ring (BR)	1.5	41.8	66.2	**36.5**	108.4	223.8	**166.1[c]**	**88.3[b]**
	F			**ns**			*	**ns**

Means within a column lacking a common superscript letter were significantly different in individual comparisons using Wilcoxon matched pairs tests (P < 0.05).

These data were reflected in the soil damage data. Table 5 shows that the proportion of ground actually dug up was approximately 10 times greater in UR sows than in either type of ringed sow (UR vs CR, t = 4.65, P < 0.002; UR vs BR, t = 4.47, P < 0.002; CR vs BR, t = 0.80, ns; all df = 9). This represents rooting up of about 2 per cent of the paddock in a little over 2 weeks in the case of unringed sows. Some of the UR rooting was very deep, extending to over 40cm depth in places, whereas it was little more than superficial with ringed sows, except in the very wet area in front of the trough (which could be dug out easily, often by scraping with the fore-hoof) and the wallow (where artificial assistance was given by a mechanical digger). The differences in measured depth between UR and ringed sows in Table 5 are highly significant (using the mean maximum depth for each category of rooted area, and matching for category of area: $F_{2,9}$ = 9.06, P < 0.002). The mean depth of wallows in the paddocks of UR sows was 48.5cm (vs 23.3cm in those of ringed sows); although the initial wallow was dug by tractor, this difference may be assumed to be due to additional rooting by the sow, justifying inclusion of these depths in statistical analyses. However, there

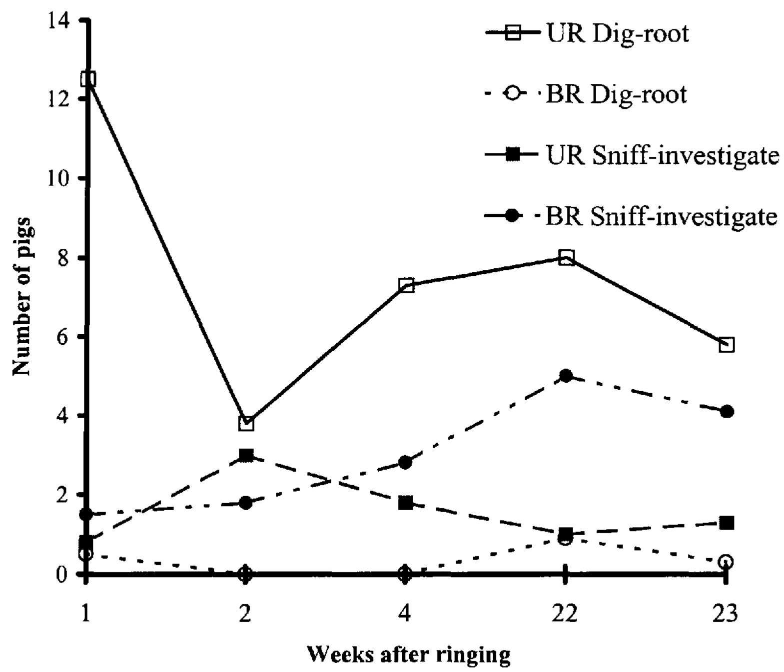

Figure 1 **Variation in dig-rooting and sniff-investigating with time since ringing for CR and BR sows. (Mean no engaged in each behaviour per observation session over a 2-day period. See text for details).**

Table 5 **Soil damage. Mean (± SEM) length of bare soil and damaged ground along a 60m line in each paddock, together with the mean depth of dug-out hollows as assessed at standard measurement points (ns – not significant.)**

	Control (UR)	Clip (CR)	Bull (BR)	Significance
Length of surface bare (cm)	383 (45.4)	378 (42.1)	463 (75.9)	ns
Length of surface dug up (cm)	1113 (213.5)	133 (26.8)	153 (25.5)	< 0.01
Depth of dug hollows (cm)	21.5 (4.92)	10.0 (3.21)	9.6 (2.92)	< 0.01

was no significant difference between conditions in the area of bare surface ($F_{2,9}$ = 1.06, ns), much of which was probably achieved by treading or scraping with hooves.

Other functional activities

Table 6 shows that the incidence of grazing over the 6-month course of the observations was consistently less in BR sows than in URs or CRs (UR vs BR using the time-scan data for the whole 6 months: $z = 2.99$, $P < 0.01$). Although the suppression was not large, with an overall grazing frequency in BRs of 84 per cent of that in URs, it remained fairly constant and was still there at 6 months. However, this was not the case for CR sows: at no stage did they differ significantly from URs, and they were, in fact, significantly more likely to be found grazing than BRs (BR vs CR over 5 months: $z = 2.35$, $P < 0.05$). Observers had the subjective impression that ringed sows, especially BRs, were altogether more tentative in their

Table 6 **Top – mean number of pigs observed grazing per 3.5h scan sampling session (maximum = 140). Bottom – mean time (s h^{-1}) focal pigs spent grazing. Summary means and the results of their statistical comparisons are shown (in bold) for observations over the first month (weeks 1-4), over two weeks at 5 months after the ringing (weeks 22-23) and over the whole observation period. See text for details of statistical analyses (**P* < 0.05; ***P* < 0.01; ****P* < 0.001; ns – not significant).**

Weeks	1	3	4	1-4 (Mean)	22	23	22-23 (Mean)	Overall (Mean)
Scans (n)								
Control (UR)	16.2	34.0	58.5	**36.2[a]**	34.0	41.0	**37.5[a]**	**36.7[a]**
Clip ring (CR)	19.5	34.0	52.0	**35.2[ab]**	39.4	45.0	**42.2[ab]**	**38.0[a]**
Bull ring (BR)	9.3	31.3	54.8	**31.8[b]**	27.5	30.6	**29.1[b]**	**30.7[b]**
	F			**< 0.1**			**ns**	*******
Focals (s h^{-1})								
Control (UR)	46.1	129.9	87.8	**87.9**	213.2	203.4	**208.3**	**138.6**
Clip ring (CR)	16.9	8.6	96.4	**40.6**	210.9	96.5	**153.7**	**85.9**
Bull ring (BR)	0	51.9	3.4	**18.4**	40.7	215.4	**128.1**	**62.3**
	F			**ns**			**ns**	**ns**

Means within a column lacking a common superscript letter were significantly different in individual comparisons using Wilcoxon matched pairs tests (*P* < 0.05).

movements with the snout and mouth when grazing. Thus, as well as being found grazing less frequently, they may have eaten grass less efficiently when grazing. This possibility, although lacking objective quantification, was supported by the herdsman's very firm statement that, by August, the UR sows' paddocks had been grazed much closer to the ground than those of the ringed sows.

This tentative approach to the ground in ringed sows, compared to controls, was also subjectively apparent at feeding time, when they were palpating the ground to pick up nuts. There was a tendency for ringed sows to keep feeding longer (mean time to finish feeding in UR, CR and BR sows: 14.7, 15.3 and 18.8 min respectively), although, with only four samples, these did not differ significantly. However, there were significant differences in the incidence of agonistic events with physical contact at feeding time, over the first 2 days after ringing (23, 9 and 9 events for UR, CR and BR sows respectively; chi-square = 9.56, *df* = 2, *P* < 0 .01); but not in threats without contact (40, 33 and 34 events in UR, CR and BR sows).

Two other functional activities for which snouts are used are digging wallows and nestbuilding. While not often seen, both of these activities occurred significantly less in ringed sows. Dig-rooting in wallows was recorded only nine times at time-sampled scans throughout the observation period; of these, eight were in UR sows and one in a BR (Binomial test: UR vs BR, *P* < 0.02; UR vs CR, *P* < 0.002.) Rooting in straw with the snout was recorded on 18, 8 and 7 occasions in UR, CR (corrected for sows with at least 2 rings in place), and BR sows respectively. Once again, this distribution was significantly non-random (chi-square = 6.73, *df* = 2, *P* < 0.05).

Since all outdoor pigs seem to stone-chew and this activity occupies considerable time, although its function is not known, we may assume that it satisfies some need which would be thwarted if stone-chewing were prevented. Table 7 shows that stone-chewing was reduced in both kinds of ringed sow over the course of the project as a whole, both in frequency of occurrence (F_r = 25.70, *df* = 2, *P* < 0.0001) and the time spent in the activity (F_r = 6.40, *df* = 2, *P* < 0.05). The effect on frequency was considerable over the first month (F_r = 15.54, *df* =

2, $P < 0.001$), with the incidence of stone-chewing in BRs reaching only 24 per cent that of URs, and CRs recorded stone chewing only 39 per cent as often as URs. The effect was significant in specific comparisons between URs and both CRs ($z = 2.93$, $P < 0.005$) and BRs ($z = 3.06$, $P < 0.005$). Although the difference had reduced substantially by 5 months after ringing, stone-chewing was still seen significantly less frequently in both CRs ($z = 2.10$, $P < 0.05$) and BRs ($z = 2.52$, $P < 0.02$) than in URs.

Table 7 **Stone-chewing. Top – mean number of pigs observed chewing stones per 3.5h scan sampling observation session (maximum = 140). Bottom – mean time (s h^{-1}) focal pigs spent chewing stones. Summary means and the results of their statistical comparisons are shown (in bold) for observations over the first month (weeks 1-4), over two weeks at 5 months after the ringing (weeks 22-23) and over the whole observation period. See text for details of statistical analyses (*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$; ns – not significant).**

Weeks	1	3	4	1-4 (Mean)	22	23	22-23 (Mean)	Overall (Mean)
Scans (n)								
Control (UR)	9.3	12.8	24.3	**15.5^a**	41.0	41.0	**41.0^a**	**25.5^a**
Clip ring (CR)	1.3	5.8	10.8	**6.0^b**	23.1	25.6	**24.4^b**	**13.3^b**
Bull ring (BR)	1.3	2.5	7.3	**3.7^b**	21.6	30.4	**26.0^b**	**12.6^b**
	F			*******			******	*******
Focals (s h^{-1})								
Control (UR)	339.6	233.3	405.6	**326.2^a**	842.6	1028.4	**935.3**	**569.9^a**
Clip ring (CR)	143.3	169.5	298.5	**203.8^a**	999.3	850.5	**924.9**	**492.2^a**
Bull ring (BR)	0	103.5	129.8	**77.7^b**	565.8	953.6	**759.7**	**350.5^b**
	F			**< 0.1**			**ns**	*****

Means within a column lacking a common superscript letter were significantly different in individual comparisons using Wilcoxon matched pairs tests ($P < 0.05$).

Possible indicators of welfare

If ringed pigs are unable to root, they must do something else with their time, unless they simply reduce their overall activity levels. Furthermore, if rooting is a behavioural need that they have a strong urge to carry out for its own sake, depriving them of the opportunity to root might be expected to give rise to abnormal behaviours reflecting this. Tables 8 and 9 present data on the incidence (in scans) and time (in focals) spent inactive, whether standing or lying down. There was a small difference between treatment conditions in the incidence (Table 8) and duration (Table 9) of time spent lying down, with both types of ringed sow observed lying down more frequently over the first month. However, the only statistically significant effect was the incidence of lying inactive between URs and CRs ($z = 2.55$, $P < 0.05$). Also over the first month, control sows were more often recorded as lying but doing something at the same time, usually rooting or grazing ($F_r = 6.17$, $P < 0.05$; CR vs UR, $z = 2.52$, $P < 0.05$; BR vs UR, $z = 1.99$, $P < 0.05$), although there were no consistent differences at 5 months.

However, the most prominent consequence of ringing for activity was a significant effect on the frequency with which sows were recorded in scans as standing but otherwise inactive ($F_r = 15.92$, $df = 2$, $P < 0.001$). Both kinds of ringed sow stood inactive much more than controls during the month after ringing. Over this period, BRs were almost 14 times as likely

Table 8 Activity levels. Mean number of sows observed standing inactive, lying inactive or lying but actively engaged in another activity per 3.5h scan-sampling session (maximum n = 140). Summary means and the results of their statistical comparisons are shown (in bold) for observations over the first month (weeks 1-4), over two weeks at 5 months after the ringing (weeks 22-23) and over the whole observation period. See text for details of statistical analyses (*P < 0.05; **P < 0.01; ***P < 0.001; ns – not significant).

Weeks	1	3	4	1-4 (Mean)	22	23	22-23 (Mean)	Overall (Mean)
Standing inactive)								
Control (UR)	0.3	0.5	0.5	**0.4^{a}**	3.8	0.8	**2.3^{b}**	**1.2^{a}**
Clip ring (CR)	5.3	2.0	1.5	**2.9^{b}**	1.3	1.9	**1.6^{a}**	**2.6^{a}**
Bull ring (BR)	8.5	8.3	1.3	**6.0^{c}**	5.0	4.7	**4.9^{b}**	**5.6^{b}**
	F			**			*	***
Lying inactive								
Control (UR)	88.8	84.8	47.8	**73.8^{a}**	52.8	45.5	**49.2**	**63.9**
Clip ring (CR)	92.5	90.0	63.8	**82.1^{b}**	57.5	38.7	**48.2**	**68.5**
Bull ring (BR)	94.5	81.5	68.3	**81.4^{a}**	52.2	47.2	**49.7**	**68.7**
	F			**			**ns**	**ns**
Lying doing								
something	4.3	2.3	6.5	**4.3^{a}**	3.8	6.8	**5.3**	**4.7**
Control (UR)	0.5	1.5	2.8	**1.6^{b}**	6.3	4.8	**5.6**	**3.2**
Clip ring (CR)	0.8	1.3	1.3	**1.1^{b}**	6.9	5.0	**6.0**	**3.1**
Bull ring (BR)	***F***			*			**ns**	**ns**

Means within a column lacking a common superscript letter were significantly different in individual comparisons using Wilcoxon matched pairs tests (P < 0.05).

Table 9 Mean time (s h^{-1}) focal pigs spent standing inactive or lying inactive. Summary means and the results of their statistical comparisons are shown (in bold) for observations over the first month (weeks 1-4), over two weeks at 5 months after the ringing (weeks 22-23) and over the whole observation period. See text for details of statistical analyses (*P < 0.05; **P < 0.01; ***P < 0.001; ns – not significant).

Weeks	1	3	4	1-4 (Mean)	22	23	22-23 (Mean)	Overall (Mean)
Standing inactive)								
Control (UR)	29.8	38.6	11.6	**26.7**	6.6	19.3	**13.0^{a}**	**21.2^{a}**
Clip ring (CR)	84.8	0	111.0	**65.3**	22.5	27.5	**$25.0^{a,b}$**	**49.2^{ab}**
Bull ring (BR)	180.0	69.0	8.1	**85.7**	61.1	142.1	**101.6^{b}**	**92.1^{b}**
	F			**ns**			**ns**	**ns**
Lying inactive								
Control (UR)	2281	2082	1323	**1895**	1475	1134	**1305**	**1693**
Clip ring (CR)	2562	2232	1591	**2128**	1688	734	**1211**	**1761**
Bull ring (BR)	2931	1875	1905	**2237**	1358	1473	**1416**	**1908**
	F			**ns**			**ns**	**ns**

Means within a column lacking a common superscript letter were significantly different in individual comparisons using Wilcoxon matched pairs tests (P < 0.05).

to be found standing inactive as URs (BR vs UR, z = 2.80, P < 0.01), and CRs 6.8 times as likely (CR vs UR, z = 2.55, P < 0.05). BR sows stood inactive more than CRs (BR vs CR, z = 2.40, P < 0.05). This effect had disappeared in CR sows by the 22–23 week observation period, but was still significant in BR sows, both in terms of its incidence in scans (BR vs CR, z = 1.95, P < 0.05) and the time spent by focal animals in this activity (BR vs UR, z = 2.10, P < 0.05).

An alternative to the use of the snout in rooting, if the need is specifically to excavate, is to scrape at the ground with a front hoof. Table 10 indicates that this occurred only in ringed animals, and all but one such event was carried out by BR sows (Kolmogorov-Smirnov test: D = 0.583, P < 0.01). On the other hand, pawing at straw and scraping or scratching other parts of the body on objects (usually the ark) were not recorded significantly more often in one condition than another.

Table 10 Total number of recorded incidents (all scans over the whole study) of pigs scratching their body on an object, scraping at the ground with a foreleg hoof, or pawing at straw (nestbuilding) in an ark. (UR – control; CR – clip ring; BR – bull ring; ns – not significant.)

	UR	CR	BR	Significance
Pawing/scraping at ground (n)	0	1	11	< 0.01
Pawing at straw (n)	3	0	3	ns
Scratching body (n)	3	8	5	ns

Oral stereotypies, such as biting or chewing bars and other objects are generally regarded as a sign of stress or boredom in pigs housed intensively indoors, as is 'vacuum-chewing' (Table 1). Apart from stones, there were few objects that could be chewed in the outdoor paddocks. Table 11 gives the incidence, over the whole project (all five observation weeks pooled), of chewing the various substrates that were available. The marginally higher incidence of grass chewing in ringed sows was not statistically significant. However, BRs did chew straw significantly more frequently than other groups (one-sample chi-square = 34.57, df = 2, P < 0.001), and all the recorded occurrences of vacuum-chewing were in ringed sows (one-sample chi-square = 8.38, df = 2, P < 0.02), although the absolute frequencies were not high for any of these.

Table 11 Total number of recorded incidents (all scans over the whole study) of pigs chewing grass, straw or nothing (vacuum-chewing). (UR – control; CR – clip ring; BR – bull ring; ns – not significant.)

	UR	CR	BR	Significance
Chewing grass (n)	15	25	29	ns
Chewing straw (n)	17	8	47	< 0.001
Vacuum-chewing (n)	0	7	9	< 0.02

Over the 5-month course of the observations, two BR sows lost their rings. One was pulled out with considerable force when it became caught in pen fittings during mating, causing considerable bleeding and distress, and a serious wound with a loose flesh flap. The other, although not seen at the time, was probably lost in a similar way, and left a similarly large, scarred flesh gap after healing. Clip rings fell out very easily, probably without significant distress. Although only one ring was lost during the first month, by the end of the five months of observations, no CR sow had all rings intact: one had none, five had one and four retained two; none of them still had the central ring on the upper edge of the snout which bears the brunt of rooting contact.

Discussion

Impact on rooting

The basic purpose of ringing is to inhibit rooting, and thus restrict pasture damage. It clearly achieved both of these objectives. The abolition of dig-rooting was almost total and permanent in sows with bull rings. It was just as complete in clip-ringed sows over the month following ringing, in mid-summer when the ground was dry and hard. That rooting had largely, although not completely, recovered in CRs by 5 months later can be attributed as readily to the fact that all CR sows had lost one of their rings (data from sows with more than one ring lost were excluded) as to the much wetter and softer ground of November. We gained the impression that, if the middle ring on the top of the snout rim was missing, the sow was effectively not ringed. Consistent with these data on rooting, the area of ground that was dug over in the 3-week period after ringing was about a tenth of that dug over by unringed sows, and the depth of rooting was also much less.

As well as real digging (dig-rooting), rooting involves exploration of the ground, by sniffing and palpating or feeling, in order to identify potential foods and items for excavation. In so far as it involves physical contact between the snout and the ground, it is not surprising that ringing suppressed palpation of the soil during the first month after ringing, although not completely. This palpation was less suppressed in CR than in BR sows: in fact, it was only statistically significant in the latter. It seems reasonable to speculate that this was due to the fact that clip rings are confined to the upper rim of the snout, and CR sows still had the surface of the snout free, allowing them to palpate more readily by using the lower part of the snout. On the other hand, bull rings dangling from the septum make contact even when the lower half of the snout approaches a surface. By 5 months after ringing, both kinds of ringed sow seemed unimpeded.

Sniff-investigating/sniff-rooting, presented a more complex picture. For the first three weeks after ringing, there was little difference between the groups. Thereafter, BR sows did this significantly more frequently and for longer periods than others. This trend shown by BR sows to increase exploratory sniffing with time, so that it became much more frequent than dig-rooting (unlike the other sows), suggests that they may have been considering or contemplating dig-rooting, but were inhibited from making contact with the ground. The behaviour of CR sows is consistent with this suggestion: they explored above the surface less than BRs but more than URs, while they dig-rooted more than BRs but less than UR sows.

The argument advanced over the last two paragraphs raises two general issues. First, it relies on comparisons between specific conditions on a subset of data, sometimes when analysis of variance across all three conditions does not identify effects. This raises the possibility, recurring at a number of points in these data, of over-interpreting the importance of what might be chance 'false positives' when making multiple comparisons within a data set. The use of more conservative and integrated parametric methods was precluded here by the skewed nature of the data. However, the cautious approach is simply to raise hypotheses, and to do so only when a number of such pieces of circumstantial evidence are integrated by a unitary explanation.

The second issue concerns the nature of concepts like 'considering' or 'contemplation'. Of course, it is not possible to infer that an animal is consciously considering two or more options in its mind. However, the facts are these. When an unringed pig sniffs across the surface of a field, there is a certain, fairly high, probability that this will be followed by dig-rooting. The probability of dig-rooting following sniff-investigation in these BR sows was much less than in unringed sows. We also have other circumstantial reasons to believe that the impact of the ring on the ground may be painful. If a human (or other animal) performs the first of two acts that normally occur in sequence, but a special circumstance results in them not doing the second, it seems reasonable to hypothesize that they were contemplating the normal sequence, but desisted from the second act because of the special circumstance. Although we cannot draw this as a logical inference, it seems a reasonable hypothesis that these animals were making an 'intention movement' but not carrying it through. We may ask what might constitute an operational definition of 'contemplation': what behaviour suggests to us that someone is 'contemplating' something if they do not tell us (or even if they do)? We cannot conclude with certainty, but we can suggest the possibility that these animals were considering an action but decided against it.

Other functional activities

The snout and mouth are of central importance to many, if not most, functional actions that pigs need to carry out. These include harvesting roll nuts provided as daily feed, grazing, digging wallows, nestbuilding, and aggressive prodding or butting of other pigs with the snout. Observers gained the subjective impression that ringed sows were more tentative in their approach to the actions involved in each of these activities. Simply picking up roll nuts inevitably involves contact with the ground, and nuts sometimes become embedded in soil or grass, requiring a mild degree of rooting for extraction. Although the basic attempts we made to quantify the rate of feeding showed only a slight, non-significant trend, separate experimental observations of feeding behaviour, carried out 5 months after ringing, have shown that ringed sows pick up a standard load of nuts more slowly, especially when the nuts are embedded or the surface is hard (Horrell *et al* 2000).

These sows grazed for around 20 per cent of the day. Although physical contact is not necessary for this and is probably largely accidental, the snout has to approach close to the ground, and ringing did reduce the frequency of grazing, in BR sows right through the 6 months of observation. Similarly, ringing interfered with the rooting out of wallows: the wallows in the paddocks of ringed sows were only half the depth of those in paddocks with unringed sows, despite the fact that the herdsman did some digging for them with machinery. Finally, physical aggression by pigs usually involves contact with the snout. The fact that ringed sows committed fewer aggressive acts at feeding time in the days immediately after ringing, again suggests they were inhibited by the potential pain. This will inevitably interfere with their ability to compete with other pigs for any other resources, as well as food.

Welfare

All the activities discussed in this paper contribute to the normal physiological and nutritional functions of the pig. In so far as nose-ringing reduces the efficiency with which these functionally important activities are carried out, it constitutes a reduction in the animal's level of welfare. In addition, it is now generally accepted that all 'higher' animals have behavioural needs – actions that they are strongly motivated to carry out, independent of the function they serve, and that result in distress if they are not satisfied (Hughes & Duncan 1988). Similarly, it is acknowledged that there are other states of 'mind' that relate to suffering, independent of the animal's physiological status. When any of these apply, we expect to see signs in the animal's behaviour: these signs of reduced welfare are often abnormal behaviours (Mench & Mason 1997).

One action that was seen only in ringed sows (mainly BRs) was scraping at the ground with the front hoof as an attempt to dig. Another behaviour seen from time to time in BR sows but not in others was an attempt to root by digging the lower jaw and teeth into the ground in a forward moving action, often scraping the teeth of the lower jaw over the surface, actions which we have analysed in detail by video recording (Horrell *et al* 1996; 2000). These are both 'abnormal' behaviours, in the sense that pigs do not normally display them. Since both provide a functional, if much less effective, alternative to rooting, it would seem that they reflect a very powerful drive to dig that is clearly thwarted by nose-ringing. It seems reasonable to regard this as 'frustrating'. However, these abnormal behaviours were the reverse of a 'behavioural need', being different attempts to satisfy the same purpose, rather than a specific action that an animal is driven to carry out for its own sake, independently of the function it serves.

If rooting is a behavioural need in its own right, we should expect the ringed sows to suffer merely because it was prevented, and this reduced state of welfare to be revealed by other behavioural signs not evident in control sows. The most common abnormal behaviours widely regarded as indicative of reduced welfare are unusually high levels of gratuitous aggression, chewing at objects or other animals without obvious purpose, repeated stereotyped actions of any kind (Morton & Griffiths 1985; Rushen 1985; Terlouw *et al* 1991; Mench & Mason 1997), and standing around listlessly doing nothing an abnormally high proportion of the time (Dybkjer 1992). As is usual with established groups in extensive conditions, we observed very little aggression except in competition for roll nuts. There were also very few objects to chew except stones. The significance of stone-chewing is unclear and discussed below. Two other oral activities with no obvious functions were observed. Lying or standing chewing straw occurred in all sows to some extent, and may have some nutritional value. However, it was seen significantly more often in BR sows than others. More clearly classifiable as an oral stereotypy of the kind found in tethered sows in intensive indoor conditions, and recorded here only in ringed sows, was vacuum-chewing.

One of the most prominent features of the period immediately after the return to pasture after ringing was the apparent listlessness of the ringed sows, especially BRs. The latter spent about 18 per cent of the time standing, engaged in no functional activity, but staring into space or at other groups rooting, or with their heads held down and snouts a few centimetres off the ground. Although this soon became much less obvious to casual observation, presumably with increasing relief from the immediate pain of the ringing operation itself, all ringed sows stood inactive significantly more than controls, over the month immediately following ringing, and BRs were still doing so more than other groups at the 5-month observation period. The fact that they were standing, rather than lying, suggests that they were not resting, but were contemplating doing something. It has already been suggested that the steadily increasing levels of exploration shown by BRs, with the snout close to the ground but not in contact, which they performed more than controls from the fourth week onwards, suggests that they wanted to root, but were inhibited from so doing.

The issue of stone-chewing and the impact of ringing on its incidence is very difficult to evaluate. Pigs kept outdoors appear to engage in a great deal of stone-chewing, with an individual pig continuing with no significant respite for an hour or more, although objective and quantitative data are few (Horrell & A'Ness 1999). It is not known what function stone-chewing serves. It has been suggested that it is a type of oral stereotypy equivalent to those displayed by tethered or stalled indoor gestating sows. Stone-chewing develops and reaches its peak frequency in the period immediately following the daily feed times and its incidence increases with food deprivation (Edwards *et al* 1993; Braund *et al* 1998; Horrell & A'Ness 1999); moreover, it is the meal itself that appears to elicit a bout of stone-chewing (Horrell & A'Ness 1999). These features are all characteristic of oral stereotypies in tethered sows (Rushen 1985; Appleby & Lawrence 1987; Terlouw *et al* 1991). Oral stereotypies in indoor sows are regarded as 'vices' reflecting a poor state of welfare (Mason 1991; Lawrence & Terlouw 1993; Mench & Mason 1997). Outdoor-raised pigs are generally assumed to occupy an enriched environment in which the causes of stereotypies indoors are absent. However, pigs in natural conditions spend 20 per cent to 30 per cent of their waking lives foraging, spreading their ingestive intake out over hours and have plenty else to do (Stolba & Wood-Gush 1989); while outdoor commercial pigs typically eat their daily ration in a single, 15-min meal, and then have only a bare paddock, with just homogenous soil, for their environment. A few stones to chew may be the only available activity. It has been argued that oral stereotypies, although they reflect a state of reduced welfare due to severe behavioural constraints, may help the tethered pig cope with its deprivations (Cronin 1985; Lawrence & Terlouw 1993). We suspect that the ringed sows in our observations engaged in less stone-chewing not because they were less motivated to chew, but because they were less able to dig up the necessary stones. If stone-chewing is a stereotypy, the reduced stone-chewing may represent a welfare-threatening constraint on one of the coping mechanisms that ringed pigs may use to compensate for their reduced foraging.

The most obvious impact of ringing on welfare can easily be forgotten. Although no attempt was made at quantification, it was obvious from the extreme vocalizations displayed that the act of fixing the rings caused pain. In addition, the fact that rooting and other functional activities were still partially suppressed 6 months after ringing can only be attributed to there still being some pain when physical contact was made between the snout and solid objects.

General conclusions and animal welfare implications

Nose-rings unequivocally achieve their purpose of greatly limiting pasture damage by inhibiting rooting. Rigid bull rings clipped through the nasal septum are substantially more effective, and stay intact much longer, than the multiple wire rings pierced through the skin around the upper edge of the nasal plate variously known as clip, boss or rim rings. In our experience, the latter are likely to fall out and need to be replaced within a few months.

However, these observations indicate that ringing causes a real, if not extreme, reduction in the animal's welfare, in three respects. First, rings almost certainly cause pain: extreme when ringing is carried out, but which appears to make itself felt for many months, at a milder level, whenever the snout is used.

Second, a number of functional activities, as well as rooting itself, were executed tentatively and less efficiently. These included feeding on roll nuts as well as rooting out any artificial or naturally occurring food in the ground, grazing, digging wallows and, possibly, nestbuilding; and most of these remained partially inhibited 6 months after ringing. It could be argued that interference with feeding does not matter when most of the sows' nutrition was acquired in concentrate eaten up in a 20-min meal. However, if ringed pigs feed with unringed (and most do, if only because rings are so easily lost), they would be at a disadvantage in obtaining their share of food, since they harvest it more slowly and would have acquired a smaller share by the time it is all consumed. Furthermore, since ringing also appeared to inhibit physical aggression, they would be less effective in direct competition with unringed pigs.

Finally, there were clear (if modest) signs that ringed sows were thwarted and suffering. They showed a strong motivation to dig into the ground by abnormal means, displayed some evidence of oral stereotypies, and spent more time standing around but inactive. In all of these respects, bull-ringed sows suffered more and for longer than those with clip rings.

There is a strong economic incentive for pig producers to ring pigs on pasture. In making a decision, they have to weigh the economic gain of pasture conservation against the real economic costs of the ringing operation itself and those arising from the pigs whose physiological state may be reduced, both by the restriction of functional activities and by any metabolic consequences mediated by the endocrinological response to stress. In addition, they have to put a value on the animals' welfare. Clip rings represent something of a compromise: the value to pasture conservation is less, compared to bull rings, and ringing needs to be repeated to remain effective, but the adverse impacts on functional activities and animal welfare are also reduced.

The observations reported here still leave a number of issues to be tackled. These fall into two, broad classes. First, the further evaluation of the welfare implications; and, second, finding practicable ways of circumventing the welfare problems. No attempt has been made to evaluate the immediate pain and disturbance of the ringing operation itself: this would require both behavioural and physiological measures. The former might include assessment of the strength of attempts to escape and of the significance of vocalizations (Weary & Fraser 1995). Also required are measurements of the autonomic, adrenocortico-hypophyseal axis and of other endocrinological responses long-accepted as indicators of stress (Dantzer & Mormede 1983; Moberg 1985), both as a direct consequence of the ringing operation itself, and later, as a indicators of long-term suffering, complementary to such behavioural signs as reported here. We also need direct evaluation of the strength of the motivation to root for its own sake.

There would seem to be two plausible approaches to circumventing the welfare problems of ringing. One is to provide pain-free and low-cost alternative opportunities for ringed pigs to satisfy the urge to root; the other is to divert pigs away from the desire to root by offering easy access to a variety of other activities. Rooting trays filled with peat or other soft and cheap substrates may allow ringed pigs to satisfy their behavioural need to root: the attractiveness of this or other substrates needs to be evaluated, together with the extent to which they deflect pigs from rooting elsewhere. The second approach, relies on the observation that as well as spending up to 30 per cent of their waking life rooting, pigs in natural conditions also do many other things (Stolba & Wood-Gush 1989). Most commercial environments provide little opportunity to engage in any of these alternative activities, and it may be that some of these activities have equivalent status in the pig's motivational system: for example, that the 'need' is not specifically to root, but that other foraging activities are satisfying alternatives. If we examine alternative environments, with additional materials and opportunities, we may find that the amount of rooting spontaneously declines in some cases, and some other activity takes its place. If these opportunities are made available to pigs in commercial conditions, they may suffer less from deprivation of the opportunity to root. There may also be other ways of reducing the motivation to root, such as increasing the satiety effect of concentrate by increasing its fibre content (Braund *et al* 1998). With all of these approaches, if the alternative provisions are really attractive or effective, they may so reduce the urge to root the pasture that the need for ringing can be obviated altogether.

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