The Welfare and Productivity of Dry Sows in Different Group Housing Systems in New Zealand

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Abstract

This research aimed to take a holistic approach to assessing dry sow welfare in relation to gestation accommodation. Multiple factors that affect the welfare of a sow were considered. In addition, the multitude of systems in New Zealand that are used to accommodate dry sows in groups were captured. Commercial pig farms (n=20 farms, 7,912 sows total) were chosen to represent the spectrum of different layouts and management practices in order to obtain data from a wide range of different systems. During each on-farm visit, data concerning housing, management, sow behaviour, welfare and productivity were collected. A number of criteria were used to describe the farms (group size, stall duration, presence of bedding, feeding method, feeding frequency). Sows kept in stalls for more than 5 weeks (n = 3 farms) had significantly higher injury scores than sows that were in stalls for a shorter length of time or sows that were not kept in stalls for any period during mating or pregnancy. Sows fed twice daily had significantly higher stereotypies ($P<0.05$) than those fed at a different frequency. A welfare index (WI) was calculated for each farm. This index incorporated each farm's total scores for injuries, stereotypies, coat condition, soiling and lameness. A low WI represented a lower presence of indicators that were associated with compromises to welfare. Hence, a low WI represented good welfare. For each farm, the minimum possible WI was 0.33, whilst the maximum possible WI was 5.0. The mean WI was 0.65 (±0.14 SD). Overall, there was not a high prevalence of indicators of compromised welfare. Out of the 20 farms, with an average herd size of 395.60 sows per farm; only 10 sows in total were lame. Only three farms had sows with a coat condition score above 0 (normal). There was no difference between mean piglets born alive per litter (BA) for stalls (12.65±0.36) vs. group housed sows for the entire gestation (12.27 ± 0.43) , or for the number of piglets weaned per sow per year (stalls: 23.70±0.59 W/S/Y, groups: 24.92±1.23 W/S/Y). As a result of this study, it is clear that there is no perfect or ideal system for keeping dry sows, because a sow's needs change throughout different stages of the production cycle. Therefore the implication is that in any housing system, both the advantages and disadvantages relating to a sow's welfare will also change over time. In light of this, operators need to understand the variation both between and within systems and how best to manage them.

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INTRODUCTION

The housing of gestating sows is currently one of the most controversial issues in terms of animal welfare within the pork industry. A call for alternative housing options has received increasing attention as concerns over the confinement of sows in stalls and the restricted environment in which they are accommodated are raised by the public. Public submissions that were received during the 2010 review of the Animal Welfare (Pigs) Code of Welfare voiced unease over the intensive farming of pigs, and revealed a deep concern for the perceived welfare of pigs. As such, a large number of submissions called for the phasing out of sow stalls. A public perception of poor welfare and an increasing demand for ethically-produced animal products are drivers for change; however, there needs to be a balance between identifying and accommodating the actual needs of farmed animals and educating the public as to why certain practices are retained in the production system.

This is the current situation in New Zealand, where the continued use of gestation stalls for sows has been questioned. Stalls were introduced to make individualised management of breeding sows possible. Sow stalls enable sows to satisfy needs relating to access to food and water, avoidance of injury, and protection from aggression. Stalls also provide a safe environment for the stockperson to carry out routine husbandry tasks (i.e. mating and pregnancy detection), individual observation of sows, and enable efficient use of building space. Whilst there are behavioural and physical restrictions placed on sows in stalls, their overall productivity is comparable to or better than sows kept in groups throughout gestation (Nielsen 1995; Anil 2005). There is no definitive evidence to suggest that sows in stalls experience greater stress than those in groups (Curtis et al. 2009; Rhodes et al. 2005). Nevertheless, the 2010 Animal Welfare (Pigs) Code of Welfare has resulted in the phasing out of the use of stalls in New Zealand, with a complete ban enforced from December 2015 (NAWAC 2010). This is in recognition that there are now viable non-confinement alternatives to sow stalls that offer greater freedom of movement and socialisation. When managed correctly, the productivity of sows in these alternative systems can equal that of sows in stalls (NAWAC 2010). It was acknowledged that confinement in stalls does not meet all of the requirements of the Animal Welfare Act 1999, in that the behavioural needs of a closely-confined sow (regarding freedom of behavioural expression and freedom of movement) were not being accommodated adequately in close confinement.

There are a number of advantages to group housing. These include providing sows with more space, allowing social interaction between group members, and enabling sows to choose between available microenvironments within the accommodation area. Despite the numerous advantages sows in groups are subjected to compromised welfare with regard to the level of aggression experienced in a group situation, given that sows are hierarchical in nature and seek to attain dominance through fighting. However, sows kept in groups outdoors experience greater environmental enrichment, with the opportunity to escape agonistic behaviour due to a greater provision of space relative to indoor group-housed sows. Outdoor production systems are often perceived by the public as being better for the sows in terms of their wellbeing, yet within an outdoor system greater opportunity exists for compromised sow welfare. Such compromises are often described with regard to the lack of control over the sow's environment; the suitability of the genotype for outdoor production, challenges with achieving adequate thermoregulation, and parasitic burden. A failure to meet the unique requirements of an outdoor pig herd can result in high pig morbidity and mortality in addition to poor productivity and financial losses (Akos and Bilkei 2004).

It must be recognised that the *net* welfare outcome is important, as opposed to focusing on singular facets of what is considered to be essential to achieving a high standard of wellbeing for farmed animals. As such, there is no perfect system for keeping breeding sows. One of the reasons for this is that the physiological needs of a sow changes over time as gestation progresses, therefore the suitability of a particular housing system may be altered. This is demonstrated well in early pregnancy, when sow aggression and fighting is detrimental to embryonic development and subsequent litter size and sow productivity. As such the gestation stall has its place in protecting the sow prior to implantation. Whereas, in later in gestation, there is a different concern arising due to a mismatch between the sow's increasing size relative to the dimensions of the stall as pregnancy progresses.

There is confusion arising from conflicting reports as to the relative welfare and productivity of sows housed indoors (either in stalls, followed by groups or in a group situation for the entire gestation) or outdoors throughout gestation. This highlights the need for an analysis that is relevant to the unique New Zealand pig industry. The analysis needs to identify whether current concerns are warranted and what the implications may be for producers faced with legislative changes regarding the future of sow housing.

The purpose of this thesis is to capture the welfare status and productivity of group housed sows in New Zealand, through assessing multiple factors that affect the welfare of a sow. The overall aim was to highlight salient aspects of housing systems and sow management that New Zealand producers may utilise in the upcoming transition towards group housing for the entire gestation. The specific aims were to evaluate sow welfare and identify trends associated with potential welfare compromise in specific housing systems; and to demonstrate the relationship between net welfare outcome on-farm and sow productivity. Additionally, based on the conflicting literature that has reported differences in sow productivity between varying housing systems, this research aims to investigate the relationship between net welfare outcome on-farm, and sow productivity.

1. LITERATURE REVIEW

This review of the housing options for dry sows focuses on the welfare and productivity of sows in three main systems that are used in New Zealand: stall housing, indoor group housing and outdoor housing systems. This update is required by the New Zealand pork industry, as it faces future legislative changes in light of a recent renewal of the Animal Welfare (Pigs) Code of Welfare in December 2010 that will affect the current operation of many New Zealand piggeries. As such, the industry requires an update on the literature concerning the potential implications of converting to a different system.

The objective of this review is to characterise and compare the options available for accommodating pregnant sows in terms of their welfare and potential for production. This also includes a review of the literature on animal welfare; how an animal's welfare may be described and what is important to consider in an animal welfare assessment that addresses a comparison of available housing options for dry sows. The aim is to examine whether there are significant differences in the welfare and productivity of sows housed in varying systems, what the primary issues are within each system, and whether the current housing options available are capable of addressing these issues without any compromise to productivity or profitability within the industry.

1. The New Zealand Pig Industry

During the first half of the 20th century, pig production in New Zealand was aligned with the dairy industry, and served as a convenient means of utilising separated milk and whey surpluses (Gregory and Devine 1999). As such, the rapid expansion of the dairy industry in the North Island between 1900 and 1930 saw a simultaneous increase in pig production. After the pig population peaked in 1930, numbers declined. Whole milk collection from dairy farms was later introduced, and the late 1960s and early 1970s saw a sharp reduction in the routine feeding of pigs with separated milk and whey products (Gregory and Devine 1999). A shift towards cereal and grain diets followed, with a corresponding change in the location of pig farms whereby the majority of herds are located in the South Island.

Currently, there are approximately 200 commercial piggeries in New Zealand. The majority of sows in the North Island are housed indoors as outdoor production is generally unsuitable due to the soil type and topography. Conversely, approximately 60% of sows in the South Island are kept outdoors at some stage (Edge et al. 2007). Approximately 60% of production originates from the South Island, as this region produces the majority of grain and cereal crops used in the industry. The New Zealand pig industry is in the position to address current welfare concerns that are primarily centred on sow confinement. There is a wide diversity of non-confinement systems used in New Zealand, which also possesses a unique production system by virtue of geographical location and internationally comparable low disease status (Gregory and Devine 1999, Edge et al. 2007).

2. Animal Welfare

The characterisation of an animal's welfare status has been the source of much debate within the scientific community. Animal welfare is recognised as a subjective state within an animal, and as such, cannot be measured directly. It follows that the animal must be both sentient and conscious, as animal welfare encompasses *experienced* sensations that may be negative, neutral or positive (Mellor and Stafford 2009). These experiences are the culmination of integrated outcomes of sensory and other neural inputs from within the animal itself, in addition to its environment. The animal's welfare status will change as the balance of these inputs change. Indirect indices that represent the animal's experiences are available and relate to physiological, pathophysiological, and behavioural responses that may be observed to reflect the overall welfare status in the face of these changing inputs. Thus, the primary assumption is that these indices relate to positive or negative experiences within an animal. Additionally, the five domains (see Figure 1) describe areas of potential welfare compromise that encompass nutritional, environmental, health and behavioural risks to welfare that result in subjective experiences in the mental domain (Mellor and Stafford 2009). The five domains of potential animal welfare compromise were adapted from the original "five freedoms" listed in the Brambell Report (1965), and later expanded by the Farm Animal Welfare Council (1993).

At present, there are three main welfare orientations. The first is a *biological function* view, where welfare is good when the animal is healthy, growing and reproducing well, and good productivity is evident (Mellor and Stafford 2009). The second is the *affective state*, emphasising the potential for an animal to suffer or have positive experiences. Good welfare is present when animals are capable of adapting or coping without suffering whilst interacting with other animals, humans, and the environment. The final view is one of a *natural state,* and proposes that welfare may be compromised as a function of how far the conditions in which an animal is kept deviates from the presumed original wild state of the species, and the extent to which the animal is able to express their range of natural behaviours (Mellor and Stafford 2009). It follows that there is debate over the relevance of each orientation to an applied animal welfare assessment. Furthermore, different interpretations that result from an assessment of an animal's welfare status are due to value-based presuppositions about what is good or bad for animals (Fraser et al. 1997).

The concept that animal welfare is related to stress has grown since the 1960s (Volpato et al. 2009), and it was recognised that stressed animals would experience poor welfare conditions, as opposed to non-stressed animals experiencing good welfare conditions . It has also been put forward that animal "feelings" are an important welfare issue. As such, the affective state may also be considered in an animal welfare assessment. What the animal itself experiences, and how that will impact on the biological and behavioural features of the animal will continue to form the ever-evolving notion of what animal welfare is, and how those indices of welfare status may be integrated to form an overall assessment of animal welfare.

Figure 1: The five domains of potential animal welfare compromise (from Mellor and Stafford 2009).

Nutrition:	Water deprivation leading to *thirst*
	Food deprivation leading to *hunger*
	Nutrient imbalances (deficiency/excess) leading to *debility or weakness*
Environment:	Extremes of cold leading to *chilling* and *debilitating hypothermia*
	Extremes of heat leading to *hyperthermic distress*
	Injurious housing leading to *pain*
Health:	Disease, injury and functional impairment leading to, for instance, *breathlessness, nausea, sickness, pain, distress, fear or anxiety*
Behaviour:	Space restrictions, isolation or barren environments leading to, for instance, *boredom, frustration, loneliness or helplessness*
Mental:	Sensory inputs arising from compromise in the other four domains, plus cognitive inputs and related mental activity arising from external challenge (e.g. eliciting 'fight-flight-fright' responses), resulting in experienced sensations of *thirst, hunger, weakness, debility, breathlessness, nausea, sickness, pain, distress, fear, anxiety, helplessness, boredom*, and so on.

2.1. Using Animal Behaviour to Assess Welfare Status

Despite the controversy surrounding the various potential measures of welfare, animal behaviour remains a widely accepted indicator that is valued as an important component of an animal welfare assessment. It may be that behaviour is considered valuable due to it being a relatively obvious factor to observe, and that an animal displays changes in behaviour in a way that allows a rapid appraisal of whether the welfare of an animal may have changed. Behaviour is a valuable adjunct to physical health, and serves as a clinical symptom in its own right (Dawkins 2003). In addition, behavioural observations are generally non-intrusive and non-invasive. However, behavioural characteristics are subject to interpretation by humans, who associate certain behavioural characteristics with particular meanings. The recognition of some behavioural patterns and what they mean may be clear for some behaviours, whilst other behaviours may need to be interpreted with caution.

It may be useful to rule out the possibility of potentially compromised welfare status by focussing on the presence or performance of behaviours that indicate positive wellbeing. For example, signs of contentment may include play, social vocalisation/communication, foraging and exploration, and social grooming (Anil et al. 2002). The presence of positive experiences inferred from such behaviour may therefore be a valuable consideration, especially when there may be little expression of any obvious behavioural patterns that may indicate otherwise. It may be that an animal's behavioural repertoire is made up of behavioural needs and wants. This infers that some behavioural patterns may be necessary, whilst others are 'luxuries'. It may be surmised that the prevention of behavioural *needs* is deleterious to an animal's welfare. When considering behavioural needs, the motivation to perform those needs is an important concern (Gonyou 1994; Volpato 2009). It may be that the drive to perform certain behaviours builds up within the animal if it is deprived of releasing stimuli (Jensen and Toates 1993). In this context, a behavioural need may be considered a state that causes suffering in an animal if it is not attained, and may be expressed through abnormal behaviour, increased risk of pathology, or abnormal levels of hormone secretion (Jensen and Toates 1993). It is widely believed that thwarting a species-specific behaviour may lead to reduced welfare, in proportion to the strength of motivation of the behaviour and the effect of preventing the outcome of the thwarted behaviour (Gonyou 1994). However, it is equally important to recognise that behavioural needs change with context.

In terms of assessing an animal's welfare, the issue of accommodating an animal's natural behaviour is often raised. However, this assumes that animals that live in a natural or wild state are all in good condition and experience good welfare, which may not be the case (Volpato et al. 2009). It may be that the goal in animal welfare is to accommodate as much behaviour as possible, without considering any as being essential for animal wellbeing. In this approach, there is no ranking that denotes one particular behaviour as being more important than another. However, therein lies the problem of identifying which behaviours are normal, and what is required for those to be satisfied. This idea also assumes that animals that achieve normal or natural behaviour are in a good state of welfare. However, it may be argued that certain behaviours *are* essential, and as such, more important to the animal in terms of its welfare.

Stereotypical behaviour in particular can be a valuable indicator of whether an animal is in a poor state of welfare. Stereotypical behaviour is considered abnormal behaviour typically associated with boredom or frustration, and is associated with a type of restraint or confinement (Barnett and Hemsworth 1990). Stereotypies are generally environment specific and may involve thwarted behavioural patterns. It is generally agreed that the presence of behavioural stereotypes represent poor welfare, and there may be a relationship between stereotypies and stress that could substantiate this. It may be that there is some evidence of changes to physiological parameters that are associated with stereotypical behaviours. In Sharman (1983), snout rubbing was induced in pigs by drugs that stimulate or inhibit brain receptors. It has also been proposed that the performance of these behaviours may serve to help animals cope with a conflict, or environmental stressors. Conversely, it was put forward that the concept of stereotypical behaviour can be difficult to interpret in welfare terms (Dawkins 2003). This arises through focussing on the consequences of these behaviours. Where injury results, it is clear that behaviour is a sign of poor welfare. However, where no overt injury is apparent, interpretation is more difficult.

Oral-nasal-facial (ONF) behaviour is a normal and frequent pattern of behaviour in pigs, in that the pig investigates its environment primarily with its head (the face, nose, mouth and the associated senses of vision, taste, and smell) (Curtis et al. 2009). Some of these behaviours, such as bar biting and sham chewing, are presumed to be ‘affect displays’ , particularly when they are classified as stereotypic in nature. Oral-nasal-facial stereotypies manifest as apparent misdirected or repetitive non-functional behaviours whereas highly functional ONF behaviours include eating, drinking and rooting (Curtis et al. 2009). Evaluations of the adaptation of sows to different types of accommodation often measure the duration and frequency of non-eating ONF activities. However, ONF stereotypies seem to be more related to the individual characteristics of sows as opposed to the accommodation environment, as the tendency to develop stereotypic ONF behaviours is related to age and parity of the sow (von Borell and Hurnik 1991; Vieuille-Thomas et al. 1995), and sows exhibiting stereotypic ONF behaviours have been observed both in group and individual sow housing systems. A comparison of sow housing systems that is based on the frequency and/or intensity of ONF behaviours alone is therefore inadequate. This arises as environmental features (e.g. bars, soil) will influence the expression of such behaviours, without it being obvious as to whether there is any significance with regard to an animal’s welfare status. It was concluded that ONF behaviours such as bar-biting are not useful measures for differentiating sow welfare across different housing systems (McGlone et al. 2004).

3. Sow Aggression and Social Behaviour

Grouped pigs establish a hierarchical social ranking that is ultimately achieved through aggressive interactions. In established groups, these confrontations are relatively regulated, and of a lower intensity than would be observed between unfamiliar animals. Fighting behaviour is essentially a tool that settles disputes between pigs; and it follows that an initial encounter between unfamiliar pigs results in a demonstration of aggression that is not far removed from that of their wild conspecifics. The retention of these fighting tactics by domestic sows is broadly similar for all age groups (Petherick and Blackshaw 1987), and is based on offensive moves whereby an animal attempts to bite its opponent, and defensive moves in which an animal attempts to avoid being bitten (Rushen and Pajor 1987).

In a natural environment, pigs are social animals, preferring to exist in small herds that consist of a few related sows and several generations of related female offspring (Stolba and Wood-Gush 1989). This formation is socially stable, with a strict dominance hierarchy in place that is based primarily on age and physical size. Aggression in the wild is infrequent, rarely results in injury, and this is primarily limited to assembly at a food source, disputes over favoured lying spaces, or invasion of unknown pigs into a territory that is already occupied and defended by a sow group (Stolba and Wood-Gush 1989). To reduce the opportunity for aggressive encounters, pigs will observe an avoidance order and maintain a certain distance from each other (Turner et al. 2006). Pigs use threats and other nonaggressive behaviours to maintain a dominance configuration within a group, which is aided by their natural habitat providing areas of refuge from other pigs. It follows that the social behaviour of sows has withstood generations of genetic selection pressure that has focussed upon economically significant traits within the commercial industry, and that this warrants consideration in the design and management of sow housing systems.

The establishment of sow groups in modern production systems may be necessarily arbitrary, and as such, not always conducive to the normal social organisation process that would be adopted naturally amongst sows. Relative to natural or semi-natural conditions, this may be seen as a form of artificial grouping in some circumstances, which creates an environment where aggressive flare-ups occur (Curtis et al. 2009). Such interactions are physically injurious as well as physiologically and psychologically stressful, and may indicate a failure to adapt to the forced proximity to unfamiliar sows. Thus, the challenge in modern pig production is to manage this aggression whilst providing pigs the opportunity to engage in a greater range of behaviours than is afforded in individual housing systems.

The level of stress and the injuries inflicted by mixing unfamiliar sows remains a significant welfare concern. In newly-formed groups of sows, almost all individuals are involved in agonistic interactions, which contribute to the rapid establishment of a dominance order between unacquainted pigs (Arey and Edwards 1998). The composition of the group may influence the frequency of aggressive interactions between sows. In general, larger group members initiate and win most fights, and there appears to be a positive correlation between social rank of sows and their weight, age, and parity (Arey and Edwards 1998). In the wild, the maintenance of the dominance hierarchy is facilitated by the extensive setting, whereby a sow can readily escape an aggressive encounter by moving away. However, when sows in a social group are gradually provided less space it follows that there are higher incidences of fighting and injury within a group. Thus, the ability of subordinate sows to perform avoidance behaviour in the face of a threat of aggression is thought to be the most important factor regulating social stability within a group (Weng et al. 1998). As such, the composition of the group, in terms of the proportion of sows that act as aggressors versus the proportion that exhibit consistent avoidance activities, is likely to influence the overall dynamic of the group.

There is no defined maximum for group size. Where sows have been kept in large groups of 300 or more, there have been no obvious detrimental effects associated with the social dynamic and aggression levels within the group (Spoolder et al. 2009). It is likely that, at such large group sizes, pigs fail to individually identify and remember all group members. As a result sows are less likely to engage in aggressive interactions; instead they express avoidance behaviour (Turner and Edwards 2000). Large groups are often operated as dynamic groups, and research has suggested that aggression towards newly-introduced sows may be influenced by the replacement rate, as replacing 10% or less of a dynamic group with new sows compromises the welfare of those sows (O'Connell et al. 2004).

Whilst fighting, pigs attempt to target the head, neck and ears of their opponent, resulting in superficial skin lesions that are predominantly concentrated around the front third of the body, or flanks when delivered in the reverse parallel posture (McGlone 1985; Fraser and Rushen 1987). In a commercial situation, pigs may be regularly confronted with sudden mixing episodes with the introduction of unfamiliar animals into an environment that has limitations in regard to the effective dispersal and display of appropriate avoidance behaviour (Turner et al. 2006). The presence and severity of skin lesions are used as an indication of the degree of aggression within a group of pigs, as well as reflecting the quality of an animal's physical and social environment (Leeb et al. 2001). The use of lesion scores has been identified as a means of rapidly assessing the level of aggression within a group of pigs mixed under a commercial situation and can be an indicator of welfare status (Barnett et al. 1996; Leeb et al. 2001).

The formation of social hierarchy in sows is a complex process. An important aspect of any system that requires sow groups to be formed is the length of time it takes for aggression to subside and for a relatively stable social structure to form. This may influence the degree of distress that is experienced by sows. The literature reports significant variation in the time taken for aggression to subside, which may be more reflective of the general skill level of stockpersons and husbandry practices on different farms. However, it is agreed that social stress is related to several detrimental consequences for sow productivity including delayed oestrus, abortion, increased farrowing time and agalactia (Arey 1999). The length of time it takes for aggression to subside and for groups of sows to become relatively stable has been reported to occur anywhere from 3 to 10 days post-mixing (Van Putten and Van de Burgwal 1990; Oldigs et al. 1992). Other studies have reported much longer periods before sows are fully integrated into new social hierarchies. An investigation of the time course for the formation of socially stable groups was carried out, and found that upon mixing sows into groups that were comprised of both familiar and unfamiliar sows, the number of fights that were observed over a 24 hour period ranged from 2-8 per group of 6 sows, with an average fight duration of 70 seconds (Arey 1999). Over 93% of fights were between sows that were previously unfamiliar with one another, and the group with the most unfamiliar sows had the highest frequency of fights in that period (Arey 1999).

However, levels of fighting can be highly variable, and may be caused by group composition in that only a small proportion of pigs may be engaging in aggressive behaviour whilst the majority mainly receive aggression. In Arey (1999), 24 sows were weaned (day 1) and randomly mixed into service pens in groups of six, mated on day five and then transferred into gestation pens at day 28. On days 28, 56 and 84, the sows were transferred into a large straw-bedded test pen (5.75 x 13m) for 3 days, where aggression scores were recorded. Aggression was observed to decline rapidly after mixing and the groups became relatively stable after 7 days as indicated by the rapid reduction in lesion scores a week after mixing (Table 1). It may, however take up to 21 days for the complete integration of unfamiliar sows, as was suggested by Moore et al. (1993) and Spoolder et al. (1996) after analysis of nearest neighbour distances following a merger of two sow groups. In such instances, sows remain segregated as two sub-groups that occupy different areas of the pen until random intermingling occurs.

Table 1: Lesion scores and aggression scores during feeding (from Arey 1999).

Day	n (sows)	Lesion Score (median and range)	Aggression Score (median and range)
1 (prior to mixing)	24	0 (0-7)	-
3	24	9.5 (0-28)	-
7	24	6.5 (0-22)	-
28	24	4.0 (0-17)	5.5 (1-52)
56	24	5.0 (0-18)	2.5 (0-33)
84	24	6.0 (0-15)	2.0 (0-28)

There is evidence that sows are able to recognise each other after being separated for up to 6 weeks as is commonly practiced when sows are individually housed in farrowing crates. Aggressive interactions continue amongst familiar animals, though at much lower levels, unless resources are limited. As such, there appears to be higher levels of aggression when sows are kept in dynamic groups where individuals are regularly removed prior to farrowing and unfamiliar sows are added at weaning. This is in contrast to static groups, where once a group of sows is established no new members are added.

Sows kept in stalls often exhibit aggressive behaviour that is directed at neighbouring sows. The duration of this behaviour has been observed to be high, most likely due to the inability to satisfactorily resolve such encounters (Barnett et al. 1987a, Broom et al. 1995). Whilst there is normally no injury resulting from these interactions, it is probable that anxiety, fear and frustration are experienced by those animals involved. Vertical bars, as opposed to horizontal bars between pigs in adjacent stalls reduced the level of stress experienced as well as the aggressive behaviour (Barnett et al. 1991). These modifications are clear examples of how the design and management of the housing system, can exhibit a direct effect on animal welfare.

3.1. Aggression and Feeding

It follows that there are several management and design features of group housing systems that may be implemented in order to reduce the level of aggression within a group of sows. As mentioned previously, fighting generally occurs at mixing. After the social stabilisation of the group, agonistic behaviour is generally associated with feeding competition. Therefore, the feed delivery system can influence the degree of aggression at feeding.

Under natural conditions sows synchronise feeding behaviour, engaging in multiple peaks of feeding activity throughout the day. Conversely under the majority of commercial systems, sows are fed a restricted amount that is generally delivered and consumed in a single meal that is eaten in 15-20 minutes (Marchant-Forde 2009). The objective of this is to prevent excessive body weight gain and fat deposition, in addition to potential dystocia complications at farrowing. Floor feeding can lead to highly competitive behaviour, giving rise to aggression at feeding time as sows fight for access (Arey, 1999). Dominant sows may monopolise the feed if its distribution is not wide enough. The aggression can be better managed by ensuring that the feeding area is widespread, that the group is relatively uniformly sized and group members have similar rates of feeding (Gonyou 2005). Similar issues are seen with trough feeding where a trough that is free from partitions can allow high levels of aggression and overfeeding of more aggressive sows, at the expense of lower ranked individuals. However, this may be improved by introducing a wet feed, or using dividers that create individual feeding places (Marchant-Forde 2009).

Trickle feeding allows each sow in the group an individual cubicle or short stall, into which feed is slowly delivered. Feed is distributed at the same rate that the sows consume it, preventing accumulation of feed at the location of the slower eaters which discourages others from moving from space to space in an attempt to steal feed from other sows (Gonyou 2005). Electronic sow feeders (ESF) however, provide one feeder per group of sows, and can be accessed by each sow in turn. The advantage of this system is that each sow is fed in isolation and sows are fed as per their individual requirements. This enables those that are in poor condition to be fed a higher allowance. However, a group of sows prefer to feed at the same time, and as such the design and location of the feeder influences the opportunity for bouts of aggression whilst queuing at the feeder. The consequence of sequential feeding that is that the entrance to the feeder can become a focus for activity for much of the day. Coupled with access to a limited feed source, agonistic behaviour may result. There is also the likelihood of dominant sows making several non-feeding visits after receiving their daily ration, thus restricting access by lower ranked sows. A major concern in ESF systems is the incidence of vulva biting (Levis 2007). This is associated with frustration as sows queue behind each other waiting for access to the feeder. It has been suggested that providing a forage material such as straw in the lying area as well as beginning the feeding cycle overnight (Jensen et al. 2000) can reduce the incidence of aggression in ESF systems.

The level of aggression and activity in herds with ESF was compared over four different farms by researchers in Denmark using behavioural observations (Jensen et al. 2000). Behavioural data was collected via 24-hour video recordings that were made over a period of eight months. Six 24-hour recordings were selected per herd for analysis. Analyses indicated that the majority of agonistic behaviour that was displayed coincided with the initiation of feeding, and continued thereafter. In the feeding area and in the total pen area, the frequency of aggression was significantly higher than in the non-feeding period (Jensen et al. 2000). Both the intensity and frequency of aggression was higher in herds that did not have straw bedding. As such, it appears that it was a difference between the management of individual herds that accounted for the variation in the frequency and intensity of aggression among herds using electronic sow feeders.

The individual feeding stalls allow sows to be shut in whilst feeding, offering a relatively high degree of protection. A primary advantage of this system is that it enables sows to be fed simultaneously, in contrast to the electronic sow feeder, whilst controlling each individual's correct dietary ration. Where group sizes are small and socially stable and sows are uniformly sized, confinement whilst feeding may not be necessary. In this situation feeding stalls are used as individual feeding stations rather than lockable stalls. However, they may serve a dual purpose for those that seek protection from overly aggressive sows within the group.

4. Stress and Early Pregnancy

Stress may be described as the inability of an animal to adapt to or cope with its environment. Moberg (1993) described stress as the biological response to an event (a stressor) that an individual perceives as a threat to its homeostasis. In response to a stressful stimulus, endogenous adrenocorticotropic hormone (ACTH) is released by the anterior pituitary gland. The target organ of ACTH is the adrenal cortex, which is stimulated to produce and release cortisol (Brandt et al. 2009). Stress also leads to the activation of the sympathetic nervous system and the adrenal medulla, which results in the release of catecholamines (noradrenaline and adrenaline). The elevation of circulating concentrations of adrenaline, noradrenaline and cortisol induced by stress results in increased heart rate, blood pressure, dilation of pupils, decreased gut motility, pupil dilation, glucose mobilisation, increased rates of lipolysis and immune suppression (Edge et al. 2007; Brandt et al. 2009; Razdan 2004). Stress also results in behavioural stereotypies and behaviour associated with anxiety and fear.

In pigs, the peripheral concentration of cortisol is an accepted indicator of stress. However, it should be noted that this association is somewhat simplistic as cortisol is also released in response to events or activities that would not be considered stressful, such as feeding or mating (Turner and Tilbrook 2005). Adrenocorticotropic hormone (either directly or through cortisol) has an effect on many organ system functions, including the reproductive system, in addition to influencing many hormonal pathways. Repeated injections of sows with synthetic ACTH on a 4 hourly basis mimic the effects of chronic environmental stress. Such experiments have shown a response in the patterns of hormonal secretions, such as an increase in the concentration of progesterone, luteinising hormone (LH) and inhibin α, and possibly a reduction in the concentration of oestradiol (Brandt et al. 2007b). The observed peak in plasma progesterone following ACTH administration was concomitant with the peak in plasma cortisol immediately after ovulation in another experiment (Razdan 2004). This is believed to originate from a release of progesterone from the adrenal glands.

The evaluation of stress is difficult, especially in a long-term situation where it may be a chronic condition. The two key hypotheses regarding the impact of stress on the reproduction of females (Turner and Tilbrook 2006) are that: A) prolonged stress impairs reproductive functionality; and B) reproduction in females is particularly vulnerable to the impact of acute stress during the specifically-timed series of endocrine events in the lead-up to oestrus and ovulation. Turner et al. (2005) showed that ovulation is only disturbed in sows that exhibited a chronic elevation of cortisol, and that repeated injections of cortisol did not disrupt ovulation. This may also be the case in early pregnancy, where no negative effects are observed on embryo survival in the event that present stressors do not lead to chronic elevation of cortisol. Alternatively, the reason for this may be that in experimental conditions, where typically only one stressor is evaluated at one time, whereas a combination of stressors may influence embryo mortality on-farm (Spoolder et al. 2009).

Administration of exogenous ACTH to sows has been shown to delay the onset of oestrus, suppress oestrus activity and also result in the development of cystic ovarian follicles (Liptrap 1970). Previous studies have shown that elevated concentrations of progesterone will have a strong inhibitory effect on LH release (Harris et al. 1999), with consequences on the functions of the oviduct, uterus and ovary (Brandt et al. 2009). The most vulnerable stages of reproduction are likely to be ovulation, the expression of oestrus behaviour, and embryonic implantation, as these events are controlled by the neuroendocrine system. It is crucial that oestrous behaviour and ovulation occur concurrently and with suitable timing, to allow the sow to be mated at a time that coincides with the period of optimal fertility. As such, disruption of any of the events of the oestrous cycle, or the timing of these events, has the potential to disrupt reproductive function.

4.1. Timing of Mixing Relative to Stage of Gestation

The housing system of gestating sows must be considered as a potential stressor in itself, given that aggressive interactions amongst sows are inevitable. This clearly applies to group housing systems, where it has been suggested that the timing of mixing relative to the stage of pregnancy can be instrumental in whether a pregnancy will be detrimentally affected. The timing of mixing is critical due to its influence upon many factors. Submissive sows within a group are likely to be the most vulnerable, as it is not uncommon for low ranked individuals to be subjected to a period of food restriction or deprivation. Depending on the severity of nutrient deprivation and the associated stress that it induces, this may lead to adrenal activation. Subsequently, a corresponding elevation of cortisol and progesterone concentrations may result, which has been implicated in embryonic losses (Edge et al. 2007). Low-ranked sows have been shown to have higher basal plasma cortisol levels and a lower total weight of live-born piglets compared to more dominant sows. Thus the effect of group housing on adrenal activation and stress in an individual female may be a consequence of the rank of that individual. Other factors such as the composition and size of the group may also be important.

There are contradictory results from examining the effect of mixing mated sows prior to and during embryonic implantation. It is apparent that environmental, social and nutritional disturbances that are experienced during early pregnancy can have detrimental consequences for embryo development and survival. These were the primary reasons for the introduction of individual gestation accommodation for sows. A large study of the performance of sows housed in dynamic groups has been carried out. It was observed that when sows were introduced to the group at 1-8 days post mating the return rate was 20%, whereas grouping the sows during the fourth week of pregnancy reduced the return rate significantly to 10% (Bokma 1990). Another investigation of the timing of grouping sows found that regrouping on the second day after mating gave the highest farrowing rate whereas regrouping on day 14 gave the lowest farrowing rate (Table 2). However, litter size was not significantly affected by the time of regrouping (Kirkwood and Zanella 2005). Conversely, it has been disputed as to whether the individual housing of sows during pregnancy has a beneficial influence on pregnancy rates and litter sizes (van Wettere et al. 2008). It may be that the aggression that is experienced at mixing acts as a short-term stressor. Thus, provided that it does not coincide with a critical stage of the reproductive cycle, detrimental effects may be avoided.

Table 2: Effect of gestational age at grouping on the fertility of group-housed sows (from Kirkwood and Zanella 2005).

Grouping day	Farrowing rate	Litter size (total)
2	86.0% (43/50)[a]	11.1±0.6
7	81.6% (40/49)	11.2±0.6
14	69.8% (37/53)[b]	11.9±0.6
21	75.5% (40/53)	11.8±0.6
28	76.0% (38/50)	11.3±0.6

Values with superscripts a and b differ significantly $P<0.05$.

The effect of stress during oestrus on the fertilisation rate and early development of embryos has been investigated. This has been carried out by stimulating stress through administering ACTH at oestrus. Sows were inseminated and anaesthetised at 48 or 60 hours post-ovulation, and results indicated that significantly fewer oocytes/ embryos were recovered from the ACTH-treated group than from the control group (51% vs. 81% $p<0.05$) (Brandt et al. 2007a).

During ovulation and early pregnancy, the patterns of hormonal secretions are altered. After fertilisation, the developing embryos synthesise and secrete oestrogens (Pusateri et al. 1996). This is critical as during the maternal recognition of pregnancy, the maintenance of pregnancy is entirely dependent on the secretion of conceptus-origin oestrogen. The maternal recognition of pregnancy in the pig is completed by day 18 of gestation. After this time, circulating oestrogen concentrations rapidly decline and remain at low levels throughout pregnancy.

Progesterone levels are relatively low prior to the onset of oestrus and during ovulation, but rapidly increase at conception. The circulating progesterone concentration peaks at approximately the 4th week of gestation in conjunction with the completion of placental development. Therefore, progesterone remains at a relatively high but constant concentration until immediately prior to parturition. Metabolites of progesterone are known to have a calming anxiolytic (anti-anxiety) effect on behaviour, and analogues of progesterone are used as anaesthetics and sedatives (Bitran et al. 1995; NAWAC 2003). The calming effect of progesterone may explain the behaviour of the sow in relation to the reproductive cycle. Sows are more aggressive during the period following weaning including at mating and soon after, when circulating progesterone levels are low. An increase in aggressive behaviour is also observed immediately prior to farrowing.

Thus, the justification for using a form of individual accommodation such as a sow stall post-weaning can be clearly related to the endocrinology of the sow at this time, with particular emphasis on the concentration of progesterone. Isolating sows at this time prevents injuries and stress associated with aggression and fighting, and enables the completion of the mechanism by which the maternal recognition of pregnancy occurs. Once implantation and placentation is complete, progesterone levels are high and have reached a plateau. This is likely to correspond to a behavioural alteration that reduces the aggressiveness of sows. As a result, a more favourable time to begin the formation of sow groups is after the 4th week of pregnancy; although, it is worth noting that there is no apparent literature that has investigated the effect of mixing sows after 28 days post-mating. Furthermore, it has been suggested that repeated periods of acute stress and elevation of cortisol in the period preceding oestrus and ovulation may not directly impact sow fertility. Nonetheless, fertility may be compromised if the stress is relatively prolonged or severe. In some cases, with group housing in particular, there would be a high probability of prolonged stress due to aggression at mixing, followed by aggressive behaviour at feeding time/s (Kirkwood and Zanella 2005). As such, this has reinforced the recommendation that sows should not be mixed prior to the completion of embryonic implantation at the 28th day of gestation.

5. Sow Housing Options

Approximately 40% of pigs in New Zealand are outdoors or stall-free whilst the remainder are housed indoors. Indoor systems encompass a multitude of possible configurations that may involve the use of stalls for a varying duration at some point in the production system. However, less than 10% of breeding sows in New Zealand spend more than 6 weeks in sow stalls. This percentage is continuing to fall as producers transition towards group housing.

Table 3: Percentages of sows housed in different systems in New Zealand (from: Sow Housing Survey October 2009, NZPIB).

	% farms	**% sows**
In stalls for > 4 weeks per gestation	28%	25%
In stalls for < 4 weeks pre gestation	21%	16%
Indoor group housed	35%	18%
Outdoor housed sows	44%	41%
Multiple systems (transitioning)	25%	-

Despite these statistics, a negative public perception of the use of individual stalls to house gestating sows remains a source of concern for the New Zealand pig industry. In New Zealand, the welfare of sows in gestation housing systems has gained national attention. As such there was a call to regulate the amount of time that a sow spends in an individual sow stall, with the ultimate objective being the complete phasing out of individual confinement. The 2010 review of the Animal Welfare (Pigs) Code of Welfare states that after December 31st 2012 a sow will be limited to a maximum period of 4 weeks in an individual stall following mating. The National Animal Welfare Advisory Committee (NAWAC) states that the use of individual sow stalls should eventually be phased out entirely in New Zealand, but only when key criteria can be met (NAWAC 2010). These criteria include the availability of alternative technology, in addition to management systems which deliver better welfare outcomes overall, at a practical and economic cost that enables New Zealand producers to remain competitive in the international market (NAWAC 2010). Consequently, after December 2015, sows and gilts must not be confined in a stall after mating. It follows that the advantages of current systems should be retained while solutions should be sought to overcome the problems that have been identified.

Public concern about how sows are housed most often relates to restrictions on a sow's freedom of movement. Individual housing in stalls does not conform to what may be observed in a semi-natural environment. However, there is little evidence to suggest that being housed in a stall is, by itself, aversive to sows provided that there is visual and other contact with other animals (Rhodes et al. 2005). Research indicates that generally accepted measures of physiologic stress are similar for sows housed in individual stalls and in group pens (Barnett et al. 1987a; Barnett et al. 1989; Tsuma et al. 1996), and that no differences in serum cortisol concentrations were evident between sows housed in stalls and those housed in group pens.

Dry sow stalls manage the negative aspects of hierarchical aggression including the potentially detrimental effects on the welfare of individuals and on embryonic and fetal survival as a result. In addition, stalls enable the individual management of nutrition, health, hygiene and social stress in the first critical weeks of pregnancy. These benefits need to be balanced against any costs associated with restriction of movement and behavioural limitations. Alternatives to sow stalls exist; however, it must be recognised that in terms of welfare and productivity there is no perfect system. Regardless of the production system that is in place, there will be inherent problems and specific risks to the welfare status of the animals involved. The degrees to which these problems manifest are primarily determined by the extent that stockhandlers properly manage any such problems. A thorough understanding of the nature of dry sows when grouped together must precede any such system being adopted. A transition into group housing systems in the absence of adequate knowledge and skills may unintentionally negatively influence sow performance, health, and welfare.

The perception that housing systems can be classified as either stalls or group pens is overly simplistic. In considering different sow housing options, there may be in excess of 72 different permutations regarding group housing systems (Gonyou 2005). These permutations include varying group sizes, stocking densities, feeding systems and feeding methods, bedding type and flooring types, manure handling facilities, group management, behavioural and disease management, in addition to several other features (see Figure 2). The lack of a 'standard system' of housing within the industry accounts for the variation regarding the inherent positive and negative features that are evident across different farms within the country. This makes a direct comparison of alternative systems difficult, however the salient features that make a production system succeed or fail can be identified.

As experimental results accumulate, it is clear that each feature of a housing system will have both advantages and disadvantages in terms of animal welfare as well as productivity and profitability. The other mitigating factor concerning housing design is that, once combined, not all combinations of different features included in a housing system will result in a successful outcome. Approximately 37 characteristics of housing systems that relate to sow welfare have been identified (Gonyou 2005). It has been proposed that weighting factors be attached to these characteristics in an effort to rank and compare different systems. These weighting factors would, however, be dependent on value judgements made by those setting them, and would invite considerable criticism.

Furthermore, selecting a housing system for gestating sows based on a single welfare issue (such as freedom of movement) has the potential to lead to other compromises to animal welfare as new issues arise or other issues are exacerbated. It is clear that no single 'optimal' or 'ideal' housing system has been developed. Possible reasons for this are that the majority of studies have not used a holistic approach in evaluating the relative suitability of differing systems. Such studies may compare systems without considering all of the features within those systems that can influence how a sow responds to and interacts with the environment (Salak-Johnson and Curtis 2007).

Figure 2: Factors involved with the design and management of housing sows and gilts in groups (from Levis 2007).

Number of animals per pen Size of animals per pen Floor space per animal Type of flooring: • Total slats • Partial slats • Solid concrete • Bedding Thermal comfort: • Heating system • Ventilation/Cooling system • Use of mould-free bedding Height of pen partitions : • Vertical bars • Horizontal bars Composition of group: • Stable • Dynamic (frequently changing) Reproductive performance Capital and operating cost Establishing of "hospital" area: • Lame and injured sows • Sick sows • Non competitive sow Aggression: • Time and method of mixing • Time and method of feeding • During daily activity of animal Method of watering animals: • Animals per drinker • Type of drinker Time and method of mixing: • At weaning • Immediately after breeding • At 35 to 42 days of gestation • Rate of morbidity & mortality	Method of feeding: • Mechanical • Non-mechanical • Floor feeding • Dump feed in a pile • Dump with spinner to spread feed • Individual feed drops • Interval feeding • Trickle feeding • Locked feeding stall • Unlocked feeding stall • Self-locking feeding stall • Electronic sow feeder Urination & defecation area Eating area Boar housing area Skill and attitude of staff Geographic location Genetic composition of sows Temperament of sows Complexity of accomplishing work tasks: • Oestrous detection • Artificial insemination of sows & gilts • Natural mating of animals • Moving animals • Feeding animals • Treating sick animals • Use of pregnancy detection device • Daily observation of animals • Locating a specific animal Ease of overall management

A computer model has been designed to evaluate the welfare of pregnant sows in a variety of housing and management systems. The SOWEL model (Bracke et al. 2002) identifies and assigns a weighting factor to welfare-relevant attributes of housing systems in relation to a sow's needs (categorised as feed intake, thermoregulation, elimination, exploration, rest and locomotion). This model encompasses 15 different housing systems and weighting factors for 20 attributes (see Table 4). This model was validated by comparing the model calculations with expert opinions that were attained through a questionnaire distributed to 29 pig welfare experts. Both the welfare scores and weighting factors that were assigned by the model correlated significantly ($P<0.05$) with expert opinion.

Using the SOWEL model, welfare is assessed based on the biological needs of the sows. Each need is assessed using welfare-relevant attributes (measurable properties) of the housing system. These attributes may be animal-based, environment-based, or management-related. Other studies have collected data from different farms, and compared the productivity and welfare of sows housed in different systems. Kongstead (2006) chose 14 herds that represented different layouts and management practices when investigating the relationship between reproductive performance, feed intake, fear, and stress in group housed pregnant sows. This was to ensure that correlations found could be linked to different systems. Data was collected on each experimental sow (553 sows in total), which were randomly chosen in the lactation unit on the day of weaning. Data included the weaning date, the dates of first service and re-mating for sows that returned to heat after first service, the farrowing date, the number of piglets born and the date and reasons for culling.

Table 4: Weighting factors for 20 welfare-relevant attributes ranked according to the weighting factors calculated by the SOWEL model (scale of 1-10) and compared to expert opinion (from Bracke et al. 2002).

Attribute	Model	Experts[a]	Friedman mean rank[b]	Friedman multiple comparison[bc]
Space per pen	10.0	8.00	13.42	wxy
Health and hygiene status	9.06	8.57	13.68	wx
Exposure to cold	8.21	5.00	8.32	xyz
Foraging and bulk	8.11	7.89	15..29	w
Social stability	7.45	7.14	13.66	wx
Social contact	6.60	8.94	15.82	w
Food agonism	6.23	7.89	14.58	wx
Rooting substrate	5.09	7.57	13.37	wxy
Synchronisation	3.96	5.00	9.00	wxyz
Water availability	3.77	8.54	15.79	w
Separate rest and elimination areas	3.40	5.00	8.95	wxyz
Scratching	2.74	2.36	5.32	z
Resting comfort	2.26	5.00	9.32	wxyz
Air quality	2.26	5.63	10.05	wxyz
Food palatability	1.23	3.17	6.21	z
Movement and comfort	1.13	7.14	13.21	wxy
Nest building (resting)	1.13	2.68	6.55	yz
Visually isolated areas	0.28	3.75	6.55	yz
Light	0.19	3.88	5.66	z
Wallowing	0.00	1.38	5.26	z

[a]The median weighting factor given by the experts (n=22).
[b]Friedman mean ranks and significant differences from the Friedman multiple comparisons test (Model vs. Experts) using data from all experts who did not have missing values (n=19).
[c]Attributes that do not share a single letter differ significantly (P <0.05)

It was found that the percentage of re-mated sows varied from 0% to 45% and the percentage of culled sows from 0 to 12% across farms. The percentage of gilts varied from 3-50% between herds, and this may be responsible for the large range in the percentage of re-mated sows after first post-weaning service.

5.1. Indoor Group Housing

Several advantages have been reported in terms of animal welfare when sows are housed in group accommodation. These include:

- Greater freedom of movement;
- Individual choice among available microenvironments (Salak-Johnson and Curtis 2007);
- More opportunity for social interactions;
- Improved cardiovascular fitness (Marchant et al. 1997);
- Improved muscle weight and bone strength (Marchant and Broom 1996);
- Decreased morbidity (Tillon and Madec 1984);
- Less abnormal behaviour (Broom 1983).

The benefits of group housing systems largely depend on group structure. The use of large dynamic groups has been reported to be more cost-effective when combined with electronic sow feeders to ensure accurate feed rationing. This configuration allows greater space per sow. However, the regular changes to the composition of large dynamic groups is associated with high levels of aggression. The successful functioning of large dynamic groups may be attributed to the utilisation of subgroup behaviour (Edwards et al. 1993), thus establishing spatially separate territories and socially stable relationships between subgroup members (Durrell et al. 2003). This may be achieved by pre-mixing small groups of sows in order to establish stable social relationships with each other prior to their introduction into the larger dynamic group. Clearly the emphasis upon which skills of the operators and stockmen are most important will vary across different systems. In group housing operations, the three key skills for maintaining sow performance in a group system are as follows:

- The ability to identify sows in the group that are unable to compete with others or have been injured, in order to provide extra care;
- Taking appropriate actions to look after the sows that are unable to fully compete or adapt in these systems;
- Undertake suitable handling techniques for sorting individual animals from a group, to eliminate animal stress and the potential for human injury.

Space allowance also influences the success of a group system. There is a need for a balance between the efficient use of space and the provision of enough space to enable escape behaviour and segregation of the pen into microenvironments that allow separate eating, dunging and sleeping areas. A study investigating the effect of differing space allowances in group housed gestating sows observed differences in litter traits, sow body condition, and lesion scores with varying treatments (Salak-Johnson et al. 2007). These traits were analysed at different stages; the first two weeks after mixing (phase 1) and weekly throughout the duration of the study (phase 2) measured over two consecutive farrowings. Sow body condition score (BCS) was affected by floor space, with sows in pens at either 2.3 or 3.3 m^2 floor space per sow having greater BCS than sows at 1.4 m^2 (Salak-Johnson et al. 2007). Sows in pens with 1.4 m^2 floor space consistently had higher body lesion scores than sows with greater space allowances. Body lesion scores increased substantially during the first 10 to 13 days of the observations (phase 1), although once the scores had plateaued they remained relatively stable throughout the experiment.

Sows that are familiar with each other upon introduction to a larger dynamic group tend to remain as a subgroup after addition, staying in close association away from other sows in the larger group (Durrell et al. 2003). However, it was observed that sows which were previously unfamiliar to each other but introduced to an established group at the same time tend to form a separate subgroup and spend more time engaging in social and lying behaviour together (Durrell et al. 2003). Furthermore, sows remained in these subgroups for several weeks or months following their introduction into the larger, pre-existing group (Moore et al. 1993; Spoolder 1998; Stolba and Wood-Gush 1984). Regardless of whether the sows were pre-mixed or previously unfamiliar with one another, the findings suggest that sows that are introduced simultaneously to an established dynamic group of sows will form a separate subgroup.

However, behavioural differences were apparent regarding the frequency of agonistic behaviours within the subgroups of newly-introduced sows. Aggressive interactions only occurred in the pre-mixed subgroup during the second week of introduction to the dynamic group. Conversely, more attacks took place between the previously unfamiliar subgroup members in weeks 1, 3 and 5. This suggests the sows that were unknown to one another when introduced simultaneously were less socially stable as a subgroup (Durrell et al. 2003).

5.1.1. Productivity of Indoor Group Housed Sows

The reproductive performance of a sow is often one of the primary indices used to determine whether a system is productive. Some studies have shown greater reproductive performance of sows in groups compared to those in stalls (Lammers et al. 2007), whereas others have found that reproductive performance is similar for sows either in groups or in stalls (Salak-Johnson et al. 2007). Yet more observations have found greater reproductive performance in sows that gestated in stalls as opposed to those that gestated in groups (Bates et al. 2003). Gonyou (2005) found that grouping sows prior to implantation reduced farrowing rates by 5% compared with farrowing rates of sows that were grouped after implantation. The same study found that overall productivity (farrowing rate and litter size) was reduced among sows that were grouped prior to implantation, whereas productivity did not differ between sows housed in stalls and those grouped after implantation.

Barnett and Hemsworth (1991) found that in 15 studies that were reviewed, 8 showed better reproductive performance in group-housed sows, whilst only 4 showed better reproductive performance with individual housing. The conflicting results that are apparent in the literature may be demonstrative of the observation that the physiological and welfare requirements of the sow change over time. This has been recognised through the adoption of management practices that utilise different forms of gestation accommodation at critical stages of the reproductive cycle, particularly during mating and early pregnancy.

In another study, there was an apparent strong effect of space allowance per sow and subsequent litter size ($P = 0.001$) (Salak-Johnson et al. 2007). A total of 152 sows were measured at one farrowing, followed by 65 of these sows at the successive farrowing (with 6 replications). Treatment groups of 5 sows per pen were assigned to $1.4m^2$ per sow, $2.3m^2$ per sow or $3.3m^2$ per sow. Additionally, 5 sows were housed in stalls for the entire pregnancy, with a floor space allowance of $1.34m^2$. Sows in pens at $3.3m^2$ per sow farrowed more piglets per litter than sows in any other treatment, although the number of piglets weaned per sow was similar among treatments. Litter weaning weight and piglet birth-to-weaning weight gains were affected by gestation floor space. Weaning weight was greater in litters born to sows that gestated in stalls. Litter weaning weight was similar for litters from sows kept in groups regardless of space allowance.

Litter size is predominantly determined by the degree of embryonic mortality in early pregnancy (Spoolder et al. 2009). Several aspects of a sow's housing environment may influence embryo mortality and subsequent litter size. This may include nutrition before and during early pregnancy, and whether the sow is subjected to stress during early pregnancy. Clearly, in a group housing system, the techniques employed in the management of the sows at different stages of the reproductive cycle are the key to achieving levels of productivity that are comparable to sows kept in stalls, where individual attention and care is possible.

5.2. Outdoor Systems

Outdoor systems offer a more diverse, enriched environment in addition to greater behavioural freedom. Outdoor 'free range' systems are often perceived as having higher standards of welfare as well as being a more ethical form of pig production. Contrary to popular perception, these systems are not without their welfare risks. In New Zealand, approximately 40% of breeding sows are housed outdoors. Such systems generally comprise fenced paddocks containing communal shelters to accommodate groups of gestating sows, in addition to individual huts or 'arcs' which house farrowing and lactating sows. The location of an outdoor pig production system is critical, as unsuitable sites may lead to poor welfare. As such, areas of low annual rainfall with flat, low-contour, free-draining paddocks are more suited to outdoor systems. If the ground conditions become poor as a result of high rainfall and unsuitable soil type, animal welfare may be seriously compromised (Edwards 2005).

Outdoor production systems generally have lower set-up costs, higher operating costs, and slightly lower productivity than intensive indoor systems. This is largely the result of a greater potential for feed wastage, lower feed utilisation efficiency, and a greater labour input. It follows that an outdoor production system is exacting in terms of the physical requirements, site, labour and management. Lower productivity and higher veterinary and labour costs may however be counterbalanced through a reduction in the costs associated with housing, heating and other equipment.

Adequate management is the key to preventing the majority of identified risk factors with a low stocking density per hectare, regular paddock rotation, shade areas and portable housing (Edge et al. 2007). Maintenance energy requirements of outdoor pigs are generally greater than those housed indoors, as there is less control of the climatic environment. Increased energy requirements will also be a consequence of higher levels of physical activity associated with a larger space allowance that enables exploratory activities. At high ambient temperatures the voluntary feed intake of sows can be depressed, with the consequence being live weight loss, and a potential incapability to meet the requirements for high production (Edwards 2005). Outdoor housed sows had higher rectal temperatures and exhibited greater temperature variation when compared to indoor housed sows (Barnett et al. 1999), suggesting that outdoor pigs may have challenges with achieving adequate thermoregulation.

Outdoor conditions are not suitable for every breed. The aforementioned problem of increased energy requirements for maintenance and a lack of control over the environment make an outdoor situation less appropriate for the commercial ‘white’ strain of pig. Physical reasons for this include relatively low subcutaneous fat (and thus poor insulation from low temperatures), and greater susceptibility to sunburn due to a lower amount of skin pigmentation. Selection of crossbred stock with some skin pigmentation ensures the herd is more robust in an outdoor environment. Conversely, generations of genetic selection that has focused on breeding pigs of a high lean muscle percentage and low fat percentage makes such pigs less efficient in an outdoor production system. The maintenance requirements of a lean genotype are higher than a genotype that has a greater proportion of fat. Thus, pigs that have the genetic potential to thrive in the conditions provided should be preferentially used.

Another significant issue is the higher parasite burden of outdoor pigs, which leads to poorer nutrient utilisation and reduced feed utilisation efficiency (Edge et al. 2007). This may be controlled to a certain degree through grazing management and leaving paddocks unoccupied for several months. Biosecurity is also an issue, given that there is limited control over the environment in which the sows live, and there is a risk of contact with other species that may act as disease vectors. Maintaining large populations of pigs outdoors has been associated with increased biosecurity risks in regard to the spread of disease epidemics (Edge et al. 2007). This was illustrated by a suspected outbreak of Post Weaning Multisystemic Wasting Syndrome (PMWS) in Canterbury where wild birds were implicated in the rapid spread of the disease throughout the outdoor pig population (Edge et al. 2007).

Behavioural observations of outdoor-housed sows have highlighted specific patterns of behaviour that have been described as redirected foraging behaviour which manifests as stone chewing. This activity is thought to be a stereotypical behaviour, and is observed in pigs that are kept in paddocks without plant cover. Stone chewing is likely to be a coping mechanism in the event that foraging behaviour is thwarted in barren or bare earth paddocks. As such, it is thought to be induced by boredom, and it may indicate that stone chewing is a possible sign of reduced welfare which may arise as a result of limited access to resources or stimuli (Studnitz et al. 2003). Furthermore, Braund et al. (1998) suggested that just as bar biting behaviour appears more often in hungry sows, stone chewing may be an analogous behaviour as it is often observed more in hungry as opposed to satisfied sows.

An additional welfare issue that concerns outdoor sows is the practice of nose ringing. This is a husbandry procedure that is carried out to reduce the extent of pasture damage caused by rooting. Normal exploratory behaviour cannot be expressed by nose-ringed sows, as the location of the ring is specifically intended to cause pain and discomfort when the sow attempts to dig and root. Furthermore, nose-ringing may lead to thwarted behaviour and compromised welfare as the sow is surrounded by stimuli that would elicit normal oral-nasal-facial (ONF) exploratory behaviour whilst being prevented from performing this behavioural repertoire. Ringing itself can be a source of considerable pain and distress, particularly if wire rings are regularly lost and replaced (FAWC 1996). The provision of bedding, in addition to faster paddock rotation and improved pasture management may be an alternative to nose-ringing.

5.2.1. Productivity of Outdoor Housed Sows

Given the highly variable environment that outdoor sows are subjected to, it is not surprising that the productivity of outdoor housed sows is equally inconsistent. The climatic and environmental circumstances, in addition to the suitability of the farm location, pathogenic pressure, hut design and profitability are all closely interrelated. Thus, failure to meet the unique requirements of an outdoor pig herd can result in high pig morbidity and mortality, in addition to poor productivity and financial losses (Akos and Bilkei 2004).

Table 5: Reasons for culling and percentages of sows culled in outdoor and indoor farms (From Akos and Bilkei 2004).

Reason for Culling	Indoor	Outdoor	P
Anoestrus	16%	29%	<0.05
Locomotor Problems	25%	39%	<0.05
Swine Urogenital Disease	26%	14%	<0.05
Periparturient Diseases	26%	12%	<0.01
Heart Failure	22%	6%	<0.01
Miscellaneous	11%	12%	NS

Outdoor sows have been shown to have a shorter longevity in the herd (3.01 ± 0.27 parities) when compared to indoor sows (4.52 ± 0.54 parities) (P<0.01). Table 5 shows the principal reasons for culling in both indoor and outdoor farms. However, it appears that some sows may have been culled on the basis of more than one of the reasons mentioned in Table 5, given that the values in both the indoor and outdoor columns add to more than 100%. In another study, the annual culling rate was 39% in indoor and 45.2% in outdoor units (Karg and Bilkei 2002). The same study also found greater longevity in indoor sows, where the average parity at death was 3.6 compared to 2.5 in outdoor herds. In comparing the lifetime performance of indoor and outdoor sows, there were significant differences in the number of non-productive days and the lifetime cumulative counts of pigs weaned (Table 6).

A study conducted by Akos and Bilkei (2004) was based on large Croatian pig production units (averaging 69 ± 17 SD sows per unit in the outdoor herds and 401 ± 39 SD sows per unit in the indoor herds). As can be seen in Table 6, there is a significant difference between the mortality rates of piglets between the outdoor (12 herds) and indoor (21 herds) units.

Table 6: Lifetime performance of indoor kept sows (mean ± SD) (from Akos and Bilkei 2004).

	Outdoor	**Indoor**	**P**
Parity at removal	3.01 ± 0.27	4.52 ± 0.54	<0.01
Non-productive sow days (%)	34.9 ± 5.0	12.9 ±1.4	<0.001
Average annual sow mortality rate	5.8 ±1 .1	8.9 ± 2.1	<0.05
Lifetime cumulative counts of total pigs born	36.1 ± 2.0	54.1 ± 4.2	<0.01
Lifetime cumulative counts of pigs born alive	33.2 ± 1.1	49.3 ± 3.3	<0.01
Lifetime cumulative counts of pigs weaned	19.4 ± 1.2	41.2 ± 3.1	<0.001
Herd days	561 ± 13	659 ± 21	<0.01

Outdoor units experienced an average preweaning piglet mortality of 41.6%, compared to indoor units at 16.4%. During this study it was observed that the majority of pre-weaning deaths occurred in the perinatal period, as during hot summers (ambient temperatures > 30° C) the sow's lactational performance was impaired. At these temperatures, there is also a low conception and farrowing rate and increased embryonic mortality (Bilkei 1995). These effects on reproductive function and piglet mortality are also seen during winter, where high piglet losses were registered when the average weekly minimum temperature dropped below freezing (Akos and Bilkei 2004).

A recent sample of New Zealand outdoor herds in 2009 were used to illustrate the differences in performance data between outdoor (12 herds) and indoor (36 herds) housed sows (see Table 7). This data highlights a difference between the two systems, as well as a difference when compared to overseas production records shown in Table 6. Preweaning piglet mortality was higher in the outdoor sows at 20.1% compared to 14.1% in indoor housed sows. However, the sow replacement rate and death rate was higher in the indoor sows. The outdoor sows had a greater number of non-productive days, which was seen in overseas data shown in Table 6.

Table 7: Production data from indoor and outdoor sow herds in New Zealand mid 2009 (from PVS, Canterbury Outdoor Pork Production Seminar proceedings 2010).

	Average Indoor	Average Outdoor
Number of Herds	36	12
Repeat services (%)	11.6%	12.8%
Avg. Weaning to first service interval	6.20	5.23
Sows bred by 7 days (%)	91.8%	96.5%
Average gilt age at first service	228	213
Average total born per litter	12.88	12.76
Average born alive per litter	11.73	11.68
Average born dead per litter	0.95	0.99
Born dead as % of total born	7.3%	7.8%
Born mummified as % of total born	1.75%	0.78%
Average parity for sows farrowed	3.59	4.24
Average gestation length	114.9	115.7
Farrowing interval	152.5	152.2
Litters farrowed / mated female / year	2.27	2.24
Total born / mated female / year	29.27	28.58
Average pigs weaned / sow weaned	10.08	9.33
Average weaning age	26.0	25.9
Pre-weaning mortality (excl. Fosters)	14.1%	20.1%
Pigs weaned / mated female / year	22.90	20.94
Female replacement rate	48.8	43.4
Female death rate	8.3	5.1
Average parity of females culled or sold	4.61	4.93
Average parity of female inventory	2.59	3.45
Avg. Non-productive days /mated female/year	46	51

5.3. Gestation Stalls

Historically, as the average pig herd increased in size, it became apparent that the work of managing all aspects of pig production was physically challenging and inefficient. Managing a large number of pigs at different stages of gestation and lactation outdoors or in unsuitable areas was a contributing factor that led to the move indoors (Curtis et al.

2009). Once sows were moved inside, there was a logical progression to develop systems that increased the utilisation of available building space by defining the minimum space that could accommodate one sow. Thus it was the desire to avoid climatic extremes, followed by a need for parasite and disease control, manure management and an increase in the efficiency of production that led to the introduction of individual indoor accommodation of dry sows. The efficacy of this system was illustrated by the exponential increase in its use, and reflected a newfound ability to effectively overcome numerous production issues in an economical way (Curtis et al. 2009).

As discussed in the first section, an overall animal welfare assessment generally encompasses several measures of welfare that originate from various scientific disciples including animal behaviour, physiology, animal health and productivity. Thus, it is difficult to compare different housing systems with one another and identify which system is better or worse. Individual stalls are designed to accommodate a sow's static space requirements (as opposed to the dynamic space requirements)-that is, the amount of space used by the sow when she is standing or lying stationary. As such, salient aspects of a sow's natural behaviour repertoire are prevented in this system.

Nevertheless, there are several advantages to the use of dry sow stalls, as individual housing of gestating sows in stalls allows the caretakers to effectively observe and access the individual sows. The treatment, vaccination and routine husbandry practices that directly influence the sow's health and welfare are much more effectively managed without risking injury to the caretaker.

The primary purposes of gestation sow stalls include (Barnett et al. 2001):

- Control over individual feed intake;
- Preventing the sow from turning around and defecating and urinating in the feeding area;
- Preventing fighting and aggression;

- Containing manure;
- Providing better control of the sow whilst protecting the caretaker during examination;
- Facilitating insemination or treatment;
- Optimising efficiency of building space.

Furthermore, most research to date has indicated that generally-accepted physiologic measures of stress are similar when comparing sows housed in individual stalls throughout gestation with those in group pens. It has been concluded that stall housing is no more physiologically stressful to sows than group housing (Curtis et al. 2009; Rhodes et al. 2005).

Whilst it would appear that there is little or no difference in the level of stress experienced by sows in stalls relative to those in groups, there are physical injuries and lesions that occur more frequently in sows kept in gestation stalls. Overgrown hooves are associated with inadequate walking on sufficiently abrasive floor surfaces. Impaired mobility can lead to lameness, arthritis and joint problems. Decreased leg muscle weight and bone strength were observed in sows kept in stalls for the entire duration of gestation relative to those kept in groups (Marchant and Broom 1996). Sows culled for foot and leg problems make up a large proportion of all culled sows, however such injuries are related more to the design of the stall, particularly the flooring, as opposed to the management of the sows. A greater incidence of decubitus ulcers has been reported in stall-housed sows, particularly at the shoulders and legs where regular contact is made with the floor and sides of the stall. Several risk factors have been identified relating to the development of shoulder ulcers in sows, which were noted whilst observing sows in farrowing crates (Zurbrigg 2006). Sows with a body condition score (BCS) of less than 3 at weaning were 3.7 times more likely to develop a shoulder lesion than those with a BCS of 3 or higher, and low flank measurement (97 to 104 centimetres) increased the risk of developing a shoulder lesion by 2.8 times (Zurbrigg 2006).

5.3.1. Productivity of Sows in Gestation Stalls

Sow performance has previously been reported as being greater in sows that gestated in stalls than in groups (Peltoniemi et al. 1999; Kongsted 2005; Karlen et al. 2007). There have been observed differences in the reproductive parameters of sows housed in stalls throughout gestation when compared to those kept in groups. However, much of the data suggests that there is no significant housing effect on litter size or litter weight at birth (Karlen et al. 2007), or the total number of pigs weaned per litter (Salak-Johnson et al. 2007). The farrowing rate has been observed to be higher in stalled sows in some studies, with the higher rate of reproductive failure in group housed sows, primarily due to a greater incidence of regular and irregular returns to oestrus (Karlen et al. 2007). Salak-Johnson et al. (2007) found that there was no treatment effect for the litter size, number born alive per litter, number weaned per litter and total weight of the litter at birth when comparing sows in stalls and groups of varying space allowances throughout gestation (Table 8). These findings were also similar to those reported in Harris et al. (2006). Piglets from sows that gestated in stalls had heavier weights at weaning, and tended to gain more weight from birth to weaning. This is in agreement with another study where piglets from sows that gestated in stalls were heavier at weaning (Bates 2003).

The results in Table 8 are based on 152 sows measured at one farrowing and 65 sows measured at the successive farrowing; giving a total of 217 farrowing records over four gestation treatment groups. The average number of total piglets born in the 3.3m^2 treatment (14.2 ±0.56) is significantly higher than all other treatments, however the number of pigs born alive and the number weaned was similar among treatments.

Table 8: Litter-related traits for sows kept in pens at various floor space allowances or individual stalls throughout gestation (LSM± SE) (adapted from Salak-Johnson et al. 2007).

Measure	Gestation Treatment				P-value
	$1.4m^2$ (n=55)	$2.3m^2$ (n=55)	$3.3m^2$ (n=56)	Stall (n=51)	Floor space
Total born (No.)	12.4 ± 0.57^b	12.0 ± 0.60^b	14.2 ± 0.56^a	11.1 ± 0.52^b	0.001
Born alive (No./ litter)	10.0 ± 0.44	9.5 ±0.49	10.5 ±0.42	9.4 ± 0.57	0.25
Weaned (N.o/ litter)	8.6 ± 0.26	8.1 ± 0.26	8.8 ± 0.34	8.7 ± 0.35	0.17
Litter BW (kg)	15.7 ± 0.71	15.2 ±0.70	16.6 ± 0.64	15.0 ± 1.1	0.40
Litter wean BW (kg)	$50.2 \pm 1.8^{a,b}$	45.5 ± 1.6^b	$49.5 \pm 1.8^{a,b}$	52.4 ± 1.4^a	0.02

[a,b]Within a row, values without a common superscript letter differ ($P<0.05$)

Given that all sows were mated in stalls and moved to their respective treatment groups after being confirmed pregnant at 25 days post-breeding, there was no difference between groups in terms of the housing system used for mating. There is no explanation offered by the authors as to why higher litter sizes were observed in the sows that were kept at a space allowance of $3.3m^2$. It is also worth noting that whilst the number of pigs weaned does not differ between treatment groups, these values are low by New Zealand standards where the minimum target for the average pigs weaned per litter weaned is 9.5 (EliteHerd 2007).

The performance of stall housed dry sows was found to be no different to that of sows housed either in free-access stalls, in groups with electronic sow feeders, or in groups with trickle feeding systems (Backus et al. 1997). There were no significant differences between treatments for the percentage of non-returns, the number of live born piglets per litter or the number of piglets weaned per sow per year.

Table 9 summarises the findings of five papers that looked at the difference in reproductive parameters when sows were housed in either stalls or groups during gestation. It can be seen that in each study, the farrowing rate of stalled sows was higher than grouped sows. Total piglets born and pigs born alive did not differ significantly between studies or within each study for different treatments.

Table 9: Effect of gestation housing system (stalls vs. groups) on reproductive performance in sows.

	McGlone et al. 2004*		Nielsen 1995		Anil et al. 2005		Karlen et al. 2007		Hulbert and McGlone 2006	
	Stall	Group	Stall	Group	Stall	Group	Stall	Group	Stall	Group
Number of sows	-	-	1450	984	176	206	320	320	80	80
Farrowing rate (%)	83.3	75.9	92	86.8	81.8	74.8	76.8	66	68.8	66.2
Total born	10.5	10.8	12.6	12.2	10.9	10.8	11.2	11.1	11.1	10.9
Born alive	9.9	9.9	11.6	11.3	9.4	9.1	10.1	10.2	10.0	10.2
Weaned	-	-	-	-	-	-	8.3	9.0	8.5	8.4
Stillborn (%)	0.58	0.73	-	-	0.94	0.92	0.7	0.6	-	-

*Sow number not available as this publication is a summary of results from a meta-analysis of 35 papers

6. Stockmanship

Sound stockmanship calls for the recognition of behavioural signs of fear, anxiety, pain and distress in addition to other negative emotions or "affects". As well as identifying negative aspects of animal behaviour and productivity that may indicate reduced welfare, it is important to also focus on those that infer that welfare is good. These may include positive social interactions such as grooming, and overall animal contentedness. The role of a stockperson, regardless of the housing system used, is to ensure high standards of animal welfare that is demonstrated through a sound knowledge of the principles and practices of animal husbandry. As such, the knowledge, skills, abilities and attitude of the stockperson are integral to the standard of welfare that is experienced by the animals under their care.

The Farm Animal Welfare Council (FAWC) proposes that there are three key attributes of a good stockperson that should be considered the essentials of good stockmanship (FAWC 2007):

- Knowledge of animal husbandry: sound knowledge of animal biology, welfare requirements and physiological requirements of animals;

- Skills in animal husbandry: demonstrable skills in observation, handling, care and treatment of animals, in addition to problem identification and resolution;
- Personal qualities: affinity and empathy with animals, dedication, patience, and motivation to expand on current skills.

There are often regular periods of intense contact between pigs and stockpersons, particularly in regard to breeding sows. Clearly, the attitudinal and behavioural characteristics of stockpersons will influence the success of any system. Likewise, the extent to which the stockperson anticipates and manages identified risk factors that are inherent to a specific system will determine the overall outcome. This applies not only to profitability, but also in regard to animal welfare and productivity. Stockperson behaviour has been shown to be strongly related to fear and reproductive performance in pigs (Hemsworth et al. 1989), and negative handling has been demonstrated to reduce the pregnancy rate in gilts (Hemsworth et al. 1986). Fear of humans in oestrous sows reduced their attraction to boars whilst in the presence of humans (Pedersen et al. 2003), and has been positively correlated to the percentage of stillborn piglets (Hemsworth et al. 1999), though this was not in agreement with other research (Andersen et al. 2006). Handling studies in pigs have consistently demonstrated that handling treatments that elicit high levels of fear will adversely influence animal productivity.

Thus, it may be important to identify specific characteristics that are desirable or suitable for pig handlers to possess. There appears to be a sequential relationship between stockperson attitude and behaviour and the level of animal fear, welfare and productivity. As such, there lies the opportunity to improve animal welfare and productivity through proper training and selection of suitable stockpersons.

7. Summary

There is controversy over the assessment of animal welfare status, as it cannot be objectively measured. Furthermore, there are three main orientations that address different aspects of what animal welfare is (Mellor and Stafford 2009). These are:

1. The ‘biological function’ view (i.e. welfare is good when the animal is healthy, growing, and reproducing well, and good productivity is evident);

2. The ‘affective state’ view (i.e. animals have potential to suffer and have positive experiences, and that good welfare is present when animals are capable of adapting or coping without suffering whilst interacting with other animals, humans, and the environment);

3. The ‘natural state’ view (i.e. welfare may be compromised depending on how far the conditions in which the animal is kept deviates from the presumed original wild state of the species, and the extent to which the animal is able to express a range of natural behaviours).

It follows that there is debate over the relevance of each orientation to an applied animal welfare assessment. Different interpretations result from an assessment of an animal’s welfare status because of value-based presuppositions about what is good or bad for animals. Animal behaviour is an important tool as it is obvious to observe, changes are rapid, and behaviour in itself is a clinical symptom of disease or injury. It is generally agreed that the presence of behavioural stereotypies and abnormal behavioural patterns represent poor welfare. Conversely, it may be that behavioural activities such as grooming and exploration suggest good welfare. However, an animal’s behaviour is subject to interpretation and is not an accurate indicator of welfare status on its own.

Sows are aggressive in nature, with a hierarchical social structure. This characteristic is important to consider in the design and management of dry sows, as the level of aggression that a sow is subjected to will ultimately influence performance and welfare. Mixing aggression is particularly significant in group housing operations, and as such, sows should be managed in a way that minimises the potential for injury. Keeping sows in static groups at group sizes that encourage the formation of subgroups is recommended above the use of dynamic groups. Another important consideration is the timing of mixing of unfamiliar sows relative to the stage of gestation. This is critical to ensure the completion of the maternal recognition of pregnancy and embryonic implantation before the sow engages in aggressive interactions with other sows.

The chosen housing system can influence the level of stress that a sow will experience, which may have detrimental effects on the animal's welfare and productivity. Limited access to resources and the inability to perform behaviour that has a strong motivational drive can alter the sow's physiology. This may lead to activation of the HPA axis and elevation of corticosteroids. Stress can result in behavioural abnormalities and anxiety, and has been shown to interfere with normal reproductive function in female pigs.

The productivity and welfare of pigs varies in each production system, be it stalls, groups, or outdoors. There are approximately 72 permutations when considering the design of a housing system for dry sows. Assessing the suitability of a housing system for gestating sows by basing it on a single welfare issue has the potential to lead to other compromises to animal welfare as new issues arise or other issues are exacerbated. Adequate management that addresses the weak points in a particular system, in addition to skilled stockmanship, are the key. The New Zealand codes of welfare reflect this through their format, in that these codes are based on a system's outputs rather than inputs. Thus, those responsible for the welfare of the animals concerned are aware of what the result should be, regardless of the action that is taken to achieve the required result.

The main points are summarised as follows:

- There are three main orientations used to describe an animal's welfare status (biological function, affective state, natural state) and this is a source of debate over defining 'animal welfare'.
- Animal behaviour is an important component of a welfare assessment as it is obvious to observe, changes in behaviour are rapid, and behaviour is a clinical symptom in its own right.
- Grouped pigs have a hierarchical social ranking that is determined through aggression and fighting. This warrants consideration in the design and management of dry sow housing.
- Physiological stress has been shown to delay the onset of oestrus, suppress oestrus activity and disrupt reproductive function in female pigs.
- Environmental, social and nutritional disturbances during early pregnancy can have detrimental consequences for embryo development and survival. Hence the timing of grouping sows after mating is an important consideration.
- Progesterone has a demonstrable calming effect that influences sow behaviour. Sows are more aggressive in the period after weaning and immediately prior to farrowing when progesterone concentrations are low. Progesterone is elevated and remains at a constant level after the fourth week of pregnancy. This has previously supported the use of individual gestation accommodation until this stage of pregnancy to minimise the effect of aggression.
- There is a multiplicity of combinations and factors involved in dry sow housing. The benefits of group housing largely depend on the group structure, the space allowance, feed delivery system, and the management of aggression.
- Outdoor systems are perceived by the public as offering the best welfare. However, there are specific risk factors associated with an outdoor operation, therefore adequate management is critical. Outdoor climatic conditions cannot be controlled and are more of a challenge in terms of achieving an optimal environment.

- Gestation stalls offer superior control over the sow’s environment and individual management. Nonetheless, the lack of mobility and the inability to express strongly motivated behaviours is a related concern.

- Ultimately the success of any system is dependent on the stockpersons involved, through ensuring high standards of animal welfare, and demonstrating the knowledge, skills attitude and behaviour that befits the chosen housing system.

- A host of systems currently used to accommodate sows are converted facilities that originally had different uses, and therefore often have pre-existing weak points.

- There is no perfect or ideal system for keeping dry sows, as throughout different stages of the production cycle, a sow’s needs change. Therefore the implication is that in any housing system, both the advantages and disadvantages relating to a sow’s welfare will also change over time. In light of this, operators need to understand the system and how best to manage them.

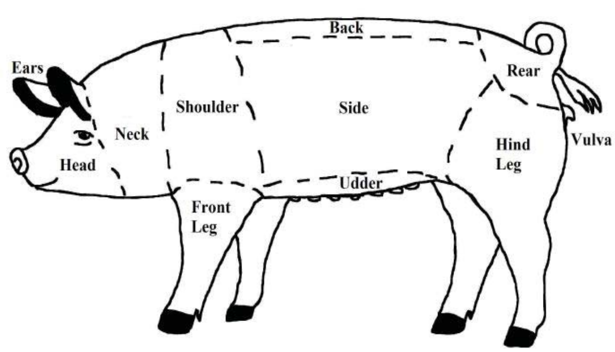
2. MATERIALS AND METHODS

Commercial pig farms were chosen to represent the spectrum of different layouts and management practices to obtain data from a range of different systems. Twenty commercial herds (farrow-finish) were selected from those registered with the New Zealand Pork Industry Board. Herd sizes varied form 120-1100 sows. Data concerning housing, management, sow behaviour, welfare and productivity was collected during one on-site visit per herd, and related to the breeding sow population of each farm. Observations were limited to the dry sows and their accommodation from post-weaning to pre-farrowing.

Housing and management characteristics were collected during the farm visit. Photographs were taken of the dry sows in their environment to provide a visual record of each of the systems visited. Production data summarising the last 12 months was collected from 13 farms. Observations of the sows (20 farms) were recorded during the visits. These observations fell into categories that related to the behavioural displays of the sows during the visit, lesion scoring, lameness scoring, and recording the general appearance of the sows (coat condition and extent of soiling). The on-farm assessment tool and the farm description survey are presented in Appendix 1 and 2.

Injuries

Sows were observed for signs of injury. At each farm, 15 sows were randomly assessed; lesion scoring was performed after feeding and before the start of the next feeding cycle if applicable. Designated anatomical areas of the sow were assessed as illustrated by the following diagram (Salak-Johnson et al. 2007):



Each anatomical region was assigned a score ranging from 0 to 3 (0- no lesions; 1- dehairing, redness, swelling; 2- abscess, moderate wound, scabbed-over laceration; 3- marked wound, fresh scratch, severe wound, open wound with discharge).

Appearance

The condition of the coat was evaluated using a random sample of sows (n=5) from five groups within the dry sow accommodation. These groups were either in separate pens within one building, or sows that were housed in defined accommodation areas on one property (e.g. deep litter eco barns, indoors on concrete). Coat condition was evaluated as a score (where 0- normal; 1-dull, coarse; 2-Poor condition, bald patches, uneven distribution) that represented the average for each group.

The extent of soiling of the sow with dung was assessed as above, in terms of using a sample of sows from five groups within the dry sow area. This was evaluated as a score (where 0- no soiling, 1- minor soiling e.g. tail only, 2- moderate e.g. tail and rear legs, 3- excessive soiling) that represented the average for each group, and was indicative of the general level of hygiene in the dry sow area.

Lameness

Lameness was evaluated from the sow's movement and standing posture. In total, 15 sows per farm were randomly evaluated for lameness. This was scored from 0-2 (0- no lameness, bears weight evenly on all legs 1- mildly lame, abnormal gait or does not bear weight on all legs, 2- clearly lame, hesitant to walk, uneven weight bearing, limping or will not stand unaided).

Behavioural observations

Behavioural displays were observed at each visit, and are described in Appendix 3. Behavioural observations were recorded in random sows from five groups within the dry sow accommodation. These groups were either in separate pens within one building (where one pen = one group of sows), or sows that were housed in defined accommodation areas on one property (e.g. deep litter eco barns, indoors on concrete). Specific behavioural displays included: sham chewing, bar-biting, tongue-rolling, champing, dog-sitting, head weaving, drinker pressing, feeder/trough interaction, apathy, and stone chewing. These behaviours are typically described as indicators of poor welfare. These behaviours were described using a score of 1, 2, or 3 (1: absent, 2: present in some animals, 3: excessive display/ frequency). Furthermore, other general behavioural displays were observed that aided in recording the general activity level of the sows on the day of the visit. These were: vocalising, foraging, rooting, floor/bedding manipulation, eating, drinking, wallowing, non-aggressive social interaction, resting (lying with physical contact), grooming, resting (lying without physical contact), agonistic (attack), and escape/ retreat behaviour. These were described using a score of 1, 2, 3, or 4 representing none, minimal, moderate frequency of display, and very frequent display respectively.

Behavioural observations were performed whilst the observer moved through the dry sow areas. These observations were completed over a two hour period on each farm, after sows had been fed (or between feeding times, in the event that sows were fed more than once daily). This length of observation allowed for sows to become accustomed to the observer, given that, at the start of observation, visible presence of the observer may affect the expression of behaviour. Observations were not performed during feeding time in order to capture a wider range of behaviours that more accurately represent typical pig behaviour within each housing system.

Farm scores and Welfare index (WI)

The total farm score was calculated as the combined total scores achieved for each parameter that was assessed on-farm (injuries, coat condition, soiling, lameness, and behaviour). On each farm, 135 observations were performed, giving a total of 2700 observations across all 20 farms. The minimum possible total farm score was 115 and the maximum possible score was 970. The total score includes the scores achieved for 'general behaviour'. As these behavioural patterns are not necessarily indicative of an animal's welfare, the on-farm welfare outcome is better reflected in the welfare index (WI).

A welfare index (WI) was calculated for each farm. The WI incorporated each farm's score for lameness, coat condition, injuries, stereotypies, and soiling, thus representing the net welfare outcome of each farm. General behaviours were not included in the WI as these were not related to the assessment of welfare, only to the activity levels of the sows and their interaction within their housing environment. Each parameter included within the WI was treated as having the same weighting based on their significance for welfare outcome in terms of the intensity of the experience; thus there is no ranking of welfare parameters. A low WI corresponded to good welfare, as this signified that there was a low prevalence of indicators of potential welfare compromise on-farm. Hence, a high WI signified a greater frequency of indicators of potential welfare compromise.

3. RESULTS

The welfare implications of sow housing during gestation are complex. Each housing system has a different set of contributing factors, and it is not always possible to identify all contributing factors that are inherent and specific to each system. The data obtained during this particular study was difficult to analyse. In some cases there are clear trends between inputs (housing system characteristics) and outputs (sow productivity, sow welfare). However, as each farm had a quasi-unique set of contributing factors (Table 10), the data are confounded. As such, data analysis has been limited to descriptive statistics, through identifying key trends relating to productivity and welfare in differing housing systems.

In addition to the animal-based observations, each of the 20 farms were described using five primary categories (group sizes, duration in stalls, bedding, feeding method and feeding frequency), so differences between housing, management, welfare outcome and productivity of sows could be evaluated. This is outlined in Table 10, where the characteristics (relating to gestating sow accommodation) are illustrated for each farm. From this, it can be seen that there is a large degree of variation between the farms in terms of the group sizes, whether bedding was used, whether stalls were used (and for what duration), how sows were fed, and the frequency of feeding.

Performance data

Average productivity was calculated for all farms and is presented in Table 11. This included average parity (2.75), average parity at removal (5.11), culling rate (41.68%), sow mortality rate (7.60%), farrowing rate (87.45%), piglets born alive/litter/sow (BA) (12.56), weaning-mating interval (5.59 days), piglets weaned/sow/year (W/S/Y) (23.98), and litters/sow/year (L/S/Y) (2.31). The average number of sows per herd was 395.60, whereas the total number of sows observed across the 20 farms was 7,912.

Table 10: Overview of the integrated factors present within the pregnant sow accommodation on-farm.

			Group size (sows/group)			Bedding		Duration in stalls (weeks)					Feeding method				Feeding frequency (24hr)		
Farm	**Herd size**	**Space allowance (m^2/ sow)**	**Small (≤6)**	**Med (≤15)**	**Large (≥16)**	**Yes**	**No**	**No stalls**	**1**	**4**	**5**	**5 +**	**Dry fed floor**	**Liquid fed auto**	**Dry fed auto**	**Dry manual trough**	**1x**	**2x**	**≥3x**
n			7	9	4	7	13	7	1	7	2	3	5	10	2	3	8	8	4
1	380	3.78			X	X				X			X				X		
2	250	2.61	X				X			X				X					X
3	437	2.33	X				X					X		X					X
4	440	2.50	X				X					X		X				X	
5	300	2.61	X				X					X			X			X	
6	248	2.50	X			X				X			X				X		
7	200	2.40	X				X				X					X	X		
8	120	2.38	X				X				X			X				X	
9	300	2.38		X			X	X						X				X	
10	720	3.41			X	X			X				X				X		
11	1100	2.40		X			X	X						X					X
12	300	4.91		X		X				X				X			X		
13	300	4.93		X		X		X							X				X
14	192	2.50		X			X			X				X				X	
15	550	2.40		X		X				X				X				X	
16	130	3		X			X	X								X	X		
17	450	outdoor			X		X	X					X				X		
18	950	outdoor			X		X	X					X				X		
19	145	5.40		X		X		X						X				X	
20	400	5.40		X			X			X						X		X	

Table 11: Summary of sow productivity for all farms (n = 13 farms).

Farm No	Sows/herd	Mean parity	Mean parity (culls)	Cull Rate %	Mortality Rate%	Farrowing Rate %	Born Alive	Wean-mating interval	W/S/Y	L/S/Y	W/S/L	Piglet Survival (%)
1	380.00	3.60	5.99	50.70	4.30	84.80	11.20	6.90	21.44	2.19	9.79	87.41
3	437.00	3.12	6.63	37.00	17.00	77.70	12.10	5.70	21.70	2.18	9.96	82.34
4	440.00	2.26	5.00	45.80	3.80	92.30	12.00	5.50	24.20	2.47	9.80	81.65
5	300.00	2.11	3.83	56.30	6.60	86.10	13.30	5.20	26.26	2.31	11.37	85.47
6	248.00	2.65	4.84	50.60	6.50	88.60	12.30	4.60	20.87	2.16	9.66	78.55
7	200.00	2.96	5.95	36.70	5.00	87.00	12.60	5.90	23.40	2.33	10.04	79.71
8	120.00	2.71	4.79	39.60	2.40	91.90	12.80	4.90	25.66	2.28	11.25	87.92
9	300.00	2.30	4.35	23.00	14.10	83.20	11.70	7.60	22.50	2.27	9.91	84.72
10	720.00	2.50	3.90	38.00	10.00	89.60	11.30	5.40	24.00	2.30	10.43	92.34
11	1100.00	2.86	4.56	35.70	5.90	92.10	13.10	5.50	25.35	2.39	10.61	80.97
13	300.00	3.33	5.12	55.90	2.90	91.00	12.00	5.10	26.90	2.49	10.80	90.03
14	192.00	2.57	5.44	40.00	11.50	88.80	14.40	5.10	24.00	2.30	10.43	72.46
15	550.00	2.74	6.00	32.60	8.80	83.70	14.50	5.30	25.50	2.32	10.99	75.80
Mean	**395.60***	**2.75**	**5.11**	**41.68**	**7.60**	**87.45**	**12.56**	**5.59**	**23.98**	**2.31**	**10.39**	**83.03**
SD	**262.39**	**0.43**	**0.86**	**9.70**	**4.47**	**4.30**	**1.05**	**0.82**	**1.93**	**0.10**	**0.58**	**5.70**

W/S/Y= weaned per sow per year, L/S/Y= Litters per sow per year, W/S/L= Weaned per sow per litter. *Mean sows/herd is based on 20 farms

Table 12: Summary of sow productivity for each farm category.

	N (farms)	Sow herd size	Mean parity	Mean parity culls	Cull Rate %	Mort. Rate%	Farrowing Rate %	Born alive/ litter	Wean-mating interval	W/S/Y	L/S/Y	W/S/L	Piglet survival %
Mean (all farms)	-	395.60	2.75	5.11	41.68	7.60	87.45	12.56	5.59	23.98	2.31	10.39	83.03
SD	-	262.39	0.43	0.86	9.70	4.47	4.30	1.05	0.82	1.93	0.10	0.58	5.70
Small groups	7	285.00	2.64	5.17	44.33	6.88	87.27	12.57	5.30	23.68	2.29	10.35	82.61
Medium groups	9	379.60	2.76	5.09	37.44	8.64	87.76	13.14	5.72	24.85	2.35	10.55	80.80
Large groups	4	625.00	3.05	4.95	44.35	7.15	87.20	10.90	6.15	24.65	2.35	10.11	89.88
Bedding	7	377.57	2.96	5.17	45.56	6.50	87.54	12.12	5.46	24.51	2.33	10.34	84.83
No bedding	13	405.30	2.61	5.07	39.26	8.29	87.39	12.75	5.68	24.13	2.32	10.42	81.90
No stalls	7	482.14	2.83	4.68	38.20	7.63	88.77	12.27	6.07	24.92	2.38	10.44	85.24
1 week in stalls	1	720.00	2.50	3.90	38.00	10.00	89.60	11.30	5.40	24.00	2.30	10.43	92.34
4 weeks in stalls	7	331.43	2.89	5.57	43.48	7.78	86.48	12.93	5.48	23.92	2.30	10.22	78.56
5 weeks in stalls	2	160.00	2.84	5.37	38.15	3.70	89.45	12.70	5.40	24.53	2.31	10.65	83.82
>5 weeks in stalls	3	392.30	2.50	5.15	46.37	9.13	85.37	12.47	5.47	24.05	2.32	10.38	83.15
Dry fed floor	5	549.60	2.92	4.91	46.43	6.93	87.67	11.37	5.63	23.39	2.29	9.96	86.10
Liquid fed auto	10	383.41	2.65	5.25	36.24	9.07	87.10	12.94	5.65	24.13	2.32	10.42	80.84
Dry fed auto	2	300.00	2.72	4.48	56.10	4.75	88.55	12.65	5.15	26.58	2.40	11.09	87.75
Dry manual trough	3	457.50	2.91	5.26	36.20	5.45	89.55	12.85	5.70	24.38	2.36	1.11	79.71
Fed daily	8	422.25	2.93	5.17	44.00	6.50	87.50	11.68	5.70	23.39	2.30	9.98	84.50
Fed twice daily	8	305.88	2.52	5.12	36.20	8.12	87.98	13.08	5.68	24.69	2.33	10.63	81.34
≥3x/day	4	447.84	3.16	5.36	46.13	20.23	87.95	12.30	5.35	25.22	2.39	10.46	84.44

W/S/Y= weaned per sow per year, L/S/Y= Litters per sow per year, W/S/L= Weaned per sow per litter

Regarding the duration of time that sows are kept in a stall; farms that used gestation stalls for 4 weeks (n=7 farms) had the highest average piglets born alive per litter (12.93, Table 12). Sow productivity was compared between sows that were group housed throughout the entire gestation, and sows that were kept in a stall for some period during pregnancy. The number of piglets born alive and the number of pigs weaned per sow per year was compared. There was no difference between means for piglets born alive in stalls (12.65±0.36) vs. group housed sows (12.27±0.43), or for the number of piglets WSY (stalls WSY=23.70±0.59, group WSY=24.92±1.23).

The highest number of piglets WSY (26.58 piglets) was seen in the sows that were fed dry meal through an automatic feeding system (Table 12, n=2 farms). Aside from the feeding system, there were no other common features between these farms. The farm category with the highest number of piglets born alive was the medium size groups category (n=9 farms, mean=13.14 piglets born alive per litter).

Out of the farms in the 'medium groups' category, five of the nine did not use bedding in the gestating sow accommodation. Five farms did not use stalls, whilst four farms used stalls for 4 weeks. Six of the nine farms floor-fed the sows a dry meal, and five farms fed sows twice daily. The 'medium groups' category had significantly more pigs born alive than those kept in large groups ($P<0.05$). Sows in large groups had the least piglets born alive out of all categories at 10.90 pigs per litter. Sows kept in stalls for one week (n=1 farm) had the highest piglet survival to weaning (92.34%).

On-farm observations of welfare

The total scores per farm for each welfare parameter that was evaluated on-farm as part of the overall welfare assessment are presented in Table 13. On each farm, 135 observations were performed, giving a total of 2700 observations across all 20 farms. There were very few observations of lameness, with only 10 sows in total from 8 farms scoring a 1 or 2 for lameness (where a score of 0 represents no lameness, 2 represents mildly lame or abnormal gait, and a score of 3 was recorded for sows that were hesitant to walk or could not stand unaided). Only three farms had sows with a coat condition score above 0 (where a score of 0 represented normal coat condition, a score of 1 was given to sows with a dull, coarse coat, and a score of 2 was recorded for poor coat condition which may have included bald patches and uneven distribution). The highest total farm score achieved for all welfare parameters was 190; however, given that the highest possible score was 970, this does not reflect a large number of indicators of potential welfare compromise.

The mean scores for each on-farm observation of sow welfare, mean space allowance per sow, and the mean welfare index for each farm category are shown in Table 14. The sows with the highest mean score for general behaviours were those kept in a stall for one week (n= 1 farm). These sows had higher scores for vocalising, resting with contact, foraging, and rooting relative to sows in other groups (where a greater score indicates a greater welfare compromise).

Table 13: Total farm scores for each parameter assessed on-farm (injuries, stereotypies, general behaviours, coat condition, soiling and lameness). Low total score represents good welfare status.

Farm (n=20)	Injuries	Stereo-typies	General behaviours	Coat condition	Soiling	Lameness	Total
Number of observations per farm	**15**	**25**	**25**	**20**	**25**	**25**	**135**
Minimum score	**0**	**50**	**65**	**0**	**0**	**0**	**115**
Maximum score	**495**	**150**	**260**	**10**	**15**	**40**	**970**
1	16	52	74	0	3	0	145
2	5	52	84	0	6	0	147
3	15	53	89	0	10	0	167
4	28	63	93	0	5	1	190
5	34	56	84	0	2	0	176
6	8	50	91	0	0	3	152
7	7	53	87	0	10	0	157
8	9	52	78	0	1	0	140
9	7	53	88	1	5	1	155
10	14	56	104	2	6	0	182
11	7	54	87	0	0	3	151
12	2	55	89	0	0	0	146
13	10	53	87	0	0	1	151
14	6	57	82	0	4	0	149
15	10	55	87	0	5	1	158
16	18	54	95	8	0	0	175
17	0	52	78	0	0	1	131
18	1	50	81	0	2	0	134
19	13	56	78	0	0	2	149
20	8	54	79	0	0	0	141
AVERAGE:	**10.9**	**54**	**85.75**	**0.55**	**2.95**	**0.65**	**154.40**

There was no lameness in sows that were in stalls for either one or five weeks (n= 2 farms), and lameness was also absent in sows that were fed a dry meal in a trough (n= 3 farms). Sows with bedding (n=7 farms) had the greatest amount of space at an average of 3.90m^2 per sow. Sows kept in stalls for up to 5 weeks (n=2 farms) had the least amount of space at 2.39m^2 per sow (Table 14).

Table 14: Mean scores for on-farm observations including : injuries, stereotypies, lameness, soiling, coat condition; (where a low score for these parameters represents fewer indicators of compromised welfare) and general behaviours, mean space allowance per sow, and mean welfare index (WI, low WI represents good welfare status) for each farm category.

			Group size (sows/group)			Bedding		Duration in stalls (weeks)					Feeding method				Feeding frequency (24hr)		
	Mean all farms	S.D Mean	Small (≤6)	Med (≤15)	Large (≥16)	Yes	No	No stalls	1	4	5	5 +	Dry fed floor	Liquid fed auto	Dry fed auto	Dry manual trough	1x	2x	≥3x
n (farms)	20	-	7	9	4	7	13	7	1	7	2	3	5	10	2	3	8	8	4
Injuries	10.90	8.45	15.10	9.00	7.75	10.43	11.15	8.00	14.00	7.86	8.00	25.70	7.80	10.20	22.00	11.00	8.25	14.38	9.25
Stereotypies	54.00	2.87	54.14	54.56	52.50	53.86	54.08	53.14	56.00	53.57	52.50	57.33	52.00	55.00	54.50	53.67	52.80	55.75	53.0
General behaviours	85.75	7.03	86.57	85.78	84.25	87.14	85.00	84.86	104.00	83.71	82.50	88.67	85.60	85.50	85.50	87.00	87.38	83.63	86.7
Lameness	0.65	0.99	0.50	0.89	0.25	0.71	0.46	1.14	0.00	0.57	0.00	0.33	0.80	0.80	0.50	0.00	0.50	0.63	1.00
Coat condition	0.15	1.82	0.00	0.11	0.50	0.29	0.08	0.14	2.00	0.00	0.00	0.00	0.40	0.10	0.00	0.00	0.25	0.13	0.00
Soiling	2.95	3.30	4.86	1.56	2.75	2.00	3.46	1.00	6.00	2.57	5.50	5.67	2.20	3.60	1.00	3.33	2.63	2.75	4.00
Space per sow (m^2)	3.12	1.10	2.48	3.22	3.60	3.90	2.46	3.62	3.41	3.44	2.39	2.48	2.48	2.79	3.77	3.77	3.33	2.88	3.07
Welfare Index	0.65	0.14	0.73	0.61	0.61	0.57	0.69	0.59	1.00	0.56	0.73	0.82	0.57	0.66	0.49	0.87	0.68	0.61	0.67

Sow behaviour

Behavioural stereotypies were scored from 1-3 (where a score of 1 = absent, and 3 = excessive display/frequency). Overall, there were few observations of behavioural stereotypies. The minimum and maximum possible total farm scores were 50 and 150 respectively, as shown in Figure 3. There were no observations of head weaving or apathy (Table 15). ‘Trough interaction’ was the only behaviour that was performed at a frequency that was described as excessive, with 2.2% of sows displaying this behaviour excessively. ‘Dog-sitting’ was the second-most commonly observed behaviour (17.78% of sows), followed by ‘sham chewing’ (13.33% of sows).

Figure 3: Total scores for behavioural stereotypies for each farm (minimum score = 50, maximum possible score = 150). A low score represents fewer observed stereotypies.

Table 12: Summary of behavioural stereotypy scores (all farms) showing the % of sows that scored a 1, 2, or 3 for each stereotypy observed.

Score	Sham chewing	Bar biting	Tongue rolling	Champing	Dog-sitting	Head weaving	Drinker pressing	Trough interaction	Apathy	Stone chewing
	%	%	%	%	%	%	%	%	%	%
1	86.67	95.56	93.33	93.33	82.22	100.00	94.44	81.11	100.00	97.78
2	13.33	4.44	6.67	6.67	17.78	0.00	5.56	16.67	0.00	2.22
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.22	0.00	0.00

Key:

1- Absent

2-Present in some animals

3-Excessive display/ frequency

Table 13: Summary of general behaviour scores (all farms) showing the % of sows that scored a 1, 2, 3, or 4 for each general behaviour observed.

Score	Vocalising	Foraging	Rooting	Floor/ bedding manipulation	Eating	Drinking	Wallowing	Social interaction	Resting with contact	Grooming	Resting no contact	Agonistic	Escape/ retreat
	%	%	%	%	%	%	%	%	%	%	%	%	%
1	44.44	73.33	62.22	68.89	89.77	83.33	73.33	52.22	38.89	97.78	41.11	98.89	97.78
2	46.67	24.44	35.56	31.11	6.82	15.56	26.67	42.22	27.78	2.22	28.89	1.11	2.22
3	7.78	2.22	2.22	0.00	3.41	1.11	0.00	5.56	23.33	0.00	24.44	0.00	0.00
4	1.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.00	0.00	5.56	0.00	0.00

Key:

1- None

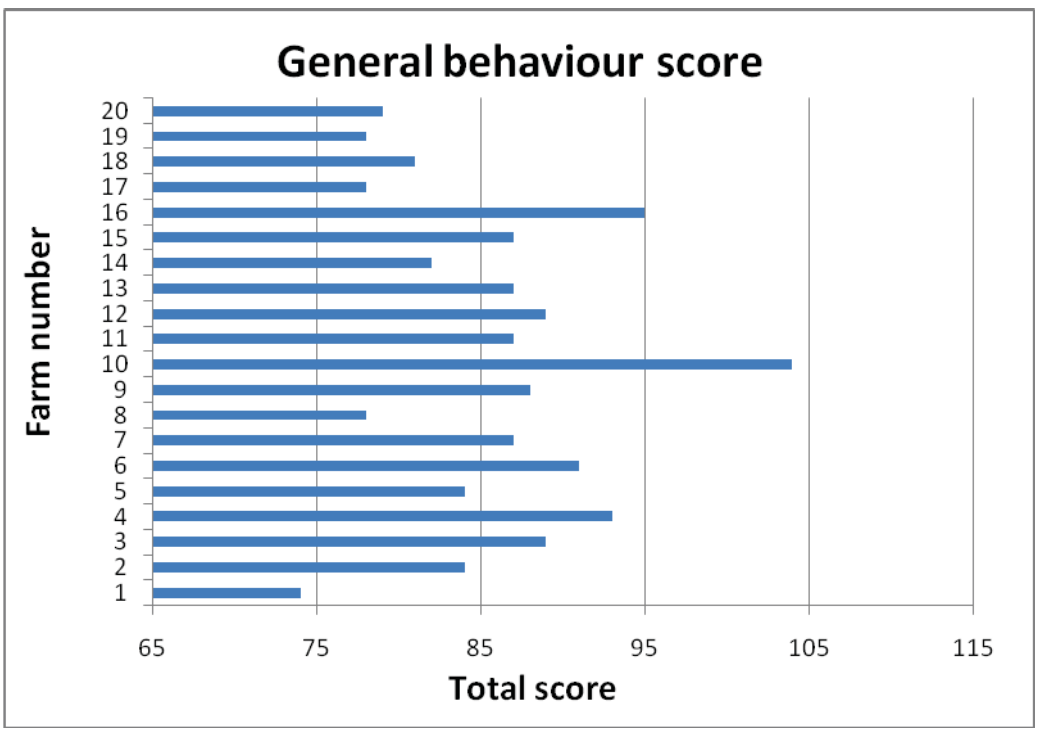
2- Minimal

3- Moderate frequency of display

4- Very frequent display

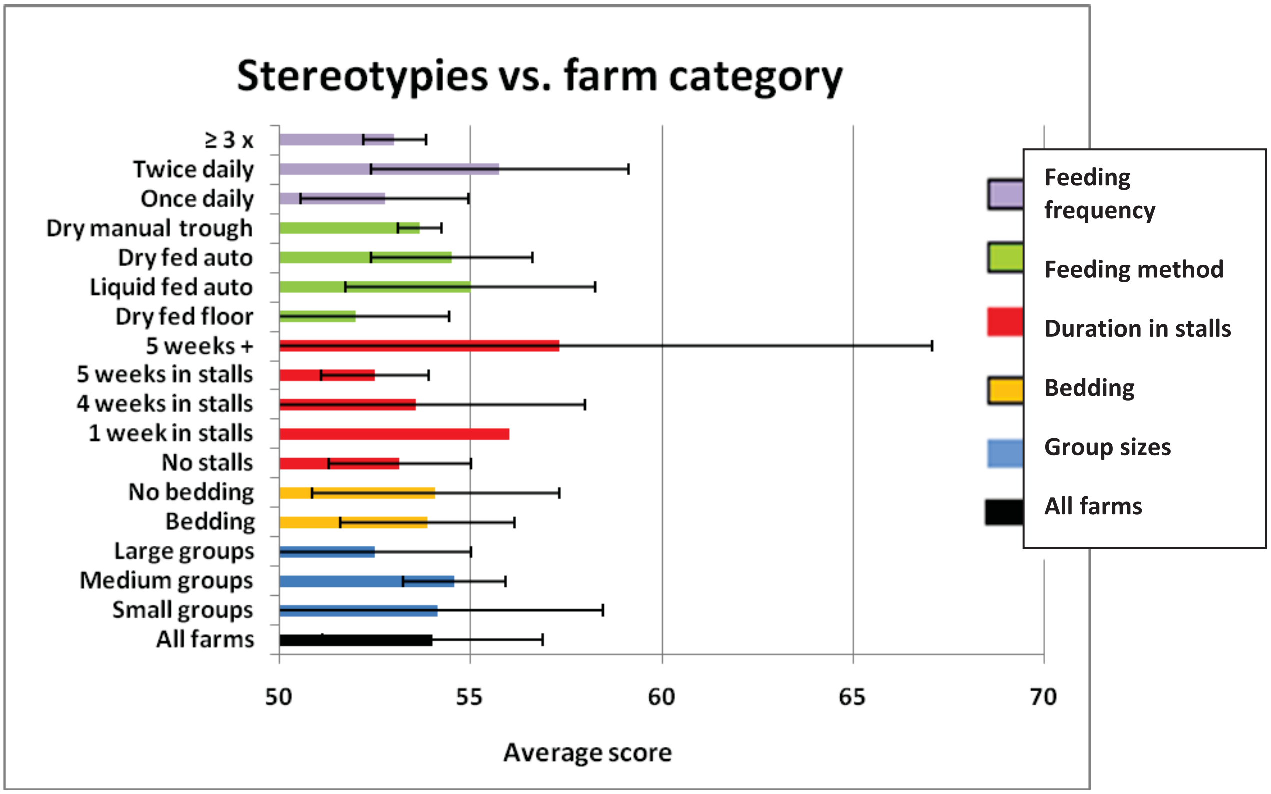
General behaviours indicated the general activity level of sows during each visit, and characterised the social and environmental interactions of the dry sows in their various types of accommodation. Table 16 summarises the frequency of general behaviours observed on-farm. The minimum possible total score was 65, and the maximum possible score was 260 for each farm, as shown in Figure 4. Resting with contact was the most frequently observed behaviour (with 10% of sows exhibiting a very frequent display) followed by resting with no contact (5.56% of sows exhibiting a very frequent display). Some behavioural patterns were specific to particular systems such as wallowing (outdoors) and rooting and foraging (outdoor sows and those with access to bedding/substrate). Agonistic behaviour was observed the least, with only 1.11% of sows engaging in this behaviour during the observation period.

Figure 4: Total scores for general behaviours for each farm (minimum score = 65, maximum score = 260). As total score approaches the minimum possible score per farm (65), this indicates that the frequency of these behaviours (and sow activity in general) was low.



As is shown in Table 14, the mean general behaviour score for the stalls (1 week) category was the highest of all categories (*P*<0.05). There were no other significant differences observed between farm categories for general behaviours.

Figure 5: Mean (±SD) stereotypies scores for each farm category (minimum score = 50, maximum score = 150). Low score represents fewer observed stereotypies.



The average scores for stereotypical behaviours in each farm category are shown in Figure 5. Stereotypies were most frequently observed in sows that were kept in stalls for more than 5 weeks (mean score =57.33, n= 3 farms). Sows fed twice daily had significantly higher stereotypies (*P*<0.05) than those fed at a different frequency. Sows that were floor-fed a dry meal (n= 5 farms) had the lowest stereotypies score (52.00) of all categories of farm systems, which was significantly lower than 'dry manual trough', 'liquid fed auto' and 'medium groups' (*P*<0.05).

Out of these five farms, four were using large groups, three had bedding, two had no stalls, two used stalls for the first 4 weeks of pregnancy, one used stalls in the first week of pregnancy, and all farms fed sows once daily.

Sow appearance

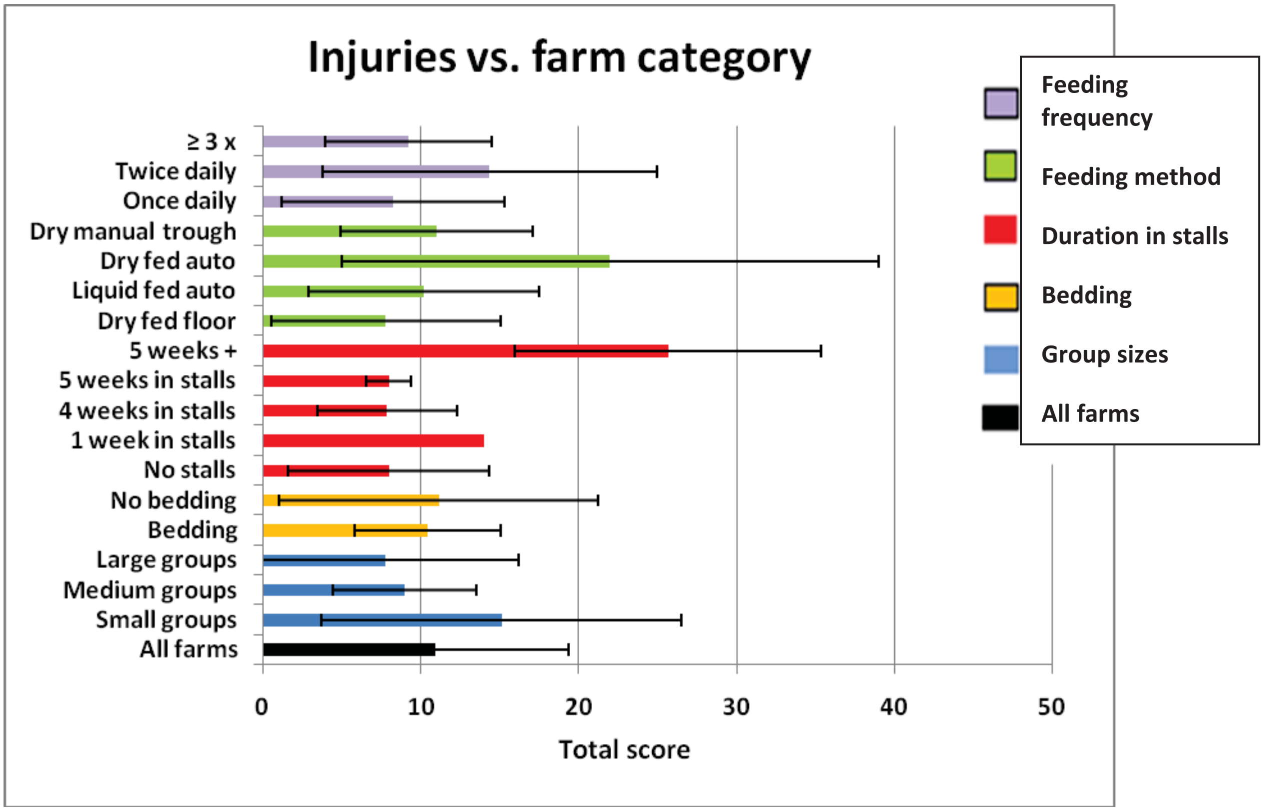
Sow appearance was evaluated from the coat condition and extent of soiling. Overall, only three farms were given a coat condition score of more than 0. One farm (farm 16) had a score of 8 out of a maximum possible score of 10 for coat condition. A significant number of sows in this herd had mange. This resulted in the majority of sows on this farm scoring a 2 (dull, coarse coat) for coat condition. Two farms shared the highest scores for soiling (Table 13); the only common features between these farms were the use of small groups and no bedding.

Sows kept in stalls for up to one week (n= 1 farm) had the highest soiling score of all farm categories, followed by sows kept in small groups (n=7 farms). Liquid feeding systems (n=10) had significantly higher average soiling scores than the 'dry fed auto' systems (n=2 farms) (3.60 vs. 1.00 respectively, $P<0.05$).

Injuries

The maximum possible total injury score per farm was 495. Injury scores ranged from 0 to 34. The single farm that had no recorded injuries was an outdoor-based operation. Injury scores were significantly higher in sows kept in stalls for more than 5 weeks (n=3 farms) (mean score= 25.67, $P<0.05$) compared to those that were in stalls for a lesser amount of time or were not kept in stalls for any period during pregnancy (Figure 6). The average injury score for farms that kept sows in small groups (≤ 6 sows per group) (n=7 farms) was significantly higher (mean score= 15.40, $P<0.05$) than farms with sows in medium sized groups (≤15 sows) (n=9 farms) (mean score= 9.00). Sows fed twice a day (n=8 farms) had higher average injury scores than those fed once daily (n=8 farms) and those fed three times daily or more (n= 4 farms, $P<0.05$).

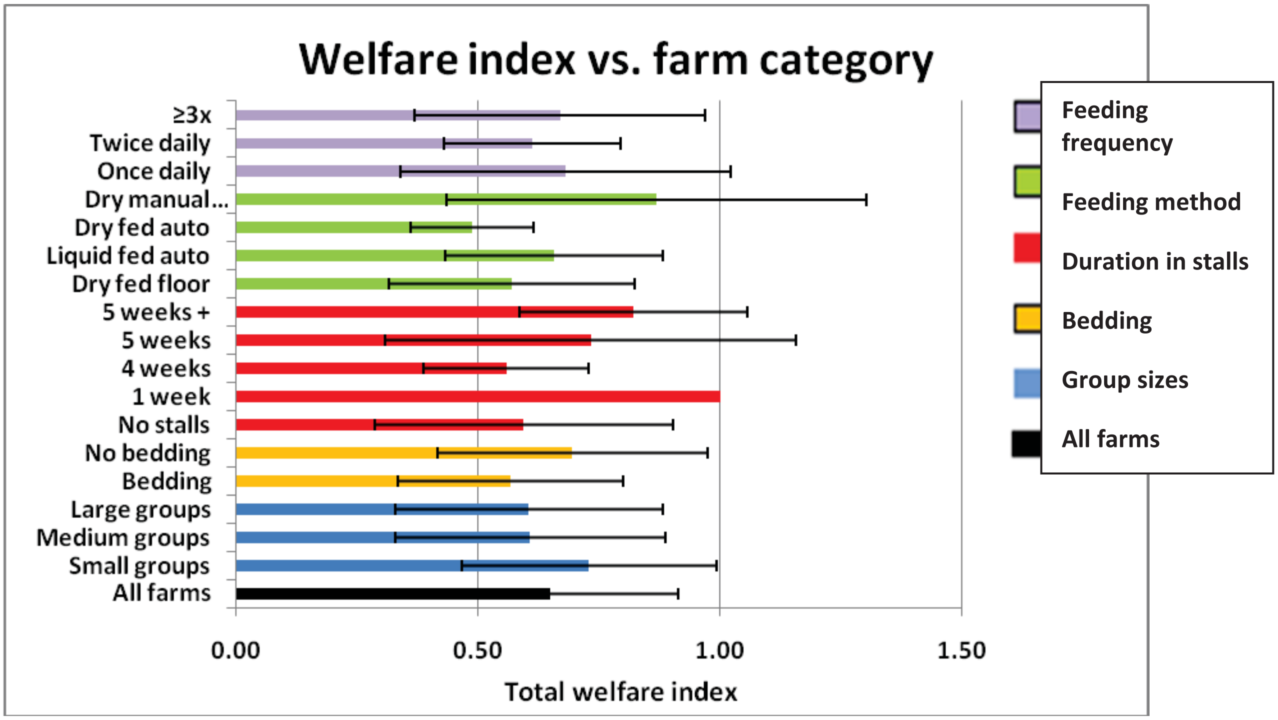
Figure 6: Mean (±SD) injuries in each farm category (minimum possible score = 0, maximum possible score = 495 per farm) . Low score represents fewer observed injuries.



Welfare Index

A welfare index (WI) was calculated for each farm. This incorporated the following parameters that were assessed on-farm: stereotypical behaviour score, coat condition score, soiling score, lameness score, and injury score. These indices were chosen as they related to areas of potential welfare compromise. Thus the final WI value represented the overall welfare outcome on-farm. This index had a minimum value of 0.33 and a maximum of 5.0. In this instance a low WI was desirable in that it represented a low on-farm presence of indices relating to poor welfare.

Figure 7: Welfare index (±SD) vs. farm category (minimum possible WI= 0.33, maximum possible WI = 5.0 per farm). Low WI represents a low prevalence of indicators of potential welfare compromise.



As can be seen in Figure 7, the prevalence of indicators of compromised welfare observed on-farm was very low. The highest welfare index was seen in sows kept in stalls for up to 1 week (WI=1.00, n=1 farm, 700 sows). These sows had a particularly high score for 'general behaviours', however this parameter was not included in the welfare index. Sows fed dry meal through an automatic feeding system had the lowest welfare index (WI= 0.49, n=2 farms). Sows fed once daily had the highest WI of the 'feeding frequency' category (NS), and those fed dry meal manually in a trough had the highest WI of the 'feeding method' category (NS). There were no significant differences between the means for injuries, stereotypies or the WI in the stalls (4 weeks) and stalls (5 weeks) in the stall duration category. Farms that kept sows in stalls for up to one week and for more than 5 weeks, farms without bedding, and those keeping sows in small groups all had a significantly higher average WI than farms with automatic feeding systems that fed a dry meal (dry fed auto) (P<0.05).

Sows with bedding had a lower WI than those without access to bedding, although there was no significant difference between these groups. Sows kept in small groups (≤6 sows per group) had a higher average WI than those in medium (≤15 sows per group) or large groups (≥16 sows per group).

The farm with the highest ('worst') WI had a score of 1.20. This farm kept sows in medium groups without bedding, did not use sow stalls, and fed sows a dry meal in a trough once daily. Two farms shared the lowest ('best') WI of 0.37. The only common feature between these farms was once daily feeding. One of these farms kept sows in large groups without bedding, did not use sow stalls, and these sows were floor-fed a dry meal. The other farm had medium sized groups, bedding, used stalls for 4 weeks, and sows were fed through an automatic liquid feeding system.

Figure 8: Sow productivity W/S/Y (piglets weaned/sow/year) vs. welfare index (minimum = 0.33, maximum = 5.0). Low WI represents a low prevalence of indicators of welfare compromise.

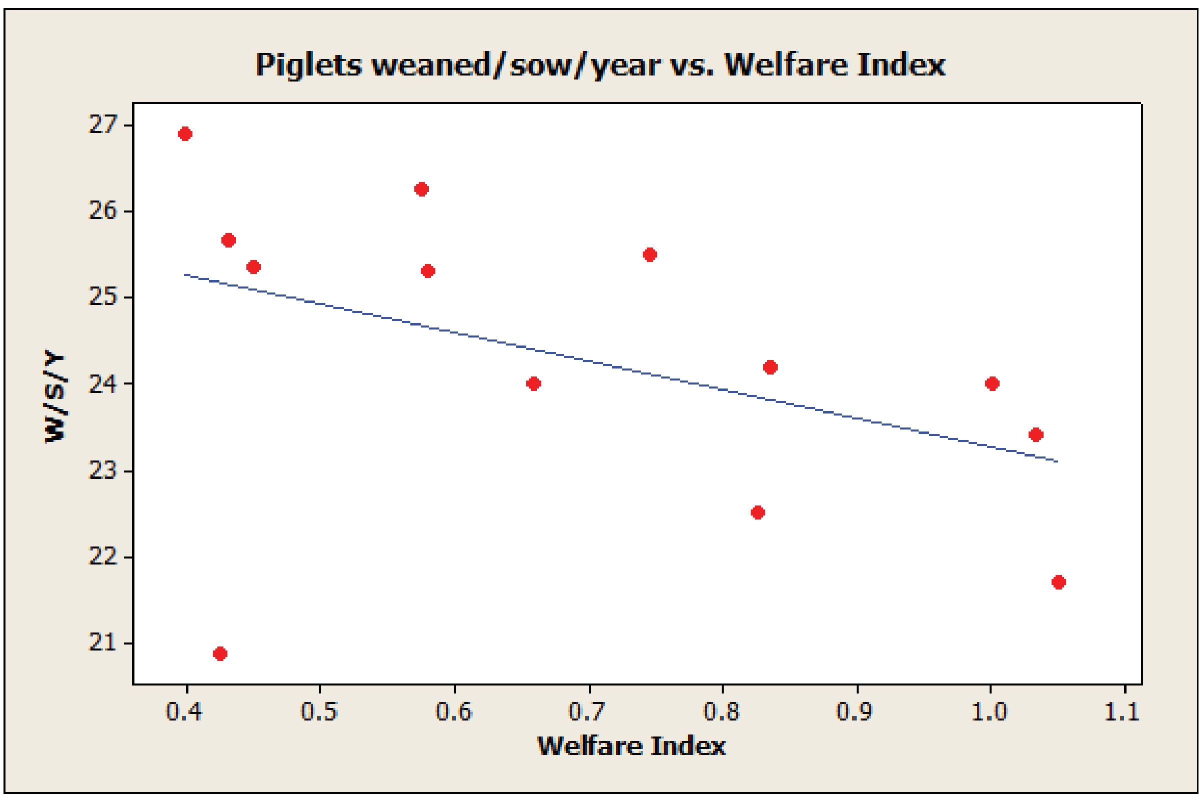


Figure 8 illustrates the relationship between welfare outcome (measured as the WI) and overall sow productivity (W/S/Y). The Pearson correlation of welfare index and W/S/Y r = -0.445 (*P* = 0.127). However, an outlier is present within this data set, representing a farm with a low number of litters per sow per year (L/S/Y) at 2.16, subsequently resulting in a much lower W/S/Y (20.87) relative to the other farms. Removal of this outlier results in a Pearson correlation of -0.822, R-sq= 0.675 (*P* = 0.001). Hence this model accounts for 67.5% of the variance, suggesting that, independent of farming system, there is a moderate relationship between good productivity and a low WI (a low prevalence of indicators of poor welfare on-farm).

As the WI increased (i.e. as the number of indicators of welfare compromise increased), there were a number of clear trends associated with sow productivity. The farrowing rate decreased (r = -0.507, *P* = 0.077), sow mortality rate increased (r = 0.575, *P* = 0.040) and the culling rate decreased (r = -0.505, *P*=0.078). The average parity of sows culled per farm increased with increasing welfare index .There was no relationship between WI and piglet survival to weaning (r = 0.056, *P* = 0.857). However, this was expected given that there are confounding variables associated with piglet survival that relate to both farrowing and lactation characteristics, which were beyond the scope of this research.

The number of piglets weaned per sow per year (W/S/Y) is a function of the farrowing rate (FR), the number of piglets born alive per litter (BA), the number of piglets weaned per litter and the number of litters per sow per year (L/S/Y). There is a correlation between the WI and the W/S/Y, however there are no strong relationships between the WI and L/S/Y (r = -0.213, *P*=0.484), between the WI and the number of piglets weaned per sow per litter (r = -0.373, *P*=0.209) or between the WI and the weaning-mating interval (r = 0.359, *P* = 0.228). There was no correlation between the WI and the number of piglets born alive per litter (r = -0.194, *P*=0.525).

4. DISCUSSION

Overall, the welfare status of group-housed gestating sows in New Zealand is high. This is illustrated by the low prevalence of indicators that are associated with reduced or compromised welfare. In addition to good overall welfare status, only 10 sows (out of 2700 that were assessed) showed signs of lameness, and two ‘abnormal’ behaviours (head weaving and apathy) were completely absent. Early studies on group housing have shown reduced reproductive performance relative to stalls in both conception rates and litter size (Nielsen 1995). The results from this investigation indicated that, of the sows kept in stalls for a period of time following mating; those confined for 4 weeks had the greatest number of pigs born alive. Avoiding social competition and mixing of unfamiliar sows around the timing of mating and embryo implantation may be the key to reproductive success. Social stress experienced during these critical early phases of the reproductive cycle can result in suppressed oestrus behaviour, reduced ovulation rate, and increased embryo mortality (Edwards 2008). Studies have shown that, early in gestation, sows in deep litter systems may experience greater challenges in relation to adapting to housing treatment, when compared to sows in conventional gestation stalls (Karlen et al 2007). Sows in a deep litter treatment during pregnancy had higher salivary cortisol concentrations in week 1 of gestation, and had poorer farrowing rates (66% vs. 77% in deep litter and stalls respectively). However, late in gestation, sows in gestation stalls had greater difficulty adapting to the housing treatment compared to those in a deep litter system, based on changes in the major cells of the immune system.

In this study, the farm category with the highest number of piglets born alive was the ‘medium groups’ category (13.14 piglets born alive per litter). This group had significantly more pigs born alive than those kept in large groups ($P<0.05$). Sows kept in large groups had the least piglets born alive out of every category, at 10.90 pigs per litter. Sows housed in stalls in early pregnancy had a slightly higher number of piglets born alive, but a lower number of pigs weaned per sow per year compared to sows accommodated in groups for the entire gestation. However, the differences between the productivity (either BA or W/S/Y) of sows kept in stalls and sows that gestated in a group situation were not statistically different. This is in agreement with other results where the influence of stage of gestation at grouping on farrowing rate and litter characteristics of group-housed sows was investigated (Cassar et al. 2007). In this study, there were no differences in the farrowing rate, litter sizes, or number of piglets born alive per litter between sows that were in stalls for either 2,7,14,21 or 28 days post-mating.

Higher average scores for injuries (NS) and behavioural stereotypies ($P<0.05$) in sows fed twice a day (vs. sows fed once or ≥3 times daily) may be attributed to increased agonistic behaviours due to competition at feeding. However, given this explanation, it would be expected that sows fed three times or more daily would therefore exhibit greater agonistic behaviour and more injuries than those fed twice daily. In this study, three out of the four farms that were feeding sows ≥3 times daily were operating liquid feeding systems. Liquid feeding is likely to contribute to greater gut fill and higher satiety compared to feeding a dry meal. Coupled with a shorter interval between feeding times as a result of feeding more frequently in a 24 hour period, this may explain why sows fed ≥3 times daily had lower injuries and stereotypies than sows fed twice a day. Once a day feeding has, however, been suggested as preferable to a higher feeding frequency. This is thought to reduce restlessness and aggression associated with sows in a group situation that fight to gain access to feed, which is perceived as a limited resource. Given this, it may be inferred that feeding more than one meal over 24 hours could result in a lack of satiety (especially in the absence of a foraging substrate and where feed is low in dietary bulk) (Edwards 2008).

However, this is in contrast to the results of this study, where the ‘best’ welfare outcome (as measured by the WI) in the ‘feeding frequency’ category was seen in sows that were fed twice daily (NS). This is a good example of the difficulty that is met with performing a subjective assessment of an animal’s welfare. It may be that specific parameters (e.g. injuries) that are incorporated within the welfare index have a greater impact on an animal’s welfare status than others (e.g. coat condition). In calculating an overall index of animal welfare, it removes the elements that contribute to the index. Hence, it is not apparent which factors were most often contributing to welfare compromise. Sows fed twice daily had significantly greater stereotypies and greater injuries than those fed once or ≥3x daily, yet those fed twice daily had the 'best' WI of the 'feeding frequency' category. Although this WI was the lowest, it was comprised mainly of a greater proportion of injuries and stereotypies. Thus, it may be more valuable to adjust for 'severity' of welfare compromise (i.e. is a low injury score 'equal' to a high coat condition score) to better reflect the composition of the WI.

The welfare index ranged from a minimum possible score of 0.33, to a maximum possible score of 5.0 per farm. The highest ('worst') individual farm index was 1.20, whilst the lowest WI (0.37) was shared by two farms. The two farms with the lowest WI shared only a single common factor: once daily feeding. One of these farms was outdoor-based with sows in large groups, whilst the other kept sows in medium groups on sawdust within an eco-shelter. Thus, it is clear from this example that there is no specific housing model that could ensure a specified standard of acceptable welfare, given that two dissimilar accommodation layouts achieved an identical welfare outcome (in terms of the welfare index) that was also the 'best'. This also highlights the importance of a holistic approach, (Salak-Johnson and Curtis 2007), not only with regard to assessing multiple indices that relate to an animal's welfare; but also with reference to the features of different housing systems that can influence how a sow interacts within that environment. Given that there are several permutations of design features, and many combinations of these different features within a housing system, it must be recognised that not all of these combinations will result in a successful outcome in terms of sow welfare and productivity.

This evaluation of sow welfare can be described as an integrated approach that assessed behaviour, physical function, and biological function. The WI for dry sows kept in a stall for 4 weeks was the lowest within the 'stall duration' category, which may relate to the low prevalence of injuries in this group. This may, in turn, be related to the anxiolytic effects of progesterone metabolites (NAWAC 2003), which have been attributed to calmer behaviour in pregnant sows after placentation is complete at ~28 days post-mating. Literature on rodents has shown that progesterone in combination with oestrogens (as occurs in gestation from ~16 days post-mating in the sow) markedly reduces aggression through the majority of pregnancy (de Jong et al. 1986; Kohlert and

Meisel 2001; Davis and Marler 2003). The concentrations of these hormones are maintained throughout gestation, and may explain why placing sows into groups later in pregnancy could reduce the level of aggression between sows at the timing of mixing.

The significantly higher injury scores of sows kept in stalls for more than 5 weeks may be the result of increasing body condition during early pregnancy. Sows that lost condition during lactation will be gaining liveweight at this time, and with increasing duration in a stall, space will become more restricted. This agrees with other findings (Karlen et al. 2007), where sows in stalls exhibited an increase in feet and leg injuries over time, which was linked to increasing liveweight and restriction of movement.

The low incidence of lameness observed in this study may have been due to the ability of stockpersons to easily observe the movement, posture and gait of sows in groups. It is likely that this enabled early identification and treatment of lameness, given that each farm in this study used group housing at some stage in the production system. There was no significant difference between the mean lameness scores for sows with or without bedding. Although, Anderson et al. (1999) found that in group housed sows, the presence of a bedding substrate reduced the frequency of abnormal gait compared to sows on a slatted floor. Bedding did allow for the observation of behaviours that may not be otherwise exhibited in non-bedded systems such as rooting, digging and foraging. It was also evident that sows close to farrowing were easier to identify in bedded systems. These sows often withdrew and isolated themselves from the rest of the group and formed a nest-like depression in the bedding substrate. Farmers commented that sows became territorial over these 'nests' and that there was the potential for a later than usual shift to the farrowing crates. This was owing to the ability of the stockperson to use inherent maternal behavioural displays to better align the movement of late gestation sows with the expected date of farrowing; in addition to preventing any accidental farrowings in the group situation.

There was no significant difference between the mean WI for sows with or without bedding. Bedding management is a vital component of deep litter housing systems. Poor quality or insufficient bedding can lead to a wet, unsanitary environment that can have negative consequences for sow health. Bedding increases the amount of solid manure, and requires a different type of effluent management compared to liquid effluent systems (Harmon et al. 2004). A consistent supply of good quality bedding throughout the year is critical for the maintenance of a successful bedded system. This has, in practice, limited the practicality of such systems to specific areas of the country.

It is well known that pigs are social animals, and that their social setting is based on a hierarchy that is instilled from birth. The establishment of a 'teat order' soon after birth serves as a noteworthy example of this. Members of a group of sows can recognise each other and identify an outsider (Scipioni et al. 2009); however it has been suggested that pigs in larger groups may fail to recognise all individuals. As a consequence, sows in large groups are less likely to engage in agonistic behaviours (e.g. pressing, levering, and attacks with or without bites), but do express more avoidance behaviours compared to those kept in smaller groups (Turner and Edwards 2000). In the current study, escape/retreat behaviour was observed at four farms, one of which kept sows in large groups (n= 35 sows/ group) (the remaining three farms had medium sized groups n= 12, 12 and 10 sows per group). Agonistic behaviour was only observed on two farms, one with large groups (n=17 sows per group), and the other with medium sized groups (n=12 sows per group). The largest group sizes observed in this study were up to 40 sows in one pen. The literature suggests that there appears to be more aggression problems in dynamic groups (Bokma and Kersjes, 1988; O'Connell et al 2002). None of the 20 farms in this study were operating dynamic systems in gestating sows.

Each farm had specific management practices in place at mixing that served to prevent stress and aggression between unfamiliar sows. Mixing protocols included mixing sows after feeding when they are more settled, and moving sows to a new pen with feed spread on the floor to distract sows from engaging in agonistic behaviours. In some cases, specially designed pens for the purpose of mixing were used (often featuring more space, sawdust on the floor for added grip, and visual barriers). On some farms, sows were left in these pens overnight. It was emphasised that once a group of sows was socially stable, those established groups must not be disturbed by adding or removing sows. Group composition was based on matching sows according to similar size, and no mixing of gilts with older, larger sows.

Farms that kept sows in small groups (≤6 sows per group) had higher mean injury scores than those with sows in medium (≤15 sows); ($P<0.05$) or large groups (≥16 sows per group); (NS). Allowing adequate space in a group situation facilitates greater freedom for behavioural expression, and in particular, social signalling of submission (Edwards 2008). The results from this study suggest that sows in larger groups (≥16 sows per group) fight less, which is supported by lower injury scores in these sows compared to those kept in medium or small groups. This appears to be the case even though all sows observed in group situations were above minimum space requirements of $2.0m^2$ set out in the Animal Welfare (Pigs) Code of Welfare (NAWAC 2010). Space per sow in this study ranged from $2.39\text{-}3.90m^2$ per sow, with an average of $3.12m^2$ per sow.

There are limited studies that give conclusive results as to the recommended space allowance for sows in groups. Nonetheless, it has been clearly shown that there are negative consequences in terms of sow welfare and reproductive performance when space is reduced. Experiments have shown that sow aggression and incidence of injuries is reduced as pen space increased from 2.4 to $3.6m^2$ (Weng et al. 1998). However, the authors emphasise the fact that these results do not necessarily reflect the outcome of other group housing systems when other factors (such as group sizes, feeding system, provision of bedding and stockmanship) are taken into account. It may also be important to consider the effect of the layout of the pen and how this influences aggression between sows. In particular, (and in light of the recent changes to the Animal Welfare (Pigs) Code of Welfare that will require modifications to existing layouts) this may relate to buildings that have been retrofitted or converted into sow housing. The initial format of these buildings may not have been ideal for the purpose of accommodating sows.

Feeding systems in a group housing system should be designed to minimise competition between sows for feed, in addition to avoiding aggression at feeding times. Floor feeding has a number of advantages: it is relatively simple and inexpensive to set up and maintain (low capital), and is well suited to smaller herds. However there are a number of disadvantages also, such as feed wastage, lack of individual feeding, and uneven feed distribution. Unequal feed intake between sows within the group has detrimental effects on body condition, especially for the low-ranking, submissive group members (Levis 2007). Conversely, in this study, sows in the ‘dry fed floor’ category had a relatively low prevalence of injuries (mean injury score = 7.80) compared to the mean injury score for all farms (10.90), indicating that the fundamental disadvantages of floor feeding were being managed effectively in the systems that were using this method. This may be due to the use of smaller, static groups of sows that are matched for size and have similar nutritional requirements.

In this study, sows that were floor fed exhibited fewer behavioural stereotypy patterns than those fed by an alternative method. The reason may be that these sows are engaging in a form of feeding behaviour that satisfies a strongly-motivated behavioural need associated with foraging and exploration in order to meet nutritional requirements. The concept of an internal trigger of stereotypical behaviours suggests that some particular behavioural repertoires may not be exclusive to a sow’s environment (Salak-Johnson and Curtis 2007). Unless it is clear that the continued expression of a specific behaviour is concurrent with reduced welfare, it may be possible to accommodate some of these behavioural patterns. Although sow behaviour can differ among housing systems, components of the design feature may be responsible for the presence of specific behaviours (Dailey and McGlone 1997, McGlone et al. 2004). In light of this, behavioural stereotypies may be partly driven by external stimuli and the opportunities within a sow’s environment, and could, therefore, be designed out of the system.

There was a relationship between the WI and productivity whereby fewer indicators of welfare compromise (low WI) were associated with high productivity (W/S/Y). This arises through a higher farrowing rate and lower sow mortality in farms with a low WI; the end result being a greater number of piglets weaned per sow per year on these farms.

There was also a moderate relationship between the WI and the culling rate (r = -0.505). As the WI increased, the culling rate decreased and the average parity of culls increased. It may be that in these farms, productivity was lower than farms with better welfare outcomes due to a culling program that was not removing older sows and those with compromised functionality that may have reduced productivity. Furthermore, it would be expected that sows with better welfare may have greater longevity (defined as 'sow productive lifetime' by Stalder et al. 2007) within the herd. Subsequently, the retention of more sows that live longer and have a good welfare status could explain the higher productivity of farms with better welfare outcomes compared to those with a higher (poorer) WI.

It would appear that when good welfare status is achieved during pregnancy, high levels of sow productivity result. Accordingly, it may be that the management of sows that led to the experience of good welfare is consistent throughout the rest of the farm, and that other classes of stock on the same farm experience similar levels of good welfare, hence reflecting the quality of stockmanship across all areas of the farm.

There was however no relationship between the WI of gestating sows, and piglet survival to weaning. The number of piglets that survive to weaning depends on two key factors: farrowing and lactation. It is generally accepted that when a decrease in performance is observed, it suggests that there is a subsequent underlying explanation or cause that may be attributed to a reduction in welfare. Conversely, a high level of productivity is not necessarily indicative of a high level of welfare (Scipioni et al. 2009).

Different sow housing systems offer different capacities to observe each sow on a daily basis. Yet, the management practices and quality of stockmanship on-farm has a direct impact on factors that contribute to culling and mortality of sows in the breeding herd. Automated systems in particular have allowed fewer people to manage more sows (Stalder et al. 2007), reducing the amount of time that a stockperson spends observing individual sows. This is especially so when herd sizes are large and sows are in group accommodation. Management is responsible for the social structure of the herd (e.g. the timing and frequency of mixing, in addition to the group composition) which causes social disruption, hence influencing sow welfare.

5. CONCLUSIONS

With regard to the fundamental aspects of group housing accommodation for sows, the following salient points summarise what may be included in a group housing system in order to achieve high levels of welfare and sow productivity:

- Indoor-based sow accommodation;
- Using purpose-built facilities as opposed to retro-fitted or converted buildings;
- Well defined sleeping, dunging and eating areas;
- Medium to large group sizes providing plenty of space for social signalling and expression of a wide range of behaviours;
- Visual and/or physical barriers for protection from aggression in a group situation;
- Individual feeding;
- Feed once daily but sequentially, (e.g. three times in 30 minutes to allow dominant sows to feed first, and submissive sows to consume enough nutrients);
- A mixing protocol that minimises aggression at mixing, which may include the use of a specially designed mixing pen;
- Either mix sows soon after mating (~2-3 days) or wait until ~ 28 days post-mating.

Group housing has already been incorporated on the majority of pig farms in New Zealand. Overall, there was a low incidence of on-farm observations (based on behavioural, physical, and biological parameters) that were used to indicate welfare compromise. This demonstrated that existing group housing systems are being managed effectively to achieve good standards of animal welfare. High welfare outcomes were closely associated with high levels of sow productivity. This bodes well for the upcoming move to group housing of sows for the entirety of gestation from 2015.

Management strategies to reduce aggression amongst grouped sows are a key component of ensuring optimal welfare status in addition to a high level of reproductive performance in sows. This aspect of sow management is largely dependent on skilled stockmanship. Furthermore, different types of management appear to be necessary depending on the phase of the reproductive cycle, in order to minimise stressors that may disrupt normal reproductive function.

This study has demonstrated that every system has advantages and disadvantages in regard to a sow’s welfare. Because of this, there is no single system that is clearly better than others, when all conditions and each criterion that is pursuant to animal welfare are considered. Even though the layout of two systems may be very similar, this was not necessarily the case with regards to sow welfare status. This is partly attributable to the shift in the importance of accommodating specific needs of a sow, given that those needs change throughout the reproductive cycle. The challenge is ensuring that the *net* welfare outcome is positive, and this is likely to be dependent on high quality stockmanship.

Few studies have made direct comparisons between housing systems. There is difficulty in finding systems that use the same management practices. There is also the problem of accounting for the multitude of other factors present on-farm. Consequently, standardising the variables in order to achieve a true comparison, where the only variable is housing, is a challenge to obtaining an accurate evaluation of welfare and productivity between differing systems. The New Zealand pig industry has progressed towards the greater use of non-confinement systems, with a commitment to end the use of sow stalls by 2015. Addressing sow welfare in the long term is reliant on retaining the advantages that current non-confinement systems possess, whilst making improvements to mitigate identified problems. Finally, these improvements should be implemented once the feasibility, practicality, and economic effects of any change make such modifications viable; supporting ongoing research in this area.

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Appendix 1

FARM DESCRIPTION SURVEY

General Farm description:____

1. **Feed Delivery System (Groups)**

Feeding method:

- Dry meal (manually fed into trough)
- Dry meal (automatic system)
- Liquid feeding (automatic)
- Dry meal floor feeding

- Other (describe):

Feeding time and frequency:

Daily feed allowance (kg/day/gestating sow)-

Daily check of automatic feeding systems:

2. **Water system (description):**

Sufficient access and appropriate design:

Daily check of automatic watering systems/ availability:

3. **Facilities for housing and treatment of sick pigs:**

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4. **Stalls**

Number of stalls:

Floor type:

Number of sows in stalls at any one time:

Duration of time spent in stalls:

Feeding system in stalls (if different from groups):

5. **Groups**

Group sizes:

Static/Dynamic:

Sows weaned per week:

Space allowance per sow:

Microenvironments available for separation of dunging, sleeping, eating areas:

Describe flooring type:

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Mixing sows

Time of day mixing occurs:

Mixing Checklist	**Yes/No**
Extra feed added to floor of pen	
Boar in pen	
Mixed at end of day/ night	
Partition walls and/or barriers	
Feed spread out (if floor fed)	
Environmental distraction (bedding)	
Separate thin/ timid sows	
Generous space allowance (~3m^2/sow)	
Even sizes of group members	

Signs of persistent aggression should be minimal:

Management protocol to minimise/ control aggression:

Management protocol for abnormal behaviour:

6. **<u>Health and Disease prevention</u>**

Response protocol for injured/sick animals:

Vaccinations and regular treatments (e.g. drenched for parasites, feed supplements):

Body condition score:

BCS of 3.5 to 4 prior to farrowing: (Y / N)

No lower than 3 after weaning: (Y / N)

Protocol for thin sows:

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7. **Culling and Mortality**

Annual culling rate of sows (%):

Number culled:

Annual sow mortality rate (deaths and euthanasia)(%):

Number:

Average parity at culling:

8. **Age structure of herd:**

Number of gilts:

Average parity of the sow herd:

Genotype:

9. **Reproductive Parameters:**

Farrowing rate:

Average litter size (pigs born alive):

Weaning to mating interval:

Percentage of AI and/or naturally mated sows:

Pigs weaned per sow per year:

Litters/sow/year:

Lactation length:

10. Outdoor sows

Nose ringed: **(Y / N)** Proportion of sow herd ringed:

Efficacy of nose-ringing (does it serve its purpose):

Nose ringing procedure (who carries it out and how):

Paddock description/ condition (grass cover, bare soil, free draining, wallow present, shelter areas etc):

Paddock rotation:

Area per sow/ group:

Housing type (number of sows/shelter, insulation, design features):

Bedding description and replacement rate/ management of bedding substrate:

Protocol for sick sows/ sows needing individual attention:

Provision of shade/ wallowing areas:

Pest control (if problem is/ was apparent):

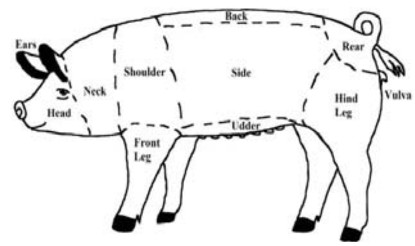
Appendix 2

ON-FARM ASSESSMENT AND OBSERVATIONS

INJURIES

Assess sows (15 sows per herd):

Area	Scores (0-3)															Total score
Ears																
Head																
Neck																
Shoulders																
Front legs																
Udder																
Sides																
Back																
Hind legs																
Rear																
Vulva																
Total/ sow																



0- No lesions

1- Dehairing, bald spots, redness, swelling

2- Swelling, abscess**,** moderate wound, scabbed-over scratch**,**

3- Marked wound, fresh scratch**,** severe wound, open wound with discharge

Notes/ Other observations:

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ANIMAL APPEARANCE

COAT CONDITION

Hair/ coat condition: sub-sample of sow population (assess 5 groups, 5 sows/ group)

Group	Scores	Average
1		
2		
3		
4		
5		

0-Normal (evenly distributed hairs, fine and shiny)

1-Dull, coarse

2-Poor, bald patches, uneven distribution

***Notes/Other observations:*___________________**

SOILING

Extent of soiling of the sow with dung (assesses 5 groups, 5 sows/ group):

Group	Scores	Average
1		
2		
3		
4		
5		

0- No soiling

1- Minor (tail only)

2- Moderate (tail and rear legs)

3- Excessive (underside and/or flanks, other

***Notes/Other observations:*___________**

MOVEMENT AND POSTURE (LAMENESS)

Standing Posture (assess 20 sows per herd):

Sow	Score
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	
20	

Key

0- No lameness: bears weight evenly on all legs

1- Mildly lame: abnormal gait or does not bear weight on all legs

2- Clearly lame: hesitant to walk, uneven weight bearing, limping or will not stand unaided

Notes/ Other observations:________________________

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BEHAVIOURAL OBSERVATIONS (STEREOTYPIES)

Stereotypical Behavioural Displays:	**Group 1**	**Group 2**	**Group 3**	**Group 4**	**Group 5**
Sham chewing					
Bar-biting					
Tongue-rolling					
Champing					
Dog-sitting					
Head weaving					
Drinker pressing					
Feeder/trough interaction					
Apathy					
Stone chewing					

Key:

1-Absent

2-Present in some animals

3-Excessive display/ frequency

Notes/ Other observations: ____

BEHAVIOURAL OBSERVATIONS (GENERAL)

General Behavioural Displays:	Group 1	Group 2	Group 3	Group 4	Group 5
Vocalising					
Foraging					
Rooting					
Floor / bedding manipulation					
Eating					
Drinking					
Wallowing					
Social interaction (non aggressive)					
Resting (lying with physical contact)					
Grooming					
Resting (lying without physical contact)					
Agonistic (attack)					
Escape/ retreat behaviour					

Key:

1-None

2-Minimal

3-Moderate frequency of display

4-Very frequent display

Notes/ Other observations: ____________________

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Appendix 3

Behaviour ethogram: description of observed behaviours.

Behaviour	Description
Stereotypies:	
Sham chewing	Chewing actions performed without the presence of food in the oral cavity.
Bar biting	Grasping the front rail in a stall with the mouth, whilst moving the head from side to side.
Tongue rolling	The tongue is extruded from the mouth and moved by curling and uncurling outside or inside the oral cavity with no food present.
Champing	Grinding and biting noisily without the presence of food.
Dog sitting	Sitting upright on the haunches.
Head weaving	Repeatedly swinging the head from side to side
Drinker pressing	Pressing an automatic drinker repeatedly without ingesting the water.
Feeder/trough interaction	Repeated visits to an empty feeder or trough that may include chewing, biting, nudging and licking the feeder/trough.
Apathy	A standing or sitting sows that does not react or engage with external stimuli (other sows, observers).
Stone chewing	Repetitive chewing on and/or swallowing stones.
General behaviours:	
Vocalising	Grunting, squealing, high or low pitch vocal sounds.
Foraging	Looking or searching for food or materials.
Rooting	Regular forward head movements with at least the disc of the snout beneath the substrate surface.
Floor/bedding manipulation	Exploring or manipulating bedding or substrate.
Eating	Head in the feeder or chewing food.
Drinking	Use of water nipple or trough for drinking.
Wallowing	Resting, rolling or wading in a pool of mud or water.
Social interaction (non aggressive)	Nosing, sniffing, licking, mounting other sows.
Resting (contact)	Lying on the belly or side whilst touching another group member/s.
Resting (no contact)	Lying on the belly or side without physical contact with another group member/s.
Grooming	Rubbing body against fixtures, scratching.
Agonistic	Attack behaviour directed towards other sows that may include pushing, knocking, biting.
Escape/ retreat behaviour	Change direction or move away to avoid another sow.