Behaviour, social interactions and lesion scores of group-housed sows in relation to floor space allowance

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Accepted 10 November 1997

Abstract

The space allowance appropriate for sows in group housing remains scientifically undefined, since the social space requirement of a group of animals and the factors which affect this are unknown. Eight established groups of six pregnant, multiparous sows were used in a replicated Latin Square design of experiment, with 7 day periods, to compare four pen sizes providing 2.0, 2.4, 3.6 or 4.8 m²/sow. For the last 48 h of each 7 day period, a continuous video recording was made to determine general behaviour and all social interactions. Time spent rooting increased progressively with increasing space allowance, whereas time spent sitting and standing inactive were both progressively reduced. The total frequency of social interactions and aggressive behaviour both increased with decreasing space allowance. The Attack:Retreat ratio was significantly higher, and the Avoidance Index significantly lower, in the smallest pen. All body regions had the highest count of lesions after sows had been in the smallest pen, with damage levels being reduced as pen area increased. Analysis of body lesion scores, combining incidence and severity, gave the same treatment effects. In conclusion, the results indicated that a minimum space of between 2.4 and 3.6 m²/sow was necessary in the conditions of this experiment to promote good welfare. This result cannot be generalised to situations of different group size, group stability or feeding method. © 1998 Elsevier Science B.V. All rights reserved.

Keywords: Pig-social behaviour; Space requirements; Anomalous behaviour

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1. Introduction

The requirement of a pig for space encompasses both the physical space that is occupied by the animal when standing or lying and during posture changes and, when animals are housed in groups, additional social space allowing them to show normal behaviour and interactions. It is relatively simple to calculate mathematically the space requirements for individual animals in different postures from the relationships between their liveweight and physical dimensions (Petherick, 1983) and space envelopes when standing and lying (Baxter and Schwaller, 1983). In addition to their static space requirements, animals generally require some space for exercise to maintain muscle tone. In the case of pregnant sows, this facilitates parturition (Ferket and Hacker, 1985) but the precise exercise need is currently unknown. The area covered by an extensively kept sow in the course of a day can be considerable, but is likely to be heavily influenced by the location of resources and the animal’s degree of hunger and foraging motivation.

When the social group rather than the individual animal is considered, other space requirements are apparent. These include space for a wide range of social interactions including the establishment of dominance (Baxter, 1985) and avoidance of aggression (Ewbank and Bryant, 1972; Jensen, 1984). Space for avoidance of potential aggressors or escape from attack is vital for the welfare of low-ranking animals in group housing. While it has been demonstrated that certain types of housing system with restricted space allowance can preclude the establishment of a stable social situation (Jensen, 1984), the precise role of the quantity and quality of space in this context is not known. In a situation of unrestricted space in a straw yard, the distance over which sows were pursued following aggressive interactions varied from 0 to 20 m (Edwards et al., 1986). Even in the absence of overt aggression, enforced proximity to another sow may in itself be stressful. Hemsworth et al. (1986) demonstrated a chronic stress response in gilts housed at reduced space allowance (1, 2 or 3 m$^2$/pig). Similarly, gilts regrouped at a space allowance of 1 m$^2$/pig showed signs of a physiological stress response, i.e., elevated cortisol level and impaired immune response, at 21 days after grouping compared with those grouped at 2 m$^2$/pig (Barnett et al., 1992). Comparable data do not exist for groups of older, mixed-parity sows. Jensen (1984) found increased aggression with reduced space allowance (1.4, 2.3 or 3.0 m$^2$/pig), but this study confounded space with housing system design (stalls, cubicles or pen with separate lying, dunging and feeding areas). The preferred distance between individuals will vary, depending on the relationship of the animals involved and their current motivational state. Foraging sows in extensive conditions maintained an average distance of 3.8 m between group members, and a distance of 50 m between different groups (Stolba and Wood-Gush, 1989). In dynamic groups with large space allowances, sows also maintained closer proximity to previously familiar individuals than to strangers (Spoolder et al., 1996).

To ensure sow welfare, housing design must, at the very least, ensure unimpeded access to necessary resources, opportunity to avoid or escape from potential aggressors, and avoidance of chronic physiological stress. The minimum space allowance necessary for these purposes for a sow in group housing remains scientifically undefined, since
although the physical space occupied during activities such as standing, lying, feeding or mating is well documented, the social space requirement for avoidance of aggression, escape, separation of specific activity areas and exploration, and the way in which such space might be time shared within a group of animals is unknown. As a beginning to understanding this issue, this study measured how general behaviour and social interactions were changed by different floor space at standard group size, in pens with individual feeding stalls, and related this to a physical indicator of welfare—the level of skin lesions.

2. Materials and methods

Eight groups of six pregnant, multiparous sows (Large White × Landrace, Pig Improvement Company), formed at weaning, were selected for the experiment at 7–10 weeks post service. These groups were used in a replicated Latin Square design of experiment, with 7 day periods, to compare four pen sizes providing 2.0, 2.4, 3.6 or 4.8 m²/sow. Sows were fed once daily, at 0700 h, when they were given 2.7 kg of a standard dry sow concentrate feed while confined in individual feeding stalls for a period of 1 h. These stalls were then closed off for the remainder of the day, so that the sows were confined to the specified space allowance in an area bedded with deep straw. Space was varied by changing the length of the pen at a common width of 4.0 m. Water was freely available from a single nipple drinker mounted on the rear wall of the pen.

At allocation, each sow was weighed, subcutaneous backfat thickness at the P2 position was measured ultrasonically as an index of body condition, and body length (crown to tailhead) and height at the shoulder were measured. Skin lesions were scored at the beginning and the end each treatment period. At this time, animals were individually inspected and each lesion (scratch or cut) was recorded and measured in cm. The lesions were drawn on a body map of each pig, such that a check could be made as to which lesions were duplicating those observed at the previous recording period, and which had appeared since that time. The distribution of lesions was categorised into eight body sections: face and ears, neck, shoulder, central body, udder, rump, tail, vulva. Each section encompassed both sides of the body. The severity of damage in each section was categorised in five classes according to the total length of lesions: 0 = none, 1 = 1–3 cm, 2 = 3–6 cm, 3 = 6–9 cm, 4 = > 9 cm.

For the last 48 h of each 7 day period, a continuous video recording was made of every pen. These recordings were analysed for general activity patterns by time sampling the behaviour of each sow at 5 min intervals. All social interactions were recorded using the ethogram of Jensen (1980). An additional category of behaviour, ‘threat’ was recorded, defined as a sudden head movement or move towards another sow which submitted or retreated without contact being made. Using these recorded social interactions, the Attack:Retreat ratio (A/R) and Avoidance Index were calculated according to the method of Jensen (1982). On completion of the recording period, sows were introduced immediately to the next treatment. Within the Latin Square design, the treatments were applied in random order, and not according to progressively increasing or decreasing space allowance.
Group totals were calculated from the individual sow data and were analysed for the effects of treatment, group and period using analysis of variance. Differences in the frequency distribution of different interaction types and location of lesion scores were analysed using the Chi-square test (Siegel, 1956).

3. Results

There were no differences between time periods in general behaviour, social interactions or lesion scores. Significant differences did occur between groups in some categories of behaviour and interactions, but not lesion scores.

Table 1 shows the general behaviour of the sows in relation to space allowance. Overall, sows spent most time lying (82%), with most of their active time being spent in rooting in the straw bedding (37% of non-lying time). Time spent rooting increased progressively with increasing space allowance, whereas time spent sitting and standing inactive were both progressively reduced.

Table 2 shows the frequency of social interactions in relation to space allowance. The behaviours of Parallel Pressing and Inverse Pressing (with or without Bites) and Levering were never observed throughout the whole experiment. Nose-to-Body was by far the most numerous interaction recorded in pens of all sizes. The total number of social interactions in 48 h, and the incidence of aggressive behaviour, both increased with decreasing space allowance. The frequency of all categories of behaviour except Nose-to-Nose was significantly higher in the smallest pen size. Head-to-Head, Head-to-Body-with-Bite, Nose-to-Body, Nose-to-Genital and Head-Tilt were all further reduced at the largest space allowance. χ² analysis indicated that the pooled distribution of types of social behaviour (eight categories with a valid frequency of expected values;

<table>
<thead>
<tr>
<th>Pen area (m²/sow)</th>
<th>2.0</th>
<th>2.4</th>
<th>3.6</th>
<th>4.8</th>
<th>SED</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lying</td>
<td>2807.6</td>
<td>2850.1</td>
<td>2851.1</td>
<td>2835.8</td>
<td>30.39</td>
<td>NS</td>
</tr>
<tr>
<td>Standing inactive</td>
<td>133.4a</td>
<td>96.9ab</td>
<td>79.5b</td>
<td>68.3b</td>
<td>19.87</td>
<td>* *</td>
</tr>
<tr>
<td>Sitting</td>
<td>104.9a</td>
<td>75.8b</td>
<td>51.9bc</td>
<td>45.4c</td>
<td>11.90</td>
<td>* * *</td>
</tr>
<tr>
<td>Moving</td>
<td>8.6</td>
<td>7.5</td>
<td>9.3</td>
<td>6.4</td>
<td>4.41</td>
<td>NS</td>
</tr>
<tr>
<td>Rooting</td>
<td>184.0a</td>
<td>205.4ab</td>
<td>244.0bc</td>
<td>286.4c</td>
<td>23.32</td>
<td>* * *</td>
</tr>
<tr>
<td>Drinking</td>
<td>50.8</td>
<td>52.6</td>
<td>54.4</td>
<td>53.0</td>
<td>3.82</td>
<td>NS</td>
</tr>
<tr>
<td>Defecating</td>
<td>10.9</td>
<td>12.9</td>
<td>11.3</td>
<td>10.0</td>
<td>2.20</td>
<td>NS</td>
</tr>
<tr>
<td>Urinating</td>
<td>11.8a</td>
<td>10.9a</td>
<td>10.6a</td>
<td>6.9b</td>
<td>1.59</td>
<td>* *</td>
</tr>
</tbody>
</table>

Values given are the number of observations/pen in 46 h (the 2 h when sows were confined in feeding stalls are omitted).

* p < 0.05.
** p < 0.01.
*** p < 0.001.

Means within rows with different superscripts differ significantly (p < 0.05).
Table 2
The effect of pen size on the frequency of social interactions in group-housed, pregnant sows

<table>
<thead>
<tr>
<th>Pen area (m²/sow)</th>
<th>2.0</th>
<th>2.4</th>
<th>3.6</th>
<th>4.8</th>
<th>SED</th>
<th>Significance* **</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total interactions</td>
<td>816.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>434.6&lt;sup&gt;b&lt;/sup&gt;</td>
<td>484.4&lt;sup&gt;b&lt;/sup&gt;</td>
<td>314.8&lt;sup&gt;c&lt;/sup&gt;</td>
<td>37.78</td>
<td>**</td>
</tr>
<tr>
<td>Head-to-Head</td>
<td>98.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>39.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>49.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>20.6&lt;sup&gt;c&lt;/sup&gt;</td>
<td>6.82</td>
<td>**</td>
</tr>
<tr>
<td>Head-to-Head-with-Bite</td>
<td>22.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.4&lt;sup&gt;b&lt;/sup&gt;</td>
<td>7.8&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.4&lt;sup&gt;c&lt;/sup&gt;</td>
<td>5.21</td>
<td>**</td>
</tr>
<tr>
<td>Head-to-Body</td>
<td>59.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>37.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>41.9&lt;sup&gt;b&lt;/sup&gt;</td>
<td>37.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>6.57</td>
<td>**</td>
</tr>
<tr>
<td>Head-to-Body-with-Bite</td>
<td>40.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>9.6&lt;sup&gt;c&lt;/sup&gt;</td>
<td>19.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>8.6&lt;sup&gt;c&lt;/sup&gt;</td>
<td>4.72</td>
<td>**</td>
</tr>
<tr>
<td>Nose-to-Nose</td>
<td>6.6</td>
<td>5.3</td>
<td>5.6</td>
<td>2.3</td>
<td>2.05</td>
<td>NS</td>
</tr>
<tr>
<td>Nose-to-Body</td>
<td>324.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>219.6&lt;sup&gt;b&lt;/sup&gt;</td>
<td>207.5&lt;sup&gt;c&lt;/sup&gt;</td>
<td>162.4&lt;sup&gt;c&lt;/sup&gt;</td>
<td>23.4</td>
<td>**</td>
</tr>
<tr>
<td>Nose-to-Genital</td>
<td>9.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.4&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.4&lt;sup&gt;c&lt;/sup&gt;</td>
<td>2.3&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.91</td>
<td>**</td>
</tr>
<tr>
<td>Threat</td>
<td>49.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>19.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>28.9&lt;sup&gt;b&lt;/sup&gt;</td>
<td>10.8&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4.63</td>
<td>**</td>
</tr>
<tr>
<td>Head-Tilt</td>
<td>74.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>35.4&lt;sup&gt;b&lt;/sup&gt;</td>
<td>42.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>20.9&lt;sup&gt;c&lt;/sup&gt;</td>
<td>4.78</td>
<td>**</td>
</tr>
<tr>
<td>Withdraw</td>
<td>132.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>60.2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>78.3&lt;sup&gt;c&lt;/sup&gt;</td>
<td>48.1&lt;sup&gt;c&lt;/sup&gt;</td>
<td>8.59</td>
<td>**</td>
</tr>
<tr>
<td>Attack:Retreat ratio</td>
<td>1.08&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.93&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.97&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.99&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.040</td>
<td>**</td>
</tr>
<tr>
<td>Avoidance Index</td>
<td>0.67&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.78&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.74&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.81&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.045</td>
<td>**</td>
</tr>
</tbody>
</table>

Values given are the number of observations/pen in 46 h (the 2 h when sows were confined in feeding stalls are omitted).

For method of calculation of Indices, refer to Section 2.

* = $p < 0.05$.
** = $p < 0.01$.
*** = $p < 0.001$.

Means within rows with different superscripts differ significantly ($p < 0.05$).

Head-to-Head-with-Bite and Head-to-Body-with-Bite were combined, as were Nose-to-Nose and Nose-to-Genital) differed with pen size (all interactions: $\chi^2 = 46.06$, df = 21, $p < 0.05$). When considering only aggressive interactions (Head-to-Head, Head-to-Body, Bite, or Threat), interactions with Bites occurred at a higher frequency than expected in the smallest pen size, whilst Head-to-Body occurred a higher than expected frequency in the smallest pen and lower than expected frequency in the largest pen (aggressive interactions: $\chi^2 = 25.33$, df = 9, $p < 0.05$). The distribution of Nosing-type interactions (Nose-to-Body or other) was not affected by pen size ($\chi^2 = 1.71$, df = 3, $p > 0.05$), and neither was the type of submissive behaviour (Head Tilt or Withdraw) which was shown ($\chi^2 = 0.85$, df = 3, $p > 0.05$). The Attack:Retreat ratio was significantly higher, and the Avoidance Index significantly lower, in the smallest pen.

Table 3 shows the incidence of skin lesions in relation to space allowance. The most common sites of body lesions were the central body, shoulder and rump. All body sections had the highest count of lesions after sows had been in the smallest pen, with damage levels being reduced as pen area increased. Analysis of body lesion scores, combining incidence and severity, gave the same treatment effects as for lesion counts. The pooled site distribution of body lesions (four categories as in Table 3) did not differ between treatments ($\chi^2 = 2.60$, df = 9, $p > 0.05$). From the diagrams made at each recording of the location and length of scratches, it was apparent that very few were the same as at the previous recording and that the total score was a reasonable representation of the effects of that treatment. To determine whether the short time period had
Table 3
The effect of pen size on the incidence of skin lesions in group-housed, pregnant sows

<table>
<thead>
<tr>
<th>Pen area (m²/sow)</th>
<th>Total lesions</th>
<th>Face, ears, neck</th>
<th>Shoulder</th>
<th>Central body, udder</th>
<th>Rump, tail, vulva</th>
<th>Total lesion score</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0</td>
<td>129.4a</td>
<td>21.0a</td>
<td>37.4a</td>
<td>33.3a</td>
<td>326.8a</td>
<td></td>
</tr>
<tr>
<td>2.4</td>
<td>72.4b</td>
<td>10.1b</td>
<td>21.8b</td>
<td>16.0b</td>
<td>182.0b</td>
<td></td>
</tr>
<tr>
<td>3.6</td>
<td>57.0c</td>
<td>9.3b</td>
<td>20.9b</td>
<td>10.9b</td>
<td>132.6c</td>
<td></td>
</tr>
<tr>
<td>4.8</td>
<td>53.1c</td>
<td>7.8b</td>
<td>16.6b</td>
<td>10.6d</td>
<td>129.3c</td>
<td></td>
</tr>
</tbody>
</table>

Values given are the number of lesions/pen at the end of the 7 day period.
For method of calculation of lesion scores, refer to Section 2.

Means within rows with different superscripts differ significantly at:
* * * = p < 0.001.
* * = p < 0.01.
* = p < 0.05.

influenced the incidence of lesions, the data recorded for each group before commencing
the experiment (at which stage they had been maintained at a space allowance of 2.4
m²/sow since group formation) was compared with the mean value for the 2.4 m²/sow
experimental treatment. There were no significant differences for any body region.

4. Discussion

When deciding on the adequacy of space for group-housed sows, a number of factors
can be considered. The most important criteria must be that there is adequate space to
avoid physical injury. Although none of the lesions recorded in this experiment were of
a severe nature, any increase in the frequency of lesions can be considered to be an
indication of an inadequate environment (De Koning, 1985). Consideration of the lesion
incidence and severity score would suggest a space allowance of greater than 2.4
m²/sow to be necessary under the circumstances of this experiment. De Koning (1985)
was unable to detect a difference in lesion scores between groups of sows maintained at
< 2.5, 2.5–5.0 or > 5.0 m²/sow, but his survey involved confounding of many other
between-farm factors such as group size, floor type and feeding method. However, lower
lesion scores were recorded in very large pens (> 20 m²), while no difference was
found between pens with a total area of < 12 or 12–20 m². The two larger pens in this
study exceeded this area, so the results obtained are in concordance in this respect.

The extent to which the lowest space allowance induced physiological stress could
not be determined in this experiment, since animals were not chronically catheterised for
stress-free withdrawal of blood samples and the time period was too short to consider
alternative measures of change in adrenal function or immune response. Study of each
treatment over a prolonged period would have necessitated adoption of a randomised
block, rather than a Latin Square design, because of the constraints imposed by the
limited time between confirmed pregnancy and farrowing. Since significant effects of
group were found in analyses of behavioural measures, this would have involved a loss in precision of measurement of the treatment effects. The adequacy of the 7 day period used in the experiment to detect true treatment differences might be questioned but, since all groups were well established prior to the experiment (a supposition supported by the absence of time period effects on the measured parameters), a rapid and consistent short term response to change in space would be expected. The adequacy of the experimental period is also supported by the high degree of concordance between lesion scores at the same space allowance after the 7 day experimental period and the 7–10 week pre-experimental period.

The second criteria for adequacy of space has been suggested to be a normal social interaction pattern (Jensen, 1984). The total number of social interactions was significantly lower in the largest pen than in all other treatments. However, when potentially damaging interactions (those involving bites) were considered, only the lowest space allowance resulted in a significant increase in frequency. The ability of subordinate sows to perform avoidance behaviour has been suggested as the most important factor regulating social stability (Jensen, 1982). The highest frequency of avoidance behaviours (Head-Tilt and Withdraw) was seen in the smallest pen, but it is the relationship between aggressive and avoidance behaviours which is likely to be more important. Jensen (1984) used two calculated parameters to evaluate this relationship. The Attack/Retreat ratio is a parameter which, when it has a value of less than 1.0, indicates that animals are avoiding aggressive encounters by showing submissive behaviour. The values obtained in this experiment are all close to 1.0, but only the lowest space allowance gave a value higher than 1.0, and a significantly higher ratio than all other treatments. The values obtained for all treatments are much lower than the values of 2.7 (cubicles) and 8.2 (stalls) obtained in the more confined of the housing systems studied by Jensen (1984), probably reflecting the fact that all pens in the present experiment provided unobstructed space for movement. The values are, however, higher than that of 0.7 obtained in his least confined system, which is surprising in view of the fact that two of the treatments provided substantially more total and uninterrupted space, and much higher than the value of 0.1 obtained under free-ranging conditions (Jensen and Wood-Gush, 1984). The Avoidance Index is a measure of group stability and expresses the number of settled pair-relations (i.e., pairs demonstrating unidirectional interactions) compared to the total number of possible combinations within the group. A value of 0.0 means that no relationships are settled, whereas a value of 1.0 indicates all pairs are settled. The value for this index was again lower at the smallest space allowance, indicating an abnormal social situation in established groups. The other values are generally comparable to those obtained in the least confined system of Jensen (1984). It can therefore be concluded that the interaction data indicate a space allowance of 2.0 m²/sow to be inadequate for normal social function, but no significant benefit to providing additional space above 2.4 m²/sow.

In the pen providing 2.0 m²/sow, the frequency of interactions was by far the highest recorded. Barnett et al. (1992) found a reduction in aggressive behaviour when newly mixed, pregnant gilts were provided with very small space allowance (< 1.0 m²/pig), and suggested that limited space may interfere with or inhibit aggressive behaviour. This was supported in a subsequent study with ovariectomised gilts (Barnett et al., 1993) in
which aggression following mixing was lower in small rectangular pens (1.4 m²/pig) than in square pens providing the same space allowance or in larger pens (3.4 m²/pig). However, in both studies this result related only to the 90 min following regrouping, and the subsequent total number and severity of lesion scores was not reduced. This suggests that, while reduction in space may inhibit initial aggression between unfamiliar animals, the opposite situation pertains in the longer term in stable groups. Alternatively, if reduced space does result in suppression of social activity (Barnett et al., 1992; Jensen, 1984), it does not appear that the lowest space allowance of 2.0 m²/sow investigated here had reached this threshold. While fewer aggressive interactions might be considered an indication of good welfare, the use of very limited space to achieve this is likely to be associated with greater chronic social stress, as indicated by the chronically elevated cortisol levels measured in gilts with low space allowance (Barnett et al., 1992).

A third possible criterion for adequacy of space is the expression of unmodified time budgets by the animals. In this experiment, the frequency of rooting, the predominant exploratory behaviour, was reduced by decreasing space allowance and the frequency of sitting and standing inactive increased. The ability to express exploratory behaviour has been considered to be an important component of pig welfare (Wood-Gush and Vestergaard, 1993) and these results would therefore indicate that a space allowance of greater than 2.4 m²/sow is required for the normal expression of behaviour.

In attempting to generalise from the results of this experiment to other situations, great care must be taken. Firstly, it must be borne in mind that the sows in this experiment were in settled groups prior to commencement. Aggressive interactions are likely to be more severe, and the space requirement for escape and avoidance much higher, in the period immediately after regrouping when relative dominance is still being contested (Edwards et al., 1993a). The second qualifying circumstance is that the sows were individually fed each day in protective feeding stalls. It has been shown that the use of feeding stalls can reduce measures of poor welfare, including aggression around feeding, lesion scores and total plasma cortisol, in groups of recently mixed gilts in small pens (Barnett et al., 1996), and in stable groups of gilts over a complete pregnancy (Edwards et al., 1993b). Ewbank and Bryant (1972) stated that submission and domination relationships were only enforced in competition situations which, in the case of the pregnant sow, most commonly relate to access to food (Edwards, 1992). The space requirement for sows in a system with competitive floor-feeding might therefore be very different. In this experiment, the only significant resources over which to compete would have been the drinking point (although water was freely available at all times) and preferred space. The use of straw-bedded pens in this experiment might also have influenced the results obtained, since some studies have shown provision of roughage to reduce aggression in group-housed sows (Edwards, 1992). Finally, the experimental results relate to only one group size (six sows). With larger groups, the potential for time sharing of the space above that physically occupied by the bodies of the sows is increased. With larger group size and constant space allowance per sow, the total pen area is also increased. This can allow greater choice of social companions, avoidance of feared individuals and increased total escape area. Such opportunities are exploited by the animals, as evidenced by the formation of spatially distinct sub-groups within the overall pen area (Edwards et al., 1986; Van Putten and van de Burgwal, 1990). The
survey results of De Koning (1985) indicated the possibility that total pen space might be more important than space per sow in the avoidance of injury.

5. Conclusion

The results indicate that a minimum space of between 2.4 and 3.6 m²/sow was necessary in the conditions of this experiment to promote good welfare. This result cannot be generalised to situations of different group size, group stability or feeding method.

Acknowledgements

We thank Mr. A.H. Stewart and the staff of Tillycorthie Farm who assisted with this experiment. SAC receives financial support from the Scottish Office Agriculture, Environment and Fisheries Department.

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