NZ PORK

Appendices to NZPork's Submission on the Proposed Code of Welfare for Pigs and Associated Regulations

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Appendix A

A scientific commentary on the National Animal Welfare Committee (NAWAC) Report titled "Five Domains Model assessment of the relative impacts of a range of farrowing and mating management options on the welfare state of sows and piglets"

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1. Executive summary

This report is a review and commentary based on the scientific literature of the main conclusions of the New Zealand National Animal Welfare Advisory Committee (NAWAC) Report titled "A Five Domains Model assessment of the relative impacts of a range of farrowing and mating management options on the welfare state of sows and piglets".

When considering the literature on the effects of housing, it is important to recognise that comparisons of livestock housing systems, particularly in commercial settings, are complex because of potentially confounding differences in the physical, climatic and social environments, genetics, nutrition and management, and consequently, these factors are an important consideration in examining housing comparisons.

The conceptual framework of biological functioning has been utilised in our review of the literature and our opinion on the NAWAC Report's conclusions on the effects of housing systems on risks and enhancements to pig welfare. Web of Science (WoS) was utilised as the primary database to ensure a comprehensive review.

We recognise and appreciate the effort that the panel has put into this difficult exercise of assessing the welfare implications of housing systems. However, we have concerns about the NAWAC report. Our main concerns are as follows:

1. **The use by NAWAC of the Five Domains Model to assess options for farrowing and mating management systems for pigs**

   The NAWAC Report utilised the Five Domains Model as an analytical tool to assess options for farrowing and mating management systems for pigs. Although there are advantages in the use of the Model in this context, e.g., identifying potential impacts and enhancements associated with housing systems, there are also a number of serious concerns, including the aggregation process and the weighting of impacts and enhancements, validity of the indicators (heavy reliance on behavioural indicators, stress physiological indicators not included in the assessment, live-born piglet mortality not included as an indicator, etc.), and the impact ratings assigned to some indicators.

2. **There is either insufficient or conflicting evidence in the literature to support some of the NAWAC Report's conclusions. For example:**

We do not support the NAWAC Report's conclusions that:

a. "*the farrowing and lactation system scenarios D (Temporary crating plus), E (Temporary crating), and F (Current management, FC) pose the highest relative risk of Moderate/High negative IMPACTS on affective states of both sows and piglets compared to the farrowing and lactation system scenarios B and D (indoor group and pen systems)*" and that "*Scenarios D (Temporary crating +), E (Temporary crating) and F (Current management) were considered unlikely to provide any significant ENHANCEMENTS and resulting positive experiences for either sows or piglets*".

   We conclude based on the literature, that continuous housing indoors in both farrowing crates and loose pens with or without enrichment has welfare advantages and disadvantages because of the conflicting needs of sows and piglets. The weight of evidence indicates that housing in farrowing crates pre-partum (and during early post-partum) is not a serious stressor for sows, while loose housing at this time poses a serious risk of live-born piglet mortality, a welfare consideration that is often overlooked. Farrowing crates can safeguard piglet welfare by limiting live-born piglet mortality, an extremely important factor for the welfare of the individual piglet. However, farrowing crates have a number of disadvantages with respect to sow and piglet welfare later in lactation. We believe based on the scientific literature, that hybrid systems such as temporary crating which restrict sow movement during parturition and early lactation, offer the opportunity to reduce live-born piglet mortality without any serious welfare consequence for the sow, and that loose housing after temporary confinement offers some benefits for piglets relating to social development during rearing as well as for the sow in terms of less confinement.

   We agree that enhancement opportunities (which also include greater floor space) are limited for sows and their piglets in farrowing crates, in comparison to outdoor systems. However, enhancements for piglets can be achieved by providing more floor space (i.e., loose housing of sows following temporary crating). Furthermore, material can be provided in these loose pens, thus providing opportunities for more play, foraging and explorative behaviour and less piglet-directed oral manipulative behaviours. Obviously, loose housing of sows following temporary confinement also provides sows with more space and the opportunity for provision of materials that can be orally manipulated. Providing piglets in farrowing crates with appropriate material to forage and explore can also provide enrichment. Therefore, while further research is required, it is our opinion that there are opportunities to provide sows and piglets in loose indoor pens and those in temporary confinement (confinement at parturition and in early lactation, followed by loose housing) with enhancement opportunities. Providing piglets and particularly sows in farrowing crates with enrichment opportunities is more challenging and requires research.

b. "…… *the mating system scenarios rated with more IMPACTS on affective state of Moderate or High Likelihood are D (2 hours in stall – indoors), E (Voluntary stalls), and F (Current – 7 days in stall). The leads to the conclusion that confined, barren, environments have the highest risk of Moderate/High negative IMPACTS on affective state of sows during the week that they are coming into oestrus and being mated." And "Mating systems A (Natural), B (Artificial insemination without restraint), and C (2 hours in stall – outdoors) were considered to provide the greatest Likelihood for ENHANCEMENTS (Figure 3). Scenarios D (2 hours in stall – indoors) and E (Voluntary stalls) were each considered to provide one opportunity for ENHANCEMENT, but none in scenario F (Current 7 days in stalls)"*.

   The NAWAC Report provides no information on the design details of each of the six mating scenarios. Furthermore, there is insufficient evidence in the literature to conclude on the welfare benefits of grouping sows from weaning to insemination relative to stall housing imposed either briefly around insemination or from weaning. To our knowledge, there is no literature demonstrating detrimental effects of short-term confinement of weaned sows relative to group housing of weaned sows. In fact, there is evidence that mixing sows after weaning results in higher physiological stress, based on cortisol concentrations, than housing in stalls. Therefore, we do not accept the NAWAC Report's conclusions on housing around mating.

   We agree that enrichment opportunities in indoor mating systems (i.e., around mating) are limited. While material that can be orally manipulated, thus providing opportunities for foraging and explorative behaviour, can be provided to weaned sows in pens, it is questionable whether the lack of such enrichment in the brief period between weaning and mating is a serious stressor.

c. *"…. sows and piglets in outdoor and indoor group housed systems have the greatest Likelihood for positive experiences… Systems that provide space, complexity and opportunities for appropriate social interactions are more likely to provide sows and piglets with positive experiences" and "Outdoor systems (scenario A) were also rated as having more Moderate and High IMPACTS for piglets, but not sows compared to indoor group and pen systems (B and C)".*

   In comparison to indoor pig production, substantially less research has been conducted on the welfare of pigs in outdoor systems, and even less on comparisons between the welfare of pigs in outdoor and indoor housing systems. Therefore, it is difficult to provide recommendations on outdoor housing and management systems. We agree with the NAWAC Report's conclusions that sows and piglets housed in outdoor systems have substantial opportunities for positive experiences. However, there appear to be a number of issues for sows in outdoor housing systems that need to be addressed. Furthermore, we disagree with the NAWAC Report's conclusion on near-miss crushing since the literature suggests that the risk of piglet mortality, especially from crushing in outdoor systems is higher than moderate as concluded by the NAWAC Report. We also suggest that thermoregulation, particularly in cold weather, requires study.

2. Introduction

The report titled "A Five Domains Model assessment of the relative impacts of a range of farrowing and mating management options on the welfare state of sows and piglets" was prepared by an expert panel comprising of six members of the National Animal Welfare Advisory Committee (NAWAC). As indicted by the title of this report, the expert panel used the Five Domains Model (Mellor and Beausoleil, 2015; Mellor et al., 2020) as a welfare assessment tool to evaluate the options for farrowing and mating management systems for pigs. The panel considered six different housing system scenarios for both pre-farrowing to weaning and weaning to mating and used the Five Domains Model to assess animal welfare in each of the housing scenarios. In relation to farrowing-lactation systems, the NAWAC panel's main conclusion was that "Farrowing crate systems (including temporary crating) have the highest risk of moderate/high negative impacts on affective state of both sows and piglets. Outdoor systems also have the highest risk of moderate/high negative impacts on affective state of piglets, but not sows." In relation to sow welfare during mating, the panel concluded that ""Mating systems with voluntary stalls and confined, un-enriched, environments have the highest risk of moderate/high negative impacts on affective state of sows." Our report is a review and commentary based on the scientific literature of the main conclusions of the New Zealand National Animal Welfare Advisory Committee (NAWAC) Report.

The main impetus for 'modern' intensive animal production occurred after the Second World War, when Western governments developed policies to increase the availability of cheap, safe food for their populations (Hodges, 2000). Research and industry development has resulted in housing and production methods and management, health and breeding practices that have generally increased animal productivity and health, improved quality of food and lowered the cost of food (Cronin et al. 2014; Hemsworth, 2018a). Furthermore, these developments have reduced or eliminated several welfare problems, such as predation, thermal stress, some infectious diseases and nutritional stress. However, these developments have exacerbated or created other welfare problems, such as overcrowding, social restriction and lameness. In contrast to intensive systems, extensive animal production systems generally have different welfare risks, such as frequency of inspections, ease of intervention if animal health or welfare problems are encountered, extreme climatic conditions and natural disasters (Hemsworth, 2018). While there is a focus on intensive housing systems particularly within both the public and private domains (Matthews and Hemsworth, 2012), research has indicated that the design and management of both indoor and outdoor housing systems is probably more important for animal welfare than is generally recognised (Rushen and de Passillé 1992; Barnett et al. 2001; Hemsworth, 2018a).

In considering the literature on the effects of housing, it should be recognized that there is complexity and wide disparity in the design and management of commercial housing systems, although many of these features can affect pig welfare. For example, features of sow group housing, including floor space allowance, group size, static and dynamic groups, weaned sow mixing pens, and sow nutrition, including diet, ration, and feeding system, may affect sow welfare (Spoolder et al., 2009; Verdon et al., 2015). Farm animal welfare may also be influenced by animal characteristics, such as genetics, experience, stage of reproduction, and parity (Verdon et al., 2015). In addition to housing design features and animal characteristics, the management of any production system can markedly affect farm animal welfare (Rushen and Passillé, 1992; Barnett et al., 2001; Lay et al., 2011; Verdon et al., 2015; Rushen, 2017; Hemsworth, 2018a). Animal management can be considered at two levels, farm level and stockperson level (Hemsworth and Coleman, 2011). At the farm level, human resource management practices, including employee selection and training, animal management practices, such as best practice in housing and husbandry, and implementation of welfare protocols and audits, affect farm animal welfare. At the stockperson level, together with the opportunity to perform tasks well, stockpeople require a range of well-developed husbandry skills and knowledge to effectively care for and manage farm animals. These management factors obviously affect the welfare of the animal.

Thus, comparisons of livestock housing systems, particularly in commercial settings, are complex because of these potentially confounding differences in physical, climatic and social environments, genetics, nutrition and management (Lay et al., 2011). Consequently, these management, housing design features and animal characteristics are an important consideration in examining the welfare implications of any specific housing system. Both generalised and comparative assessment of housing systems is often confounded by lack of uniformity in the design and management of each housing system, under both research and commercial conditions.

The conceptual framework of biological functioning has been commonly used by scientists to assess risk to animal welfare (Hemsworth et al., 2015). A key precept in this approach is that animals use a range of behavioural and physiological responses to assist them to cope with challenges in their lives and, while biological regulation in response to these challenges occurs continuously, successful adaptation is not always possible (Broom and Johnson, 1993). Marked challenges may overwhelm an animal's capacity to adapt, leading to biological costs to the animal, such as damage, disease or even death. Thus, the rationale for this approach is that difficult or inadequate adaptation will generate welfare problems for the animal and that the risks to welfare can be assessed at the following two levels: first, the magnitude of the behavioural and physiological responses to the challenge and, second, the biological costs of these responses. Methodologically this approach to welfare assessment has involved measuring a range of biological responses such behavioural measurements (e.g., variables such as stereotypies, fear, pain and illness behaviours) and physiological stress measurements (e.g., variables reflecting activation of the sympathoadrenal system and the hypothalamo–pituitary adrenal axis) and their fitness consequences (e.g., impairment of growth, reproduction and health, including injuries). Behaviours that may be accompanied by positive affective experiences include play and allogrooming in farm animal species, such as cattle, horses and pigs, and grooming and vocalisations in some species such as rats, cats and sheep. In contrast to behavioural indicators, physiological indicators of positive affective state are currently lacking. This approach to welfare assessment has been utilised in our review of the literature and our opinion on the NAWAC Report's conclusions on the effects of housing systems on risks and enhancements to pig welfare.

It should be recognised that most of the studies on animal welfare in the literature have examined animal behaviour, but considerably less have examined stress physiology. Furthermore, welfare assessments are commonly based on an absence of, or a reduction in, physiological stress responses. The welfare studies that have examined stress physiology have generally focused on the hypothalamo–pituitary adrenal axis by measuring concentrations of glucocorticoids (e.g., cortisol) in the blood.

3. Aim

The aim of our review was to provide the New Zealand Pig Industry Board with a scientific commentary on the report by New Zealand's National Animal Welfare Advisory Committee (NAWAC) titled "A Five Domains Model assessment of the relative impacts of a range of farrowing and mating management options on the welfare state of sows and piglets" specifically in terms of the scientific validity of:

1. The Five Domains Model in assessing the welfare implications of housing systems.
2. The main conclusions of the NAWAC Report.

4. Methodology

4.1. Scoping of our literature review

To ensure a comprehensive review, we consulted with selected Web of Science (WoS) as the primary database to be used. Primary searches were conducted using the pig/type name (sow, gilt, piglet), combined with the term "welfare" and the type of housing systems (farrowing crate, loose-housing system, group-housing system, weaned housing and outdoor housing). A summary of the number of articles (research and review) available for each of the search combinations is listed in the table below (Table 1). Articles that did not mention sow/gilt/piglet and stress/behaviour/mortality were excluded from being shortlisted further. Articles that were related to different stage of the production than the ones mentioned in the search were also excluded from being shortlisted further. We then conducted a series of secondary searches using the pig/type name and combining it with key terms in the following order: behaviour, stress, behaviour, mortality and health. A total of 74 research papers (24 review articles, 50 original research articles) were used to support our conclusions on the impacts of housing systems on pre-farrowing to weaning gilts/sows and piglets. Our conclusions on the impacts of housing systems during mating were based on 20 research papers (14 review articles, 6 original research articles). Eighteen research papers (10 review articles, 8 original research articles) were used to base our conclusions on the impacts of outdoor housing system on gilts/sows and their piglets. Although the opportunities for enhancement were discussed at relevant places in sections 5 and 6, we provided more general discussion on enhancements that was based on 14 research papers (12 review articles, 2 original research articles)

4.2. Use of original research and review publications

Publications from experiments conducted under both commercial and research conditions have been used to inform our opinion throughout this scientific commentary. Where there is good agreement in the scientific literature, reviews were used to indicate such agreement and reduce citations. However, in instances where the literature on a contentious welfare issue is ambivalent, we have used original peer-reviewed research publication to form our opinion on the topic.

Table 1: Summary of articles available to review sow and piglet welfare

Stage of production	Pig type	Type of housing	Primary search		
			Research articles	Review articles	Excluded articles
Pre-farrowing to weaning	Sow	Farrowing crates	176	16	79
		Loose-housing	75	7	40
		Group-housing	334	27	101
	Gilts	Farrowing crates	20	3	3
		Loose-housing	6	3	4
		Group-housing	21	2	11
	Piglets	Farrowing crate	156	14	3
		Loose-housing	48	6	12
		Group-housing	22	2	12
		Outdoor housing	33	4	10
Weaned housing	Sow		69	5	56
Outdoor housing	Sow & Piglets		88	8	15

5. Validity of the use of five domains model for welfare assessment of housing systems

The Five Domains Model (Mellor and Beausoleil, 2015; Mellor et al, 2020) provides a conceptual framework for identifying areas of animal welfare risk in the animal use sector. It was developed as a system for assessing the impact of a proposed animal experiment or usage on research animals (animals used in research, teaching and testing) and was known as 'Five Domains of Potential Welfare Compromise' model (Mellor and Reid, 1994). Using the Five Freedoms as a basis, the freedoms were transformed into 'domains of potential compromise' and were redefined to emphasise the extent of welfare compromise rather than the absence of compromise.

The Model was originally configured to provide a systematic, coherent, and inclusive method for identifying potential welfare compromise in animals (Mellor and Reid, 1994) by reference to four physical domains (health, nutrition, environment, and behaviour) and one mental domain (to reflect the animal's overall affective experience). However, more recently, the Model has been updated to also enable identification of rewarding experiences that may be associated with positive affective states (Mellor and Beausoleil, 2015) and incorporate human interactions (Mellor et al., 2020). It has since been applied to a variety of animal groups impacted by humans, including research animals, livestock, companion animals, zoo animals and wildlife.

Whilst conscious emotional experiences such as pain, fear and contentment cannot be assessed directly, behavioural and physiological indicators of emotion can be measured. Researchers have used these measures to describe how animals respond to situations assumed to cause discrete affective states (negative and positive experiences). When using the Model, potential impacts (both negative and positive ones) in each of the four physical domains are evaluated by assessing quantitative changes in behaviour, physiology, neurophysiology, and pathophysiological indicators of functional disruption (Mellor et al., 2009). The identification of potential compromise in one or more of the physical domains is then used to infer potential negative impacts in the fifth domain.

Thus, the conceptual model is a desktop-based process that provides a structured and systematic way of considering animal welfare risks and potential enhancement for sentient animals. The Model's outputs are qualitative and rely on the use of panels to obtain expert opinion. However, more recently the original conceptual model has been used in the literature as an animal welfare assessment tool to deliver 'grades/scores' purporting to compare and/or rank different animal husbandry or management practices/procedures, housing systems or situations. Again, this is generally achieved by assembling a panel of key stakeholders including welfare scientists, industry personnel and members of the general public, who are asked to use their knowledge and relevant literature to assign scores to all likely affective experiences (negative and positive). After all likely affects have been graded/scored, a judgement is made about their overall affective impact on the animal, and a grade is assigned for overall impact on the animal (domain 5) (Mellor and Beausoleil, 2015).

There are, however, concerns with aggregating the grades/scores to assess overall welfare impact on the animal, because a judgement has to be made on how the impacts (i.e., changes in behaviour, physiology, neurophysiology, and pathophysiological indicators) should be graded or ranked. Several protocols have been developed for the integrated assessment of farm animal welfare in the field; for example, the large EU Commission-funded project Welfare Quality® and The LayWel project funded by the EU Commission and national funding by several EU countries. Expert opinion is increasingly used to rank the importance and indirectly the validity of different indicators used in these protocols (Nicol et al., 2009). However, the validity and relative importance of the welfare indicators have been questioned. For example, several authors have challenged the validity and relative importance of the welfare indicators used for cattle, pigs and hens at the farm level developed in Welfare Quality® project (e.g., Phythian et al., 2011; De Vries et al., 2013; Heath et al., 2014a; Heath et al., 2014b; Richmond et al., 2017; Sandøe et al., 2019).

Therefore, while the Five Domains Model is increasingly being used to assess the overall welfare impact on the animal, there remains several challenges and limitations in using the Model for welfare assessment rather than its original conceptual use, that are often not addressed. These limitations include (1) perceived validity of the indicators, (2) relative importance or weighting of the indicators (and thus how you may integrate or aggregate), and (3) animal welfare is not a simple additive function of negative or positive states/experiences.

We recognise and appreciate the effort that the panel has put into this exercise, and there are several advantages in the use of the Five Domains Model in this context. For example, identifying potential impacts and enhancements associated with housing systems. However, in additional to aggregation and weighting, we have a number of concerns, such as:

- Validity of the indicators: We have concerns about the inclusion of some indicators and the exclusion of others. For example:

- why weren't stress physiological indicators included in the assessment? The NAWAC Report notes physiological indicators of stress were inferred from behavioural indicators; however, this is indirect and appreciating behavioural patterns of physiological stressed animals is problematic in some situations e.g., redirected behaviours that may be effective in assisting an animal in coping with a stressor.

- why was live-born piglet mortality not included as an indicator since this is a major welfare concern for piglets?

- we would also contend that some of behavioural indicators of impact are problematic. For example, piglet vocalisations as indicators of lack of maternal care (see below).

- there is a heavy reliance on behavioural indicators, less on health and pathophysiological indicators and no direct reliance on stress physiological indicators. This heavily weights the contribution of behavioural indicators in the assessment, when in fact behavioural, physiological and fitness variables are commonly used to assess welfare.

- Consideration of the relevant scientific literature appears to be limited: the identified impacts, enhancements and likelihoods reported for the different housing system scenarios often lack evidence and appropriate support from the scientific literature (see sections 5-8).
- We also question the impact ratings assigned to some indicators. For example:

- abnormal repetitive behaviours (ARB) and non-fatal crushing: we would argue that the impact of live-born piglet mortality is markedly higher than ARB (and non-fatal crushing) and yet the combined rankings for ARB in confined housing is the same as for non-fatal crushing in loose farrowing and lactation housing. This is an example of the limitations of the scoring, in which there are limited levels of classifications (high, moderate and low) and thus insufficient differentiation between these indicators. Alternatively, perhaps ARB should be scored lower e.g., moderate impact, and if so, confined systems would score higher overall. We note that the panel had low confidence in their assessment of ARB impact. Indeed, research highlights the difficulty in interpretating the welfare implications of ARB (Mason and Rushen 2006), however, stereotypies in captive animals have been generally viewed either as an adaptive coping response to the captive environment or as the inappropriate output in a conflict or thwarting situation (Mason and Latham, 2004).

- Furthermore, we would also argue that the piglet likelihood ratings are problematic for some indicators. For example:

- we suggest that the interpretation of piglet vocalisations is questionable; While there is evidence that farrowing crates reduce maternal responsiveness in sows, there is no evidence of increased piglet vocalisation (e.g., Hayes et al., 2021) and, therefore no evidence that piglets explicitly vocalise if there is a lack of maternal attention. Piglets may certainly vocalise if deprived of milk intake for example, but there is generally no evidence of differences between farrowing crates and loose housing systems in terms of piglet growth rate corrected for litter size (e.g., Oostindjer et al., 2010; Hayes et al 2021). We accept that vocalisations arising due to other factors (e.g., poor milk yield, injury, poor health, etc.) may be indicative of negative affective states in piglets. Consequently, farrowing system scenarios E and F are penalised substantially by including the vocalisation variable (and thus, the moderate and high scores for impact and likelihood).

- aversive response to sow? What this variable relates to is not clear, is it a response of a sow to other sows? If so, as the NAWAC Report states, it depends on floor space and quality. Mating system scenarios A, B and C are scored moderate, D and E are scored high and F is scored low, however it is not clear how these scores were derived. Voluntary stalls (E) have been shown to reduce aggression at mixing and are likely to allow non-oestrous sows to avoid courting sows (see review by Verdon and Rault, 2018) and 7 days in stalls (F) has been shown to reduce stress in comparison to group housing pre-insemination (similar to D) (see Section 7.2 and Rault et al., 2014). As such, the high likelihood score for mating system E is probably questionable.

- As indicated earlier, we remain concerned about the aggregation process and the weighting of impacts and enhancements.

6. Assumptions made in the NAWAC report

We have concerns that some assumptions made during the process of welfare assessment in NAWAC report ignore some important welfare considerations. For example:

- *Use of hyperprolific sow lines*

The relationship between large litter size and piglet mortality is well documented in the literature, with suggestions of a stronger association in hyperprolific sow lines. Some of the key features of a large litter size that contribute to increased piglet mortality include longer farrowing duration (Oliviero et al., 2019), increased stillbirths and hypoxic piglets (Langendijk et al., 2018), increased competition at udder (Declerck et al., 2017), reduced colostrum intake per piglet (Hasan et al. 2019), intrauterine growth restriction (Matheson et al., 2018). Indeed Edwards et al. (2019) reported between 30-40% piglets born in large litters are affected by some form of growth restriction and its associated pathologies requiring more targeted intervention. Furthermore, the risk of liveborn piglet mortality from crushing increases with increasing litter size, particularly in loose-housed sows (Moustsen et al., 2013). Hyperprolific sows also have more piglets born per litter than the number of available teats, resulting in some piglets unable to have ownership of a

functional teat. Large litters from hyperprolific sow lines require additional stockperson intervention to cross-foster, artificially rear or establish nurse sow for the surplus piglets (Baxter et al., 2013). In farrowing crates access to piglets is unimpeded by the sow, making it easier for stockpeople to intervene during the critical period after birth (Baxter et al. 2018). Furthermore, nearly 30% of hyperprolific sows produce insufficient colostrum to meet the nutritional demand of all the piglets (Decaluwe et al., 2013; Quesnel et al., 2012). The quality of colostrum in terms of immunoglobulin content rapidly declines after 4 hours post-partum, and with the average farrowing duration of 7.5 hours in hyperprolific sows, there is increased risk that later born piglets may not get good quality colostrum. Hyperprolific sows may need additional nutritional intervention such as increased provision of roughage to reduce constipation, which consequently reduces the effect of litter size on farrowing duration (Thorsen et al., 2017, Baxter et al., 2020).
Management of hyperprolific sows require specific interventions targeting both sow and piglets with additional assistance required from stockpeople around the time of farrowing.

- *Cross fostering is not occurring*

As acknowledged by the NAWAC report, cross fostering is a common management intervention in commercial pig production systems. If implemented successfully, cross fostering is intended to provide a balanced litter size and improve piglet growth, especially in case of growth restricted piglets that will benefit from udder with small-sized teats. If cross fostering is performed too early or too late or too frequently, it can be stressful and disruptive and can have long-term effects on survival, growth, reproductive success and immunity of pigs (Rober and Matineau, 2001; Straw et al. 1998). Excluding the ease of cross fostering from welfare assessment during farrowing and lactation period, ignores a critical task that needs to be considered when reviewing housing systems, that is as discussed earlier, management interventions intended to reduce piglet mortality are easier in farrowing crates than loose farrowing and lactation systems (Edwards et al., 2018).

- *Pens/huts are built to recommended specifications*

According to the current NZ Code of Practice (NZ-COP 2018) , many areas in New Zealand are unsuitable for large scale systems of outdoor production. Despite these limitations, according to current estimates, outdoor herds make up for about 40% of the pig production in New Zealand . As the current COP does not have any specification for the size of outdoor farrowing huts, it would be difficult to ensure suitable welfare standards are met in NZ outdoor enterprises.

7. Scientific commentary on the NAWAC Report: Impacts of indoor housing systems on pre-farrowing to weaning gilt/sow and piglet welfare

7.1 The NAWAC Report's conclusions on IMPACTS of indoor housing systems on pre-farrowing to weaning gilts/sow and piglet welfare

"The panel concluded that the systems with the highest relative risk of Moderate/High negative IMPACTS on affective states of both sows and piglets are D (Temporary crating plus), E (Temporary crating), and F (Current management; Figure 2a). Outdoor systems (scenario A) were also rated as having more Moderate and High IMPACTS for piglets, but not sows compared to indoor group and pen systems (B and C). IMPACTS were likely in all systems i.e., all systems were rated as having at least one or more IMPACTS at Low or Moderate Likelihood. Overall, the risks of negative IMPACTS on the affective state of both sows and piglets are greater in systems that restrict pigs in terms of space and the expression of normal behaviours".

"The panel also concluded that sows and piglets in outdoor and indoor group housed systems have the greatest Likelihood for positive experiences (Figure 2b). Scenarios D (Temporary crating +), E (Temporary crating) and F (Current management) were considered unlikely to provide any significant ENHANCEMENTS and resulting positive experiences for either sows or piglets. Systems that provide space, complexity and opportunities for appropriate social interactions are more likely to provide sows and piglets with positive experiences."

7.2 Our review of literature on IMPACTS of indoor housing systems on pre-farrowing to weaning gilt/sow and piglet welfare

The farrowing crate reduces the risk of mortality of liveborn piglets, saves space and labour and facilitates inspection of sows and piglets and thus intervention if needed (Barnett et al., 2001; Johnson and Marchant-Forde, 2009). However, criticisms of the farrowing crate have generally focussed on sow welfare, since they restrict the movement of sows (e.g., the capacity to turn around) and the opportunity for sows to perform natural behaviours, such as nest building and freely interacting with their piglets

(Barnett et al., 2001) and, consequently, there is continuing interest in providing farrowing and lactating sows with less confinement (Baxter and Edwards, 2018; Hemsworth, 2018a; Baxter and Edwards, 2021).

While farrowing crates continue to be the most common system of housing farrowing and lactating sows in most countries, there is considerable impetus, in Europe at least, to investigate and trial alternative farrowing systems that allow the sow greater freedom of movement (Baxter et al., 2018). Many types of loose farrowing-lactation pens have been developed and studied over the last two to three decades. These pens normally include pen fixtures that protect the piglet and assist the sow during postural changes and enable provision of straw for nest-building and the more detailed farrowing pens include specialised areas for feeding, nesting and dunging (Baxter et al., 2011), such as the Werribee farrowing pen, Norwegian farrowing pen and the PigSAFE (Piglet and Sow Alternative Farrowing Environment) system (see Morrison et al. (2011), Baxter et al. (2018)). Furthermore, temporary confinement of the sow during parturition and early lactation has also been studied in the last decade.

This section briefly reviews the influence of confinement and its timing and duration relative to sow parturition on the welfare of sows and piglets.

7.2.1 Physiological stress in pre-farrowing to weaning gilts and sows

(i) Acute stress in gilts

There is considerable evidence that pregnant gilts experience an acute physiological stress response on entry to either farrowing crates or loose housing (pens), and that pregnant gilts introduced to farrowing crates have a greater acute stress response than those introduced to pens with straw. For example, pregnant gilts had higher plasma cortisol concentrations on entry to farrowing crates (day 110 of gestation) than those on entry to pens with straw (Cronin et al., 1991), however there was no difference in plasma cortisol concentrations 2 days later (day 112 of gestation). Similarly, gilts in farrowing crates had increased plasma cortisol concentrations 24-12 hours pre-farrowing and during parturition than gilts in straw-bedded pens (Lawrence et al., 1994), however there was no evidence of elevated cortisol concentrations on days 1, 2 and 7 of lactation. Jarvis et al. (1997) found that plasma adrenocorticotropic hormone (ACTH) and cortisol concentrations were higher in gilts in farrowing crates from 24 hours pre-farrowing to parturition than those in pens with straw. Jarvis et al. (2001a) found similar effects on cortisol in gilts as Jarvis et al. (1997), however, both the level and pattern of plasma cortisol concentrations between the crated and penned sows were much less in the later study than previously reported by Jarvis et al. (1997). Furthermore, while Jarvis et al. (1998) found no difference between crated and penned sows in baseline cortisol concentrations from the onset of nest-building behaviour (approximately 12 hours pre-farrowing) and parturition, there was a tendency for crated gilts to have higher cortisol concentrations in the hour prior to parturition.

In a study examining the effects of space (crate versus pens) and straw (present versus absent), Jarvis et al. (2002) found that space, but not straw, affected both plasma ACTH and cortisol concentrations across the entire pre-parturient phase, with crated gilts having higher concentrations than penned gilts irrespective of straw availability, but particularly at the peak of nest-building activity. Jarvis and colleagues observed that when space was available but straw was absent, pre-parturient gilts redirected their nest-building behaviour to the floor and thus the authors proposed that the ability to express substrate-directed behaviour as a result of increased space is reflected in reduced physiological stress.

These six studies reported here provide evidence of a greater acute stress response, particularly in the pre-partum period, in gilts introduced to farrowing crates than those introduced to pens with straw bedding. Furthermore, the study by Jarvis and colleagues (2002) indicates that reduced space rather the presence straw is responsible for the greater acute stress response in gilts in farrowing crates. It is difficult to determine the welfare consequences of an acute stress response around parturition, since parturition *per se* is associated with an increase in cortisol concentrations.

(ii) Acute stress in sows

Results of studies that have examined the effects of the housing system on the stress response of sows around parturition are contradictory. Jarvis et al. (2001b) found that relative to sows in pens with straw, sows in farrowing crates (without straw) had elevated plasma cortisol concentrations from 48 hours pre-farrowing to farrowing, with the most significant difference occurring at 6-4 hours before farrowing. However, this difference pre-partum in cortisol concentrations between crated and penned sows was less than that previously seen in gilts (Jarvis et al., 1997), suggesting some adaptation through prior experience of farrowing in a crate. Also, Cronin et al. (1993) suggested that sows may adapt to farrowing in barren crates because the nest-building behaviour of older sows in farrowing crates was not affected by the provision sawdust, a resource that elicits nest-building in gilts and sows.

Oliviero et al. (2008) found that multiparous sows in farrowing crates, while having similar cortisol concentrations in the period from 5 days pre-partum to 1 day post-partum as penned sows with straw bedding, sows in farrowing crates had higher cortisol concentrations from days 2-5 post-partum than those penned. Yun et al. (2019) found that loose housed sows had higher salivary cortisol concentrations on day 3 pre-partum, but not days 2 and 1 pre-partum, than those confined during this period.

Two studies have been conducted on both gilts and sows. Hales et al. (2016) found that loose-housed parity 1 and 2 sows had higher salivary cortisol concentrations from 1 day pre-partum to 3 days post-partum than those confined during this period. In contrast, Nowland et al. (2019) found that parity 1-3 sows in pens had similar cortisol concentrations from 24 hours pre-partum to the birth of the last piglet than parity 1-3 sows confined during this period.

It is difficult to explain theses conflicting results. Differences between studies, such as pen and crate design, provision of bedding/nesting materials and flooring, previous gestation housing, animal experience and genetics, and husbandry management, may be responsible for these conflicting results. One obvious difference between the studies by Jarvis et al. (2001b) and Oliviero et al. (2008) and those by Hales et al. (2016), Nowland et al. (2019) and Yun et al. (2019) is that of floor space in the loose pen: floor area of the pens in the studies by Cronin et al. (1993), Jarvis et al. (2001b) and Oliviero et al. (2008) were markedly greater than those studies by Hales et al. (2016), Nowland et al. (2019) and Yun et al. (2019). Nevertheless, further research on the stress response of sows to housing during parturition and early lactation is clearly required.

(iii) *Chronic stress in gilts*

There is evidence of chronic stress in gilts housed in farrowing crates in the fourth week of lactation. While Cronin et al. (1991) found no evidence of prolonged stress in lactating gilts in farrowing crates between the first and third weeks of lactation (days 1, 7, 14 and 21 of lactation) on the basis of cortisol concentrations, gilts in crates had higher cortisol concentrations by the end of the fourth week of lactation than gilts in straw-bedded pens. The authors suggested that while four weeks might be the 'natural' weaning age for piglets in confined conditions, the level of attention by the piglets to the sows after four weeks of lactation may result in this prolonged or chronic stress response in gilts in farrowing crates at day 28 of lactation.

In an experiment examining the stress physiology of gilts housed in farrowing crates with or without straw bedding and large strawed pens, Jarvis et al. (2006) found no treatment effects on baseline plasma ACTH and cortisol concentrations in the first to fourth week of lactation (days 2, 8, 15, 22 and 28 of lactation). However, CRH (corticotropic releasing hormone) challenge tests suggested changes in the HPA axis, consistent with chronic stress, by the end of the lactation period: cortisol response to CRH on day 29 post-partum was higher in gilts in crates with straw bedding than those in large strawed pens and tended to be higher in gilts in crates without straw bedding than those in large strawed pens.

(iv) Chronic stress in sows

The authors are unaware of any studies comparing the long-term effects of housing sows in farrowing crates and pens. However, in a study examining the effects of temporary crating, Goumon et al. (2018) found that temporary confinement in farrowing crates from 5 days pre-partum until 4 days post-partum did not affect salivary cortisol concentrations in sows at 6 and 25 days post-partum relative to sows housed in farrowing crates from 5 days pre-partum until 25 days post-partum.

7.2.2 Behaviour of gilts/sows and their piglets during pre-farrowing to weaning

Housing pre-parturient gilts and sows in farrowing crates without bedding/nesting material reduces the level of a major behavioural aspect of maternal behaviour, pre-farrowing nest-building behaviour, compared with gilts and sows in more enriched environments. Considerable research has been directed at investigating the effects of the peri-parturient environment of the gilt and sow, such as space, bedding/nesting material, and social contact, on pre-farrowing nest-building behaviour and space appears to be the most important determinant of the expression of nest-building (see review by Baxter and Edwards (2021)).

Although the expression of maternal behaviour can vary between sows (Špinka et al., 2000; Andersen et al., 2005), sows with lower piglet mortality rates displayed more nest building behaviour (Andersen et al., 2005; Wischner et al., 2009), were calmer during farrowing (Andersen et al., 2005) and were more careful during lying down movements (Burri et al., 2009). There is evidence that sows in loose farrowing and lactation housing systems with bedding material have improved maternal behaviour, based on increased interactions with their piglets and increased responsiveness to piglet vocalizations (Cronin and Smith, 1992; Cronin et al., 1996; Thodberg et al., 2002; Nowland et al., 2019).

Provision of bedding material, such as straw, increases the level of pre-farrowing nest-building behaviour (see review by Barnett et al. 2001), however, the implied welfare risk for sows as a consequence of reduced nest-building in a farrowing crate has not been well demonstrated. While sows will utilise straw if it is freely available, Arey (1992) using an operant conditioning technique, found that although food appeared to be more important to sows during the nest-building phase than straw, as farrowing approached, the demand for straw by sows greatly increased. Providing access to sawdust in the pre-partum period has been shown to reduce the duration of parturition of gilts and sows in farrowing crates and lower the incidence of overlayed piglets in parity 1-3 animals (Cronin et al., 1993). Pre-partum sows in farrowing crates had a higher frequency of bar-biting than those in pens with an open farrowing crate and either sawdust or abundant nesting material (Yun et al., 2015), however, farrowing duration was shorter in sows with pre-partum confinement than for those not confined. It has been suggested that this increased incidence of bar biting may be indicative of either intended nest-building behaviour to cope with the prepartum environment or physiological stress induced by thwarting prepartum natural behaviour (Lawrence et al., 1994; Lawrence et al., 1997). Jarvis et al. (2004) found that the provision of straw increased the duration of parturition of gilts housed both in crates and open pens, but this did not affect piglet survival. Interestingly, provision of increased space, rather than straw, in this study resulted in maternal behaviour after the birth of the first piglet that more closely resembled that in free ranging sows, that is a more active period involving interactions with piglets, followed by a more inactive and passive period.

Several authors have also proposed that a function of nest-building behaviour is to influence the course of parturition and thereby the survival of piglets (Cronin et al., 1993; Cronin et al., 1996). In a review of the literature, Yun and Valros (2015) proposed that nest-building behaviour appears to be positively related to the parturition process and post-partum sow behaviour and piglet survival. Nest-building activity by sows, as well as their behavioural response to piglet distress calls, nose contact with piglets during posture changes and restlessness when piglets are removed, has been shown to be negatively correlated with the risk of piglet crushing (Andersen et al., 2005). However, longer farrowing durations in sows in crates have been reported to be associated with higher stillborn rates in some but not all studies (see review by Baxter et al. (2018)). Higher incidences of savaging of piglets have been reported for sows confined in crates (Lawrence et al., 1994; Johnson and Marchant-Forde, 2009) and there is limited evidence suggesting that increased nest-building is associated with a faster farrowing process with fewer complications (Morrison et al., 2011).

As indicated earlier, increased space and the provision of bedding/nesting materials appear to increase the maternal responsiveness of sows to piglets. In comparison to multiparous sows and their litters remaining in farrowing crates, transferring sows from farrowing crates without bedding to pens without bedding at 3 days post-partum resulted in increased sow–piglet interactions and increased maternal responsiveness based on the behavioural response of sows to audio recording of unfamiliar piglet screams (Singh et al., 2017). Cronin et al. (1996) found that crated primiparous sows vocalise less towards their piglets when presented with an audio recording of a screaming piglet in comparison to penned sows with straw, while Thodberg et al. (2002) found that sows in crates took longer than sows in pens with straw to react as they moved to a lying position when an audio recording of a screaming piglet was played. Nowland et al. (2019) found that sows in pens displayed more positive interactions with their piglets, such as nosing or nuzzling piglets, than those sows crated.

A major difficulty in reviewing research on the effects of farrowing and lactation housing systems is the considerable variation in housing design features, including floor space and bedding/nesting materials during farrowing and lactation as well as gestation housing, which all may affect sow behaviour and welfare. Nevertheless, a lack of space and bedding/nesting materials can reduce maternal behaviour in sows such as responsiveness to piglets, sustained lateral lying, and carefulness when changing posture, which have implications on piglet mortality and welfare (see reviews by Barnett et al., 2001; Johnson and Marchant-Forde, 2009; Hemsworth, 2018a; Hemsworth, 2018b; Baxter and Edwards, 2021). Furthermore, confinement can reduce the ability of sows to thermoregulate, increase risk of hoof, leg and shoulder lesions and reduce muscle mass due to prolonged reduction in movement (see reviews by Barnett et al., 2001; Baxter et al., 2018; Hemsworth, 2018b; Baxter and Edwards, 2021).

There is evidence that piglets reared in farrowing crates may be deprived of some benefits relating to social development. While all sows and their piglets were initially confined in farrowing crates for 4 days post-partum, piglets reared from 4 days post-partum either in loose pens with straw, wood shavings, peat and other substrates or smaller loose pens with enrichments showed more play and less oral manipulative behaviours, such as belly nosing as well as nibbling, sucking or chewing piglets, during lactation than piglets reared in either smaller loose pens or farrowing crates, both without enrichments (Oostindjer et al., 2011). Furthermore, piglets reared in loose pens with straw showed more play behaviour during lactation than piglets reared in farrowing crates provided daily with straw post-partum (Martin et al., 2015). Rearing in large pens (60% more floor space than standard farrowing crates) with straw tended ($P<0.10$) to increase pre-weaning play behaviour in comparison to standard farrowing crates but not farrowing crates with more floor space (20% more space than standard farrowing crates) and straw (Chaloupková et al., 2007). Similarly, piglets reared in farrowing crates and released into pens with increased floor space but without bedding at 3 days post-partum played more and manipulated others less during lactation than piglets remaining in farrowing crates until weaning (Singh et al., 2017). Kinane et al. (2021) found no effects of housing in farrowing crates or in loose pens, both with hessian sacks and fibre plants, on play behaviour of piglets during lactation, however the total floor area in loose pens were only slightly larger (16%) than that in farrowing crates. These studies indicate that a more complex environment, such as bedding/nesting material and increased space, may improve overall piglet welfare and therefore the piglet's motivation to engage in play and increased space may make it physically easier for play behaviour to be expressed (Chaloupková et al., 2007). Similarly, poorer welfare in piglets may lead to increased oral manipulative behaviours, such as belly nosing as well as nibbling, sucking or chewing piglets.

While aggression was not studied, it has been recently shown that piglets reared in loose pens without bedding/nesting material had higher injury scores during lactation than those reared in farrowing crates without bedding/nesting material (Hayes et al., 2021). Furthermore, the piglets reared in loose pens without bedding/nesting material were more reactive to routine husbandry procedures and more fearful of novel and human stimuli. In this study, positive handling of piglets in both housing treatments also reduced the reactivity of piglets to routine husbandry procedures and fear of novel and human stimuli. Recent unpublished research (M.E. Hayes, unpublished data) examining the same treatments as those of Hayes et al. (2021) but on a larger sample size, found more aggression in piglets during lactation in loose pens than farrowing crates and similar effects of housing and human contact on responses of pigs to routine husbandry procedures and novel and human stimuli as found in earlier study by Hayes et al. (2021). Increased contact available to piglets in crates with stockpeople and other sows and piglets may be responsible for reduced fearfulness (Hayes et al., 2021), but clearly further research is required on the effects of early housing.

There is also evidence that housing during rearing affects post-weaning behaviour, but some of the findings are contradictory. For example, rearing piglets in standard farrowing crates, farrowing crates with more space (20% more) and straw, and loose pens with substantially more space (60% more) and straw had no effect on aggression and injuries after mixing at weaning (Chaloupková et al., 2007). In contrast, piglets reared in loose pens with straw had higher levels of aggression early after mixing at weaning than piglets reared in farrowing crates provided daily with straw post-partum (Martin et al., 2015), but there was no effect of housing pre-weaning on injury scores post-weaning.

Oostindjer et al. (2011) found that while enrichment of the lactation pen in itself had few effects on post-weaning behaviour, but interacted with postweaning enrichment and sow housing: piglets from a loose-housed sow switching from a barren to enriched environment had higher levels of play behaviour, while piglets from a confined sow switching from an enriched to a barren environment had high levels of belly nosing and low levels of play. In the study by Hayes et al. (2021) described earlier, while play was not affected, piglets reared in loose pens without bedding were more frequently observed to be active, vocalising, nosing a pen mate and nosing the pen floor during the first day after weaning than pigs reared in farrowing crates.

There is also evidence that social experience with unfamiliar pigs during lactation reduces aggression, injuries and physiological stress following mixing with unfamiliar pigs at weaning. In comparison to piglets reared in farrowing crates, piglets reared in multi-litter group lactation systems both with and without bedding/nesting material were less aggressive and displayed more play behaviour and less damaging oral manipulation post-weaning (including tail biting and ear biting) than piglets reared in farrowing crates (Li and Wang, 2011; Bohnenkamp et al., 2013; Van Nieuwamerongen et al., 2015; Verdon et al., 2016; Verdon et al., 2020). However, these comparisons of housing systems are confounded by space allowance in the multi-litter group housing. There is also evidence that piglets reared in multi-litter group lactation systems are less aggressive towards unfamiliar piglets in a social confrontation test than piglets reared in farrowing crates (Hillmann et al., 2003). Furthermore, piglets reared in multi-litter group lactation systems had less skin lesions and lower cortisol concentrations post-weaning than piglets reared in single litter farrowing systems in which the sow was crated (Grimberg-Henrici et al., 2018; Lange et al., 2020). It is suggested that piglets housed in large multi-litter group systems may adapt to be more tolerant of unfamiliar pigs (Van Nieuwamerongen et al., 2014), and the increased space and environmental complexity may improve their social development by enabling the expression of more submissive behaviour (Lammers and Schouten, 1985) and play behaviour (Bolhuis et al., 2005; Oostindjer et al., 2011). Verdon et al. (2016) also suggested that socially experienced piglets appear better able to recognise their fighting ability relative to others and thus form a dominance hierarchy more quickly and with less aggression.

While there is considerable evidence that piglets reared in multi-litter group lactation systems are less aggressive when mixed with unfamiliar piglets at weaning, recent research has shown that in comparison to farrowing crates, multi-litter group lactation increased piglet mortality and injuries after mixing during lactation (Verdon et al., 2020). Furthermore, sows in multi-litter groups also had higher cortisol concentrations and injuries after mixing during lactation (Verdon et al., 2020). Increased skin lesions due to aggression with other sows and higher cortisol concentrations during lactation have also been reported in multi-litter group lactation systems (Grimberg-Henrici et al., 2018).

These behavioural studies indicate that both loose housing of sows accompanied by more floor space for piglets and provision of bedding/nesting materials increase play behaviour and reduce piglet-directed oral manipulative behaviours in piglets during lactation. While there is consistent evidence that multi-litter group lactation systems reduce aggression in piglets when mixed with unfamiliar piglets at weaning, recent evidence indicates increased stress and skin injuries in lactating sows after mixing during lactation than sows in farrowing for the entire lactation.

7.2.3 Piglet mortality

Piglet mortality continues to be a major welfare and economic concern (Baxter and Edwards, 2021). In general, there have been no significant improvements in piglet mortality over the last three decades, with total mortality (i.e., stillborn and live-born deaths) per litter averaging between 16% and 20% (Baxter and Edwards, 2018), and therefore piglet mortality remains a significant risk to piglet welfare (Baxter and Edwards, 2021). While there is some discussion about the welfare implications of mortality *per se*, many causes of piglet mortality are a welfare concern because asphyxiation, starvation and physical trauma associated with piglet mortality are considered potentially noxious subjective experiences (Edwards, 2002; Mellor and Stafford, 2004). The majority of piglets that do not survive to weaning die within the first 3-4 days of life and the main cause is attributed to crushing and weakness/starvation (Dyck and Swierstra, 1987; Marchant et al., 2000). As some have argued (e.g., Baxter et al., 2018b), the least welfare concerns relate to those piglets that never develop full breathing (i.e., never gain full consciousness because they die during labour or immediately after), intermediate welfare concerns relate to piglets that develop full breathing but descend quickly into hypothermia (and thus unconsciousness) and high welfare concerns relates to piglets that develop full breathing, are not hypothermic, but suffer deaths from hunger, injury or disease. It is this third group of piglets that have the potential to suffer for a considerable period. While stillborn piglets, that are intra-partum deaths occurring just before expulsion is initiated, during expulsion or just after being born, are of intermediate concern, it is particularly the third group of piglets that have the potential to suffer and to suffer for a considerable period.

There is considerable variability in pre-weaning piglet mortality in loose farrowing and lactation systems (Baxter et al., 2012; Moustsen et al., 2013), presumably due to variability in management and housing design features, and the mortality of liveborn piglets in loose farrowing and lactation systems is usually higher than that in farrowing crates (Cronin et al., 2014). In collations of two large data bases, Cronin et al. (2010a) reported that total mortality (including stillbirths) was lower in farrowing crates than farrowing pens for the majority (64%) of these comparisons, while Baxter et al. (2012) reported that total mortality (including stillbirths) was similar in farrowing crates and farrowing pens. A recent meta-analysis of published research on the effects of farrowing and lactation housing on piglet mortality found that the relative risk of pre-weaning mortality was 14% higher in farrowing pens when compared with farrowing crates (Glencorse et al., 2019). Two large studies of industry data from Switzerland (Weber et al., 2007) and UK (KilBride et al., 2012) are useful to note because they highlight the risk of liveborn deaths due to crushing. These two studies involving analyses of farrowing records from commercial farms in Switzerland (655 farms comprising 63661 litters) and the UK (112 farms comprising 2143 litters), revealed no difference in total piglet mortality (stillbirths and liveborn deaths) between loose farrowing pens and farrowing crates, but live-born mortality attributable to crushing was higher in loose pens and mortality due to other causes (e.g., stillbirths, savaging and *Escherichia coli* diarrhoea) was higher in farrowing crates.

The importance of management by stockpeople on piglet welfare and mortality has been recognised by many authors. Because most deaths occur around the time of farrowing and during the first few days of life, Kirkden et al. (2013) concluded that the periparturient period is a particularly important time for management interventions intended to reduce piglet mortality: a number of the procedures that assist piglet welfare and survival require a stockperson to be present during and immediately after farrowing; supervision in general but particularly on methods for the treatment of dystocia and programs of piglet care, such as fostering; and need for good stockmanship, which consists of not only to technical skills but also positive attitudes and behaviour towards pigs and working with pigs. Furthermore, management interventions intended to reduce piglet mortality are easier in farrowing crates than loose farrowing and lactation systems (Edwards et al., 2018).

Since the majority of live-born piglet mortality occurs in the first few days of lactation (Marchant et al., 2000; Johnson and Marchant-Forde, 2009), there is interest in brief confinement of sows during parturition and early lactation for two reasons: improving piglet welfare as well as productivity through minimising liveborn piglet deaths. During nest building, the activity level of the sow increases, whereas in early lactation the activity level of the sow is generally low, and her behaviour is characterized by prolonged lateral lying (Weary et al., 1996; Baxter et al., 2011). As discussed earlier (7.2.1.), since the welfare implications of an increased acute stress response around parturition in farrowing crates are uncertain, the effects of housing system on physiological stress of farrowing sows is contradictory, and sows appear to show some adaptation through prior experience of farrowing in a crate, confinement of the sow in early lactation may not be a serious risk to her welfare. However, this clearly requires further research.

Experiments utilising several loose-housed systems with an option to confine sows in crates have examined the effects of confining sows before, during and after farrowing on piglet mortality. Danish researchers have shown that brief confinement of sows around parturition and in early lactation, when the risk of piglet mortality risk is greatest, can be effective in limiting live-born piglet mortality in this period to rates similar to those achieved with continuous confinement in crates. The results of studies by Moustsen et al. (2013) and Hales et al. (2015b) demonstrated that crating sows for 4 days post-partum was sufficient to reduce live-born piglet mortality in comparison to loose housing. Hales et al. (2015a) however, found that while confinement for the first 4 days of lactation reduced piglet mortality in this period, the lowest live-born piglet mortality to weaning was achieved when sows were confined before farrowing (day 114 of gestation) and for 4 days after farrowing. This study also suggests that liveborn piglets are also at risk during the farrowing process and highlight the importance of confinement from the time of the birth of the first piglet to the last piglet. In a New Zealand study, Chidgey et al. (2015) found that total mortality of piglets prior to weaning was higher in sows in temporary crating from day 112 of gestation (3 days pre-partum) until 4 days post-partum than sows in conventional farrowing crates. A greater proportion of piglets aged 4 days or older were found to have died after sows were released from confinement in temporary crating than in farrowing crates. In an UK study, King et al. (2019) found that the period following crate opening in temporary confinement was a high-risk time for piglet mortality, presumably due to accidental crushing by the sow. However, increases in piglet mortality after crate opening were reduced by opening crates individually rather than simultaneously, and particularly in the afternoon. The authors concluded that sow habituation to disturbance before crate opening may have reduced post-opening piglet mortality, perhaps by reducing the difference in pre- and post-opening sow behaviour patterns.

Baxter et al. (2018) considered that while temporary crates are the least costly, least risky ‘alternative’ to farrowing crates, they offer less in the way of improving sow welfare and, as these systems do not have design features to promote good maternal behaviour, it is likely that when operated with the sow completely free, piglets will be at risk of crushing resulting from a combination of poor maternal behaviour and limited space. However, the studies reported earlier indicate that temporary confinement of sows in crates around parturition and early lactation may be an effective strategy in reducing live-born piglet mortality in comparison to loose housing. For example, in relation to conventional farrowing crates, while Chidgey et al. (2015) reported increased mortality in piglets aged 4 days or older after sows were released from confinement, Hales et al. (2015a) reported reduced live-born piglet mortality to weaning when sows were confined pre-partum to 4 days post-partum. Furthermore, as discussed earlier, King et al. (2019) showed that management practices to reduce sow disturbance around releasing sows from confinement can be effective in reducing piglet mortality at this time. Therefore, overall the results of these studies on temporary confinement of sows indicate that loose housing combined with brief confinement of sows pre- and post-partum offers considerable promise in terms of reducing liveborn piglet mortality in comparison to continuous loose housing. However, these results also highlight the need for further research and development to optimise management of temporary confinement of sows for example, as shown by Hales et al. (2015a) and King et al. (2019) in the importance of the timing of both confinement and release of sows from confinement.

7.3 Our summary of literature on pre-farrowing to weaning housing systems

(i) Physiological stress

Most of the studies on the effects of pre-parturient, parturient and post-parturient housing on female pigs have been conducted on gilts rather than sows. These studies on gilts indicate that pre-partum gilts introduced to farrowing crates experience a greater acute cortisol response than gilts introduced to pens with straw bedding. There is limited evidence that reduced space, rather than the presence of straw, is responsible for the greater acute stress response in gilts on introduction to farrowing crates. The welfare implications of an acute stress response around parturition in gilts in farrowing crates are uncertain, since parturition *per se* is associated with an increase in cortisol concentrations. In contrast to the studies on gilts, the results of studies on the effects of housing sows in farrowing crates or loose pens around parturition on stress physiology are contradictory and clearly further research is required.

There is limited evidence that housing lactating gilts in farrowing crates results in a greater stress response as measured by increased activity of the HPA axis late in lactation (4 weeks post-partum) than those housed in straw pens. The authors are unaware of any published research on the long-term effects of housing lactating sows in farrowing crates. This finding on stress in gilts late in lactation warrants research on gilts and sows because of its implications on welfare late in lactation

(ii) Behaviour

Housing pre-parturient gilts and sows in farrowing crates without bedding/nesting material reduces pre-farrowing nest-building behaviour compared with gilts and sows with more space and/or bedding/nesting material. However, the consequence of reduced nest-building in a farrowing crate has not been well demonstrated. Nevertheless, depriving pre-parturient gilts and sows of opportunities to perform behaviours that appear to be highly motivated such as nest building and freely interacting with their piglets, presumably deprives gilts and sows of increased opportunity for positive emotional experiences. The provision of increased space, rather than straw, appears to result in maternal behaviour after the birth of the first piglet that more closely resembles that in free ranging sows, that is a more active period involving interactions with piglets, followed by a more inactive and passive period.

There is evidence that piglets reared in farrowing crates may be deprived of some benefits relating to social development during lactation, with crated piglets during lactation displaying less play behaviour and more piglet-directed oral manipulative behaviours, such as belly nosing as well as nibbling, sucking or chewing piglets than those reared in loose-housed systems. A more complex environment, such as bedding/nesting materials and more floor space, appears to be responsible for these effects on play and piglet-directed oral manipulative behaviours in piglets.

There is also evidence that housing system during rearing affects post-weaning behaviour of the piglet. The most consistent finding is that social experience with unfamiliar piglets in multi-litter group lactation systems reduces piglet aggression and injuries following mixing with unfamiliar piglets at weaning. However, there is evidence of increased piglet mortality and injuries early post-mixing during lactation as well as increased injuries and cortisol concentrations in sows during this time. These findings raise some serious pig welfare concerns for piglets and sows in multi-litter group lactation.

(iii) Piglet mortality

There is considerable variability in pre-weaning piglet mortality in loose farrowing and lactation systems and the mortality of liveborn piglets is generally considered to higher than that in farrowing crates. Reducing live-born piglet mortality is an important welfare consideration and several relatively recent studies show that temporary confinement of sows in crates around parturition and early lactation can be effective in reducing live-born piglet mortality in comparison to loose housing. Therefore, while further research is obviously required, temporary confinement of sows offers the potential to minimise live-born piglet mortality without serious risk to sow welfare. Furthermore, loose housing after temporary confinement offers some benefits for piglets relating to social development during rearing such as increased play and less piglet-directed oral manipulative behaviours, such as belly nosing as well as nibbling, sucking or chewing piglets. Loose housing after temporary confinement also provides sows with benefits such as a reduced period of confinement.

7.4 Our opinion of the NAWAC Report's conclusions on pre-farrowing to weaning housing systems

As others have remarked (for example Johnson and Marchant-Forde (2009)), assessing the welfare of pigs in farrowing and lactating housing systems is difficult because of the conflicting needs of the sow and her litter. Farrowing crates can safeguard piglet welfare by limiting live-born piglet mortality; an extremely important factor for the welfare of the individual piglet. However, farrowing crates have a number of disadvantages with respect to sow and piglet welfare during other stages of lactation.

For example, while introduction to farrowing crates has been shown to cause a greater HPA-axis specific acute stress response in gilts than introduction to farrowing pens with straw, it is difficult to determine the welfare consequences of an acute stress response around parturition, since parturition *per se* is associated with an increase in cortisol concentrations. Furthermore, there is evidence that this increased acute stress response pre-partum in crated gilts is due to reduced floor space rather than a lack of nest-building material. In contrast to the gilt, research on the effects of housing on stress physiology of the sow around parturition are contradictory, and clearly further research is required. The research is also limited by only focussing on the HPA axis and not including other physiological systems activated during stress. A further gap in knowledge is a lack of understanding of the mechanisms by which the activation of physiological stress systems affects pig welfare.

There is limited evidence that long term housing of lactating gilts in farrowing crates results in chronic stress and that floor space in farrowing crates deprives farrowing and lactating gilts and sows of the opportunity to perform highly motivated behaviours, such as nest building and freely interacting with their piglets, which are behaviours that are likely to provide positive emotional experiences for gilts and sows. We consider chronic stress associated with long term housing of lactating gilts in farrowing crated to be a potential welfare problem and requires further research. Rearing piglets in farrowing crates not only increases piglet-directed oral manipulative behaviours in piglets but appears to reduce their interactions with the sow as well as their play behaviour, thus reducing opportunities for positive emotional experience. However, there is limited evidence that rearing piglets in loose housing systems may increase their fear of novelty and humans. A more complex environment during rearing, such as bedding/nesting materials and more floor space, appears to be responsible for these effects on piglet play behaviour and piglet-directed oral manipulative behaviours, such as belly nosing as well as nibbling, sucking or chewing piglets. There is also evidence that social experience with unfamiliar piglets in multi-litter group lactation systems reduces piglet aggression and injuries following mixing with unfamiliar piglets at weaning, however there is evidence of associated welfare costs, such as increased piglet mortality and injuries early post-mixing during lactation as well as increased injuries and cortisol concentrations in sows during this time.

We conclude that the weight of evidence indicates that housing in farrowing crates pre-partum (and during early post-partum) is not a serious stressor for sows. Furthermore, loose housing at this time poses a serious risk of live-born piglet mortality, a welfare consideration that is often overlooked. Hybrid systems such as temporary crating have the advantage of reducing the risk of early live-born piglet mortality that may occur in loose systems. However, the long-term housing in farrowing crates on sow stress physiology requires further examination.

Although loose housing systems may be advantageous for parturient and lactating sows, a persistent problem has been that of live-born piglet mortality. There is considerable variability in pre-weaning piglet mortality in loose farrowing and lactation systems and it is generally recognised that the mortality of liveborn piglets is usually higher than that in farrowing crates. Consequently, pig producers have been reluctant to adopt loose farrowing and lactation pens for economic reasons, due to the higher piglet losses and higher costs from the extra floor space in comparison to crates (Morrison et al., 2011; Baxter et al., 2012). Recent studies show that temporary confinement of sows in crates around parturition and early lactation can be effective in reducing live-born piglet mortality in comparison to loose housing. Reducing live-born piglet mortality is an important welfare consideration.

While there is a focus on intensive housing systems, research has indicated that the design and management of both indoor and outdoor housing systems is probably more important for animal welfare than is generally recognised (Rushen and Passillé, 1992; Barnett et al., 2001; Hemsworth, 2018) and thus irrespective of the housing system, RD&E efforts should ensure that the design and management of the housing system is optimal from an animal welfare perspective. In relation to current crated and loose farrowing and lactation housing systems, continuous housing in both crated and pen systems have advantages and disadvantages because of the conflicting needs of sows and piglets. There is likely to be continuing development of farrowing and lactation systems during parturition and early in lactation, as well as the remainder of lactation to safeguard sow and piglet welfare. Hybrid systems may reduce some of these limitations, but clearly further research is required. However, any farrowing and lactation housing system will need to be economical for large-scale commercial production (Johnson and Marchant-Forde, 2009; Vosough Ahmadi et al., 2009).

Therefore, we do not support the NAWAC Report's conclusion that "the farrowing and lactation system scenarios D (Temporary crating plus), E (Temporary crating), and F (Current management, FC) pose the highest relative risk of Moderate/High negative

IMPACTS on affective states of both sows and piglets compared to the farrowing and lactation system scenarios B and D (indoor group and pen systems)". It is our opinion that the scientific literature on farrowing and lactation housing systems does not support this NAWAC Report's conclusion because the scientific literature is either insufficient (limited) or conflicting to support the conclusion or does not support the conclusion. We conclude that continuous housing indoors in both farrowing crates and loose pens with or without enrichment has welfare advantages and disadvantages because of the conflicting needs of sows and piglets. We believe that based on the scientific literature that hybrid systems such as temporary crating that restrict sow movement during parturition and early lactation, offer the opportunity to reduce live-born piglet mortality without any serious welfare consequence for the sow and that loose housing after temporary confinement offers some benefits for piglets relating to social development during rearing as well as for sows in terms of less period of confinement. Furthermore, while multi-litter group lactation systems may have the advantage over single-litter systems in that they reduce piglet aggression and injuries following mixing at weaning, recent research indicates several welfare concerns with multi-litter group lactation systems, such as increased piglet mortality and injuries early post-mixing during lactation, as well as increased injuries and cortisol concentrations in sows during this time.

In relation to the NAWAC Report's conclusion that "Scenarios D (Temporary crating +), E (Temporary crating) and F (Current management) were considered unlikely to provide any significant ENHANCEMENTS and resulting positive experiences for either sows or piglets. Systems that provide space, complexity and opportunities for appropriate social interactions are more likely to provide sows and piglets with positive experiences.", our opinion is provided in Section 8, Enhancement.

8. Scientific commentary on the NAWAC Report: Impacts of housing systems during mating in sows

8.1. The NAWAC Report's conclusions on IMPACTS of housing systems during mating in sows

"…… the mating system scenarios rated with more IMPACTS on affective state of Moderate or High Likelihood are D (2 hours in stall – indoors), E (Voluntary stalls), and F (Current – 7 days in stall). The leads to the conclusion that confined, barren, environments have the highest risk of Moderate/High negative IMPACTS on affective state of sows during the week that they are coming into oestrus and being mated."

"Mating systems A (Natural), B (Artificial insemination without restraint), and C (2 hours in stall – outdoors) were considered to provide the greatest Likelihood for ENHANCEMENTS (Figure 3). Scenarios D (2 hours in stall – indoors) and E (Voluntary stalls) were each considered to provide one opportunity for ENHANCEMENT, but none in scenario F (Current 7 days in stalls). Systems that provide space, complexity and opportunities for appropriate social interactions during mating were considered more likely to provide sows with positive experiences."

"Mating systems with voluntary stalls and confined, un-enriched, environments have the highest risk of moderate/high negative impacts on affective state of sows."

8.2. Our review of literature on the IMPACTS of housing systems during mating in sows

As discussed in the Introduction (1), the design and management of both indoor and outdoor housing systems have critical roles in determining the influence of a housing system on pig welfare (see reviews by (Verdon et al., 2015; Hemsworth, 2018a; Verdon and Rault, 2018; Hemsworth, 2021). With the move away from housing of breeding sows in stalls and growing consumer pressure, there is interest in the use of group housing of sows at weaning (Edwards, 2000). There is evidence that group housing may affect subsequent sow behaviour and reproduction. While group housing may facilitate sexual behaviour, grouping sows at weaning may stimulate the sexual behaviour of dominant sows but suppress that of subordinate sows (Pedersen et al., 1993; Pedersen et al., 2003a). Furthermore, there is evidence of longer weaning-oestrus intervals, and reductions in subsequent farrowing rates and litter sizes in group-housed sows post weaning (Backus and Vermeer, 1997; Langendijk et al., 2000; Pedersen et al., 2003b; Karlen et al., 2007; Munsterhjelm et al., 2008; Rault et al., 2014). Therefore, we conclude that the report's conclusion on the relative welfare risks of the six mating scenarios is problematic for several reasons. First, there is a lack of comparative research data. Second, contrary to the NAWAC Report, confinement of the farrowing sow is not an appropriate model for stall housing of weaned sows for 2 hours or 7 days, since the predominant motivations, such as those pertaining to maternal behaviour (e.g., nest building and maternal care) versus those pertaining to social and sexual behaviours, and their relative strengths are unknown. In addition, the durations of these two stages of production (farrowing-lactation and weaning to mating) are markedly different and the duration of the stressor (as well as the intensity of the stressor and other factors such as experience and genetics) affect the magnitude of the behavioural and physiological stress response (Broom and Johnson, 1993). Furthermore, the stage of reproduction influences stress resilience (Tilbrook et al., 2002; Tilbrook and Clarke, 2006; Tilbrook and Ralph, 2018), although we are unaware of any comparative data for the sow on stress resilience during farrowing and lactation versus weaning to oestrus. Furthermore, the duration of the two stages of reproduction, farrowing and lactation and weaning to mating, markedly differ.

No information is provided in the NAWAC Report on the design details of each of the six mating scenarios. While there is a lack of research comparing sow welfare in these mating systems, numerous factors, such as spatial requirements for physical size and basic movement, access to key resources such as feed, water, and lying space, temperature and humidity, and opportunities to interact with other sows, to explore (particularly if hungry), and to prolong satiety between meals through higher feeding levels and provision of additional fibre, affect the welfare of weaned and gestating sows (see reviews by (Barnett et al., 2001; Verdon et al., 2015; Hemsworth, 2018a; Verdon and Rault, 2018; Hemsworth, 2021). Less is known about the effects of design features in outdoor mating systems (see review by (Barnett et al., 2001; Marchant-Forde, 2009), however similar design principles apply to both indoor and outdoor systems, although outdoors systems obviously provide a more complex environment, with more features that are enriching and some that may challenge pig welfare (AgriBiz report 1999, Barnett et al., 2001).

Although there is a lack of comparative research on these six mating scenarios, there is evidence that is relevant to this discussion on the impact of mating systems on the welfare of weaned sows. While mixing weaned sows (either at weaning or after insemination) results in aggression and sexual behaviour, and consequently the possibility of injuries, Rault et al. (2014) have shown that sows housed in groups at weaning and regrouped after insemination experience higher physiological stress, based on cortisol concentrations, than sows housed in individual stalls at weaning and mixed in groups after insemination. Furthermore, Rault et al. (2014) found greater weight loss in group-weaned sows one-week postweaning with a tendency for sexual behaviour to be positively correlated with weight loss. Skin injuries, fresh and old, did not differ between the two treatments post-insemination.

Thus, optimising critical design features of weaned sow pens with or without free-access stalls should be a fundamental objective in reducing aggression, sexual behaviour, injuries and stress induced by the activation of HPA axis in weaned sows. Stall housing of weaned sows for 7 days obviously restricts basic movement and opportunities to explore, however, as shown by Rault et al. (2014), there was no evidence that sows housed in individual stalls post-weaning had higher stress levels based on cortisol concentrations than sows housed in groups post-weaning. In fact, sows housed in groups after weaning had higher cortisol concentrations and lost more weight than sows housed in stalls. Perhaps the lack of temporary confinement on stress induced by the activation of HPA axis is not surprising since the period of confinement in stalls post-weaning is limited and stall housing eliminates intense courting and mounting by other sows, although some sexual behaviours are possible in stalls, such as close contact, including nosing the body of adjacent stall-housed sows. In addition, feeding stalls in weaned sow pens provides opportunity for subordinate sows to avoid dominant sows at feeding (see review by Verdon and Rault, 2018) and mounting by courting sows.

8.3 Our summary of the literature on housing systems during mating

There is large variation in the management of weaned sows, with some being housed in gestation stalls until pregnancy confirmation, following which they are grouped or they are group-housed from weaning (Hemsworth, 2021). Management and housing of weaned sows is often overlooked both in research and the industry. However, the time after weaning is critical for sows, from both a production point of view as the time of insemination is dependent on the onset of oestrus, and from a welfare point of view as a newly-weaned sow has high energy demands and goes through a period of weight loss post lactation (Edwards et al., 2014).

A shift away from stall housing of sows has renewed interest in group housing of sows post-weaning. Group housing facilitates sexual behaviour in sows; however, this seems to be true for dominant sows, with sexual behaviour inhibited in subordinate sows (Pedersen et al., 1993; Pedersen et al., 2003a). Another concern with group housing weaned sows is the variation in the onset of oestrus post weaning (Rault et al., 2014), but this can be mitigated by increased boar stimulation (Langendijk et al., 2000). A relevant study examining the effects of housing weaned sows in groups or in stalls prior to insemination, found that mixing after weaning resulted in higher levels of stress than housing in stalls (Rault et al., 2014). Interestingly, there was no difference in cortisol concentration post-insemination between sows housed in stalls from weaning to post-insemination and then grouped or sows grouped from weaning to insemination and then regrouped after temporary confinement (Rault et al., 2014), indicating that the temporary confinement during insemination does not pose a serious to the welfare of previously-grouped sows.

8.4 Our opinion of the NAWAC Report's conclusions on housing systems during mating

There is insufficient evidence in the literature to conclude on the welfare benefits of grouping sows from weaning to insemination relative to stall housing imposed either briefly around insemination or from weaning. To our knowledge, there is no literature demonstrating detrimental effects of short-term confinement of weaned sows relative to group housing of weaned sows. In fact, there is evidence that mixing sows after weaning results in higher physiological stress, based on cortisol concentrations, than housing in stalls. Therefore, we do not accept the NAWAC Report's conclusions on housing around mating.

In relation to the NAWAC Report's conclusion that "Scenarios D (Temporary crating +), E (Temporary crating) and F (Current management) were considered unlikely to provide any significant ENHANCEMENTS and resulting positive experiences for either sows or piglets. Systems that provide space, complexity and opportunities for appropriate social interactions are more likely to provide sows and piglets with positive experiences.", our opinion is provided in Section 8, Enhancement.

9. Scientific commentary on the IMPACTS of outdoor housing of gilts/sows and piglets

9.1. The NAWAC Report's conclusions on IMPACTS of outdoor housing systems on gilts/sows and piglets

"Outdoor systems (scenario A) were also rated as having more Moderate and High IMPACTS for piglets, but not sows compared to indoor group and pen systems (B and C). IMPACTS were likely in all systems i.e., all systems were rated as having at least one or more IMPACTS at Low or Moderate Likelihood. Overall, the risks of negative IMPACTS on the affective state of both sows and piglets are greater in systems that restrict pigs in terms of space and the expression of normal behaviours.

The panel also concluded that sows and piglets in outdoor and indoor group housed systems have the greatest Likelihood for positive experiences… Systems that provide *space, complexity and opportunities for appropriate social interactions are more likely to provide sows and piglets with positive experiences".*

9.2. Our review of literature on outdoor housing of gilts/sows and piglets

In comparison to indoor pig production, substantially less research has been conducted on the welfare of pigs in outdoor systems, and even less on comparisons between the welfare of pigs in outdoor and indoor housing systems. As with indoor housing systems, the design and management of the outdoor housing system are critical determinants of animal welfare.

Outdoor housing continues to gain considerable interest as an alternative to conventional indoor housing, potentially due to lower upfront investment cost (i.e. infrastructure, facilities, equipment) (Araújo et al., 2016) as well as increased opportunity for animals to perform species-specific behaviour (Von-Borell et al., 2001; Millet et al., 2005). Although a well-managed outdoor production system can generally satisfy the biological needs of both sows and piglets, there are challenges associated with outdoor housing. As many authors have remarked (e.g., Dawkins, 2007; Fraser, 2008; Barnett and Hemsworth, 2009; Sherwin et al., 2010; Mellor, 2015), providing animals with access to natural or free-range environments does not necessarily guarantee high levels of welfare because these animals may still be exposed to a wide range of challenges. For example, climatic conditions, pasture availability and soil quality, severe nutritional inadequacies, exposure to pathogens and other diseases, as well as traumatic injuries and, depending on the species, being a target for predation (Engineering, 1999; Mellor et al., 2010; Pietrosemoli and Tang, 2020). Therefore, high welfare indoor systems should not be discounted just because they are not 'free-range' (Dawkins, 2007). Potential welfare issues affecting pigs in outdoor production systems include inadequate shelter, wallow design and management, thermoregulation, effect of nose-ringing, litter desertion, inadequate feed intake by lactating sows with implications of lower back fat, and unsuitable genotype (Barnett et al., 2001; Marchant-Forde, 2009).

Pre-weaning piglet mortality remains a concern in outdoor housing systems. A number of studies have compared pre-weaning piglet mortality in outdoor and indoor housing systems (KilBride et al., 2012; KilBride et al., 2014; Rangstrup-Christensen et al., 2018). Piglets and recently weaned pigs are highly susceptible to hypothermia caused by lower temperatures, which can have negative implications for both their health and welfare (Barnett et al., 2001; KilBride et al., 2014). The majority of liveborn piglet mortalities are believed to occur within 3 days post-partum (English and Morrison, 1984; Marchant et al., 2000), with piglet crushing by sows accounting for a high percentage of piglet mortality in outdoor systems (61%, Roehe et al. (2009); 74%, KillBride et al., 2012). Longer parturitions have been reported in sows housed in outdoor systems, when compared with indoor housed sows (e.g., 450 minutes in Thorsen et al. (2017); 258 minutes in Schild et al. (2019)). Increased parturition in farrowing sows in outdoor housing systems has been shown to increase the risk of stillbirths (Baxter et al. 2009; Thorsen et al. 2017) and may also increase live-born piglet mortality (Schild et al. 2019).

A large-scale study on 3393 farrowings at 9 commercial Danish outdoor production farms found 29.5% total liveborn piglets in the Danish outdoor housing systems died before weaning, with stillbirths and piglet crushing being the main causes of pre-weaning piglet mortality (Rangstrup-Christensen et al., 2018). Data from the UK showed a trend towards increased pre-weaning mortality in outdoor reared piglets compared to piglets reared in farrowing crates indoors (14% outdoor vs 10% indoors, O'Reilly et al. 2006; 12.8% outdoors, vs 11.7% indoors, KillBride et al. 2012). Furthermore, there is significantly higher risk of live born piglet crushing in outdoor housing compared to farrowing crates indoors (KillBride et al. 2012). Baxter et al. (2011) reported high levels of piglet mortality in the outdoor system (17.9%) compared to piglets born indoors in a farrowing pens (12.5%). The authors also reported higher piglet weights at weaning in the indoor system compared to the outdoor.

A study by Lau et al. (2013) examined the effect of rearing environment (farrowing crate vs outdoor group paddock) had on behavioural responses of piglets to a novel arena test on the day that they were weaned and mixed into large groups. Overall, outdoor-raised piglets ate more and were scored as more 'calm/passive', while farrowing crate-raised piglets spent more time investigating the environment and were scored as more 'playful/inquisitive'. In conclusion, the authors did not find differences in behaviour between outdoor-raised and farrowing shed-raised piglets that would indicate any welfare issues.

9.3. Our opinion of the NAWAC Report's conclusions on outdoor housing

It is important to recognise that relative to indoor pig housing, substantially less welfare research has been conducted on outdoor housing and thus it is difficult to provide recommendations on housing and management systems.

Nevertheless, we agree with the NAWAC Report's conclusions that sows and piglets housed in outdoor systems have substantial opportunities for positive experiences. However, there appear to be a number of issues for sows in outdoor housing systems that need to be addressed. Limited data suggests there is a need for additional research on for example, thermoregulation particularly in cold weather, feed intake in sows and sow fertility in outdoor pig production. Furthermore, we disagree with the NAWAC Report's conclusion on near-miss crushing as the literature suggests that the risk of piglet mortality, especially from crushing in outdoor systems is higher than moderate as concluded in the report.

The NAWAC's Report rated outdoor housing systems (scenario A) to have the least negative IMPACT on sows and moderate and high IMPACTS for piglets, although the report acknowledged thermal discomfort was a problem with outdoor housing, and the likelihood was rated as low. We suggest that thermoregulation particularly in cold weather requires study.

10. Scientific commentary on the NAWAC Report: Enhancement

10.1. The NAWAC Report's conclusions on ENHANCEMENT of pre-weaning to farrowing housing systems and weaning to mating systems

"Sows and piglets in outdoor and indoor group housed systems have the greatest Likelihood for positive experiences (Figure 2b). Scenarios D (Temporary crating +), E (Temporary crating) and F (Current management) were considered unlikely to provide any significant ENHANCEMENTS and resulting positive experiences for either sows or piglets. Systems that provide space, complexity and opportunities for appropriate social interactions are more likely to provide sows and piglets with positive experiences".

"Mating systems A (Natural), B (Artificial insemination without restraint), and C (2 hours in stall – outdoors) were considered to provide the greatest Likelihood for ENHANCEMENTS. Scenarios D (2 hours in stall – indoors) and E (Voluntary stalls) were each considered to provide one opportunity for ENHANCEMENT, but none in scenario F (Current 7 days in stalls). Systems that provide space, complexity and opportunities for appropriate social interactions during mating were considered more likely to provide sows with positive experiences".

10.2. Our review of literature on ENHANCEMENTS of pre-farrowing to weaning housing systems on gilt/sow and piglet welfare

We have reviewed the literature relevant to enhancement opportunities in the earlier sections on pre-farrowing to weaning housing systems (Section 5.2) and weaning to mating systems (Section 6.2). Here we will briefly consider the effects of barren environment and enrichment on breeding sows and piglets (farrowing and lactation housing and mating systems).

While definitions of what constitutes a 'barren' environment differ in both the scientific and popular literature, a useful definition is an environment that does not allow animals to perform 'highly motivated behaviours' that if deprived cause biological disruption (Mason, 2006). Barren environments have been implicated in the development of stereotypies in captive animals. In long-term conflict or thwarting situations, stereotypies may develop and there is evidence that stereotypies can develop in response to barren or restricted environments (Mason, 1991; Würbel et al., 1998). Once developed, stereotypies can become ritualised to the extent that they become part of the behavioural repertoire and persist even in the absence of the original eliciting conditions (Mason 1991).

There has been, and still is, ongoing discussion and research on the welfare significance of stereotypies. But stereotypies in captive animals have been generally viewed either as an adaptive coping response to the captive environment or as the inappropriate output in a conflict or thwarting situation (Mason and Latham, 2004).

Stereotypies have been reported in sows in a range of housing systems, including in tethered, stall-housed and group-housed sows (Schouten and Rushen, 1992; Vieuille-Thomas et al., 1995; Barnett et al., 2001). Thus, lack of stimulation in the pig's environment may lead to boredom and stereotypies, but there is no evidence to indicate that confinement of the farrowing and lactating sow or the weaned sow is sufficient to cause stereotypies. However, as discussed in Section 5, there is limited evidence of chronic stress with confinement of lactating sows in farrowing crates for 4 weeks.

Environmental enrichment, which can be defined as an increase in the biological relevance of captive environments by appropriate modifications (Newberry, 1995), has been shown to assist animals in adapting to barren environments. For example, enriched environments may mitigate deleterious stress effects on neurobiological systems and endocrine profiles and promote stress adaptability in rodents (Abou-Ismail et al., 2010; Lehmann and Herkenham, 2011; Abou-Ismail and Mendl, 2016).

The European Union Commission directive 2001/93/EC (EC, 2001)(European Commission Directive 2001, p. 37) states that 'pigs must have permanent access to a sufficient quantity of material to enable proper investigation and manipulation activities, such as straw, hay, wood, sawdust, mushroom compost or a mixture of such that does not compromise the health of animals'. However, the extent to which this provides effective enrichment has been questioned (Marchant-Forde, 2009; van de Weerd and Day, 2009).

While the utilisation of enrichments has been studied in the growing pig, the effects of enrichment on stress adaptability and indicators denoting poor welfare have not been extensively studied in lactating or weaned sows. The effects of floor space and enrichment on piglets during lactation have been discussed in Section 5.

With the extensive use of fully or partially slatted, non-bedded and non-enriched environments for young and breeding pigs, particularly in the long-term, further research is required to identify effective enrichment. This research should identify objects or situations that have functional relevance to the animal and act with a foreseeable rewarding outcome (Newberry 1995). In other words, it should identify objects or situations that actually improve stress adaptability and welfare in pigs. This topic has been particularly neglected for the gestating sow. However, the implications of non-enriched environments for the farrowing and lactating sow and the weaned sow are less clear.

10.3. Our opinion of the NAWAC Report's conclusions on ENHANCEMENTS of pre-farrowing to weaning housing systems and weaning to mating systems

We agree that enrichment opportunities in indoor mating systems (i.e., around mating) are limited. While material that can be orally manipulated, thus providing foraging and explorative behaviour, can be provided to weaned sows in pens. However, whether the lack of such enrichment in the brief period between weaning and mating is a serious stressor is questionable. While enrichments were not provided, there is evidence that mixing sows in pens after weaning results in higher physiological stress, based on cortisol concentrations, than housing in stalls (with less space than the pens).

We also agree that enhancement opportunities are limited for gilts and sows and their piglets in farrowing crates, in comparison to outdoor systems. However, as discussed above and in Section 5, enhancements for piglets can be achieved by providing more floor space (i.e., loose housing of sows following temporary crating) and material that can be orally manipulated, thus providing opportunities for more play, foraging and explorative behaviour and less piglet-directed oral manipulative behaviours such as belly nosing, nibbling, sucking or chewing piglets. Loose housing of sows following temporary confinement obviously provides sows with more space and the opportunity for materials that can be orally manipulated. Providing piglets in farrowing crates with appropriate material to forage and explore can also provide enrichment opportunities. Clearly further research is required to examine enhancement opportunities for farrowing and lactating sows.

11. Our concluding opinion

11.1 The NAWAC Report's conclusions:

1. "The panel concluded that the systems with the highest relative risk of Moderate/High negative IMPACTS on affective states of both sows and piglets are D (Temporary crating plus), E (Temporary crating), and F (Current management; Figure 2a). Outdoor systems (scenario A) were also rated as having more Moderate and High IMPACTS for piglets, but not sows compared to indoor group and pen systems (B and C). IMPACTS were likely in all systems i.e., all systems were rated as having at least one or more IMPACTS at Low or Moderate Likelihood. Overall, the risks of negative IMPACTS on the affective state of both sows and piglets are greater in systems that restrict pigs in terms of space and the expression of normal behaviours."
2. "The panel also concluded that sows and piglets in outdoor and indoor group housed systems have the greatest likelihood for positive experiences (Figure 2b). Scenarios D (Temporary crating +), E (Temporary crating) and F (Current management) were considered unlikely to provide any significant ENHANCEMENTS and resulting positive experiences for either sows or piglets. Systems that provide space, complexity and opportunities for appropriate social interactions are more likely to provide sows and piglets with positive experiences."
3. "…… the mating system scenarios rated with more IMPACTS on affective state of Moderate or High Likelihood are D (2 hours in stall – indoors), E (Voluntary stalls), and F (Current – 7 days in stall). The leads to the conclusion that confined, barren, environments have the highest risk of Moderate/High negative IMPACTS on affective state of sows during the week that they are coming into oestrus and being mated."

4. "Mating systems A (Natural), B (Artificial insemination without restraint), and C (2 hours in stall – outdoors) were considered to provide the greatest Likelihood for ENHANCEMENTS (Figure 3). Scenarios D (2 hours in stall – indoors) and E (Voluntary stalls) were each considered to provide one opportunity for ENHANCEMENT, but none in scenario F (Current 7 days in stalls). Systems that provide space, complexity and opportunities for appropriate social interactions during mating were considered more likely to provide sows with positive experiences."
5. "Mating systems with voluntary stalls and confined, un-enriched, environments have the highest risk of moderate/high negative impacts on affective state of sows."

11.2 Our opinion of the NAWAC Report's conclusions:

1. We do not support the NAWAC Report's conclusion 1, because the scientific literature is either insufficient (limited) or conflicting to support the conclusion or does not support the conclusion. We conclude that continuous housing indoors in both farrowing crates and loose pens with or without enrichment have welfare advantages and disadvantages because of the conflicting needs of sows and piglets. We believe that based on the scientific literature that hybrid systems such as temporary crating that restrict sow movement during parturition and early lactation, offer the opportunity to reduce live-born piglet mortality without any serious welfare consequence for the sow and that loose housing after temporary confinement offers some benefits for piglets relating to social development during rearing as well as for sows in terms of a reduced period of confinement. Furthermore, while multi-litter group lactation systems may have the advantage over single-litter systems in that they reduce piglet aggression and injuries following mixing at weaning, recent research indicates several welfare concerns with multi-litter group lactation systems, such as increased piglet mortality and injuries early post-mixing during lactation, as well as increased injuries and cortisol concentrations in sows during this time.
2. There is insufficient evidence in the literature to conclude on the welfare benefits of grouping sows from weaning to insemination relative to stall housing imposed either briefly around insemination or from weaning. To our knowledge, there is no literature demonstrating detrimental effects of short-term confinement of

weaned sows relative to group housing of weaned sows. In fact, there is evidence that mixing sows after weaning results in higher physiological stress than housing in stalls. Therefore, we do not accept the NAWAC Report's conclusion 3.

3. We agree that enrichment opportunities in indoor mating systems (i.e., around mating) are limited. While material that can be orally manipulated, thus providing foraging and explorative behaviour, can be provided to weaned sows in pens, whether the lack of such enrichment in the brief period between weaning and mating is a serious stressor is questionable. Therefore, we do not accept the NAWAC Report's conclusions 3, 4 and 5.

4. We also agree that enhancement opportunities (which also include greater floor space) are limited for gilts and sows and their piglets in farrowing crates, in comparison to outdoor systems (Conclusion 2 & 5). However, as discussed above and in Section 5, enhancements for piglets can be achieved by providing more floor space (i.e., loose housing of sows following temporary crating). Furthermore, material can be provided in these loose pens, thus providing opportunities for more play, foraging and explorative behaviour and less piglet-directed oral manipulative behaviours. Obviously, loose housing of sows following temporary confinement also provides sows with more space and the opportunity for provision of materials that can be orally manipulated. Providing piglets in farrowing crates with appropriate material to forage and explore can also provide enrichment. Clearly further research is required to examine enhancement opportunities for farrowing and lactating sows. Therefore, while further research is required, it our opinion that there are opportunities to provide sows and piglets in loose indoor pens and those in temporary confinement (confinement at parturition and in early lactation, followed by loose housing) with enhancement opportunities (Conclusion 2). Providing piglets and particularly sows in farrowing crates with enrichment opportunities is more challenging and requires research.

12 References

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Appendix B: Peer review by Dr Lindsay Matthews

Independent scientific evaluation of selected sections of the NAWAC document

Evaluation of the Code of Welfare for Pigs: 2021

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Independent scientific evaluation of selected sections of the NAWAC document *Evaluation of the Code of Welfare for Pigs*: 2021

Section: Farrowing systems

Brief Summary

NAWAC is proposing two options for farrowing systems: free farrowing or temporary crating.

In summary, this critique of NAWAC's evaluation of farrowing systems, and the additional evidence provided, supports the following:

- That temporary crating offers a better balance between sow and piglet welfare than free farrowing.
- That the maximum time specified for temporary crating requires re-evaluation.
- That the minimum pen size requires re-evaluation.

Evaluation

The current Code of Welfare for Pigs (2018) permits confinement of sows in farrowing crates for up to 5 days before farrowing, and no more than 4 weeks after farrowing.

In farrowing systems, as noted in the Code of Welfare for Pigs (2018), and elsewhere (Goumon et al., 2022), there is a conflict between meeting the needs of the sow and the needs of her offspring, and a balance between their differing requirements needs to be found. The ability to nest and move are two key requirements for sows close to parturition and avoiding death by crushing is an important requirement for piglets.

NAWAC is proposing two new options for farrowing systems:

- a free farrowing system (Option A), where no restraint in crates would be permitted; or,
- a temporary crating (TC) system (Option B), that allows for a maximum of 72 hours in crates (after completion of nesting).

Other features common to both options include a minimum size of 6.5m^2 for the farrowing pen (including 5 m^2 for the sow); provision for separate lying/nesting, dunging and feeding areas; and provision of 2 kg of manipulable, destructible and chewable substrate; and sufficient space to turn around and lie down.

In considering the development of these options, NAWAC stated (in the Evaluation of the Code of Welfare: Pigs 2021) that it, inter alia, reviewed the relevant literature with the aim 'to provide an evidence base for the topics and questions most discussed' (including farrowing systems) and was informed by an analysis using the Five Domains Model. The comments that follow relate to the information contained in the Evaluation of the Code of Welfare: Pigs 2021.

If evidence used by NAWAC to assess key aspects of the welfare of piglets and/or sows in farrowing systems had shortcomings, then it would be difficult to strike a fair balance between the requirements of sows and piglets and determine the most appropriate farrowing systems.

It is contended here, that some of the information used by NAWAC, especially regarding piglet mortality, was limited in important ways, namely:

1. The assertion that it should be possible to mitigate the relatively high rates of pre-weaning piglet mortality in free farrowing systems over time.
2. The literature review comparing the impacts of different farrowing systems on rates of piglet mortality was 'simplistic' (as acknowledged by NAWAC).
3. The proposal for a maximum period of 72 hours in crates (Option B) did not appear to be derived from a systematic analysis of the available information.
4. The proposal for size of pens in Options A and B does not appear to have been derived from systematic analyses of the available information.

Baxter and Edwards (2018) argued convincingly that the predominant cause of preweaning mortality in piglets (death following crushing by the dam) should be accorded the highest level of welfare concern (when considering piglets). Thus, farming practices that lessen the probability of crushing by sows should be given appropriate consideration.

Limitation 1 Reducing piglet deaths in free farrowing systems

NAWAC asserted that it should be possible to mitigate the relatively high rates of pre-weaning piglet mortality in free farrowing systems over time. As evidence, NAWAC used data from an unpublished 10-year-old report on UK systems showing declines with time as staff gained experience. The data would have been confounded by many other factors and is not scientifically reliable. On the other hand, there is robust evidence that piglet mortality rates remain high in free farrowing systems in Sweden (Baxter and Edwards, 2018; Olsson et al., 2019) despite nearly 30 years' experience with them. It is surprising that this information was not mentioned by NAWAC, as NAWAC has highlighted other developments in Swedish free farrowing systems. Farrowing systems that provide for a period of temporary crating offer a promising way to reduce piglet mortality and provide for good sow welfare (Baxter et al., 2018; Goumon et al., 2020 – see below).

Limitations 2 and 3 - Piglet mortalities and crating duration

The NAWAC evaluation of piglet mortality in different farrowing systems used data from 16 selected studies and described general trends in the data only. Fortuitously, Goumon et al. (2022) have reported the results of a recent and comprehensive evaluation of relevant literature (a total of 33 papers and one science report) comparing the welfare of piglets (including pre-weaning mortality) and sows in three different farrowing systems; temporary crating, free farrowing and permanent crating. Two New Zealand studies (Chidgey et al., 2015, 2016) that compared TC and permanent crating were included in the analyses. Since absolute levels of mortality varied widely between studies (e.g., reflecting differences in management), the level of mortality for the TC treatment was standardized within study by expressing it as a percentage of the mortality reported for the comparator treatment (free farrowing or continuous confinement in crates). In comparison with free-farrowing, TC reduced the mortality of live-born piglets by approximately 30% and there was a trend for fewer mortalities with longer periods of confinement.

In comparison with continuous confinement, the mortality of live-born piglets was numerically higher in the TC treatment, but the difference reached statistical significance in only a few studies. There was a strong trend (p=0.051) for decreasing mortality in TC as the duration of confinement increased (with a minimum after about 4 to 5 days of crating).

Although Goumon et al. (2022) did not directly compare permanent crating and free farrowing, the latest available data for New Zealand's commercial pig industry show that the pre-weaning piglet mortality rate for outdoor free farrowing sows is 19.6% and 62% higher than that for indoor crated sows (12.1%) (2019, I. Barugh, pers comm).

Interestingly, countries that have recently decided to phase out farrowing crates (Austria and Germany) will retain the use of crating for 4 or 5 days maximum 'during the critical period for piglet survival' (Goumon et al., 2022). Further, in Sweden crates have been prohibited for nearly 30 years, but piglet mortality rates are high at about 17% (Baxter and Edwards, 2018), leading researchers in Sweden to begin evaluating temporary crating of sows for 3 days after parturition as a way to reduce piglet deaths (Olsson et al., 2019).

Goumon et al. (2022) summarised their findings thus:

> *This review shows that when pens with TC allow the sows to turn during the majority of time in the farrowing unit, it is the pen design and period of confinement in a crate within it that influence the extent to which different functional and motivated behaviors can be fulfilled. This review also indicates that there are at least short-term benefits to sows when confinement is reduced, as shown by reported increases in motivated behaviors such as exploration and interactions with piglets when not permanently crated. It remains unclear whether there are any longer-term beneficial effects (until or beyond weaning) due to the paucity of studies. Furthermore, it is uncertain whether the observed short-term benefits translate to other welfare indicators. Research findings indicate no reduction in the frequency of stereotypies or body lesions and do not provide a clear answer regarding sow stress response when released from confinement. Compared to free farrowing, TC appears beneficial for reducing piglet mortality. The impact of the time of onset of TC on the farrowing process and piglet mortality have been inconsistent. While confinement before farrowing prevents nest building behavior, consequences of this for sow physiology have been ambiguous. Confining the sow briefly after farrowing may be the best compromise, allowing the sow to perform motivated nest-building behavior, but the risks of crushing during the unconfined farrowing period may increase. Subsequent crate reopening seems to increase piglet mortality but only if done earlier than 3–5 days after farrowing. In conclusion, TC is a step forward to better pig welfare compared to the farrowing crate, as it allows some freedom of movement for sows without impairing piglet welfare*.

Considering piglet mortality data, the results of the review by Goumon et al. (2022) provide convincing evidence that supports temporary crating over free farrowing.

NAWAC has proposed limiting crate use to no longer than 72 hours. The experimental evidence presented above shows that crate use for 4 or 5 days is beneficial for piglet survival and is in line with recent welfare legislation in Germany and Austria.

Thus, the maximum duration of crating should be reconsidered.

Limitation 4. Size of farrowing pens

The total space in farrowing pens listed by NAWAC varied between 4 and 8 m^2, and between 2.66 and 18.4 m^2 in the studies described by Goumon et al. (2022). Typical pens in the Goumon et al. (2022) paper varied between 4 and 6 m^2. NAWAC did not analyse systematically the effect of variation in pen space on the welfare of sows or piglets and, to my knowledge, there is no published information on this topic. Given that space is just one of several design factors that influence the welfare of sows and piglets in farrowing pens (Baxter et al., 2018), and NAWAC is making specific recommendations on pen size, this topic requires a thorough scientific evaluation.

Summary

This critique of NAWAC's evaluation of farrowing systems, and the additional evidence provided, supports the following:

- That temporary crating offers a better balance between sow and piglet welfare than free farrowing.
- That the maximum time specified for temporary crating requires re-evaluation.
- That the minimum pen size requires re-evaluation.

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Section: Weaning age

'NAWAC considers that the available evidence supports an increase in weaning age to protect the physical, health and behavioural needs of piglets. NAWAC is proposing that the minimum age at weaning should be 28 days.'

Brief summary

A critical appraisal of the science in NAWAC's evaluation of weaning age, together with additional information, shows that the weight of evidence supports an alternative proposal to that promulgated by NAWAC, that is:

- that the physical, health and behavioural needs of piglets can be protected at weaning ages of less than 28 days, as proposed by Edwards et al. (2020).

Evaluation

The current Minimum Standard for weaning (Code of Welfare: Pigs, 2018) states that 'Weaning must be managed in a way that avoids undue stress on the sow and piglets and minimises negative impacts on their health and welfare' with an example indicator stating that 'weaning is greater than 21 days'.

A total of five scientific papers (Edwards et al., 2020; EFSA, 2007; Jensen, 1986; Robert et al., 1999; Stolba and Wood-Gush, 1989) as well as the EU Directive 201/93/EC and the OIE Terrestrial Animal Code were referenced in NAWAC's supporting documentation (Evaluation of the Code of Welfare: Pigs 2021). There is a substantial additional scientific literature that was not referenced by NAWAC.

(Note, Stolba and Wood-Gush (1989) was incorrectly referred to as Wood-Gush and Stolba (1989)).

Issues with NAWAC's interpretation of supporting documentation

i. The EU Directive 2001/93/EC1

Evaluation:

NAWAC omitted to mention crucial details of the **Directive**.

NAWAC reported (correctly) that the Directive 'states that no piglet shall be weaned from the sow at less than 28 days' but did not mention a critical, complementary section:

However, piglets may be weaned up to seven days earlier if they are moved into specialised housings which are emptied and thoroughly cleaned and disinfected before the introduction of a new group and which are separated from housings where sows are kept, in order to minimise the transmission of diseases to the piglets.'

Thus, legally, piglets may be weaned earlier than 28 days in the EU. Weaning prior to 28 days is common in countries operating under the Directive, where the average weaning age is 26 days, as noted by Edwards et al. (2020). Even though NAWAC referenced Edwards et al. (2020), it did not mention the average weaning age in the EU. Instead, NAWAC reported 'The average weaning age in Sweden and Norway is 33 days.' Sweden is an EU member state, but Norway is not.

These omissions are puzzling as NAWAC clearly considered that the EU Regulations and weaning age in the EU were relevant to its deliberations, and documents containing this information were referenced by NAWAC.

ii. Edwards et al. (2020)

a. Quoting Edwards et al. (2020), NAWAC reported that 'Data suggest that weaning at less than 25 days carries increased health risks, particularly where antibiotic use is restricted'.

Evaluation:

Edwards et al. (2020) prefaced this statement by saying that:

'… at 18-28 days of age … piglets are only just beginning to seek out and consume solid food, develop a more mature gastrointestinal tract, and a fully functional immune system. In consequence, when subjected to the multiple nutritional, environmental and social stressors associated with weaning, piglets weaned at earlier ages show detrimental effects on intestinal morphology, digestive and absorptive capacity and intestinal barrier function, as well as abnormal behaviours indicative of reduced welfare. **The severity of these outcomes, and their consequences for growth and susceptibility to disease, depend largely on the quality of management. With appropriate post-weaning nutrition, environmental control and hygiene, the detrimental short-term effects of weaning can be minimised (my emphasis)**, such that similar lifetime performance can be achieved over a wide range of weaning ages.'

Further, Edwards et al. (2020) noted, amongst other points, that:

- the gastrointestinal and immune systems develop progressively over the first 14 weeks of life with no sudden transition in functionality at 4 weeks of age (Fig 9.3)
- Piglet digestive capacity between 3 and 4 weeks of age is similar (at about two-thirds of its final capacity)
- Feed intake in the immediate post-weaning period, which is strongly influenced by weaning age, has a profound effect on intestinal structure and function - even for pigs weaned at 28 days.
- In a comprehensive study comparing outcomes for piglets weaned at three different ages (21-28 days, 35-42 days, 49-56 days), there was no significant effect of weaning age on clinical health.

In summary, the heightened risks to welfare extend across a range of weaning ages up to 28 days, and risks can be ameliorated by high quality management.

b. In referencing Edwards et al. (2020), NAWAC stated that 'Early weaned piglets show greater signs of impaired welfare by vocalisation, disrupted rest patterns and unwanted belly nosing.'

Appraisal:

- Edwards et al. (2020), referencing Weary and Fraser (1997), provided evidence that vocalisations increase as weaning age decreases (comparing

21-, 28- and 35-day weaning ages). However, this is not consistent with the results by Colson et al. (2006) who reported no differences (p>0.05) in vocalisations when comparing piglets weaned at 21 and 28 days (NB Edwards et al. (2020) stated, incorrectly, that that 21-day old piglets in the Colson et al. study vocalised for longer).

- Edwards et al. (2020) provided evidence that very early weaned piglets (7 or 12 days) rested less than those weaned at 21 or 28 days but did not report any comparisons for piglets weaned between 21 and 28 days.
- Belly nosing is one of the most investigated behaviours in weaned piglets. Edwards et al. (2020) reviewed many experimental studies, but only two compared piglets weaned at between 21 and 28 days, and the results have been inconsistent. There was no difference in belly nosing between 21- and 28-day weaners in the Colson et al. (2006) experiment. Faccin et al. (2020) compared piglets weaned at 22, 25 or 28 days and reported a higher frequency of belly nosing at 22 than 25 days, and both were higher than at 28 days. Importantly, belly nosing is ameliorated by environmental enrichment as noted by Edwards et al. (2020), but not acknowledged by NAWAC. O'Connell et al. (2005) demonstrated that, when provided with enrichment, belly nosing in piglets weaned at 21 days did not differ from those weaned at a later age (36 days). Luo et al. (2020) showed that enrichment provided after weaning is particularly effective in reducing belly nosing.

Thus, the balance of evidence does not support NAWAC's conclusion that 'early weaned piglets' (piglets weaned between 21 and 28 days) show greater signs of impaired welfare. The information presented concerning:

- The vocalisation data are inconsistent.
- The rest pattern data are outside the weaning age range under consideration i.e., 21 to 28 days.
- The belly nosing data are inconsistent, and environmental enrichment removes differences (if any) in belly nosing by piglets weaned at younger and older ages.

c. In referencing Edwards et al. (2020), NAWAC stated that 'Later weaned piglets are better able to adapt to the postweaning environment in terms of social structure, nutrition and health challenges'

Appraisal:

- Edwards et al. (2020) qualified this point with the following: 'With appropriate post-weaning nutrition, environmental control and hygiene, the detrimental short-term effects of weaning can be minimised…' and this was not mentioned by NAWAC.
- Edwards et al. (2020) further qualified this statement by identifying a threshold weaning age (< 25 days) for increased risk in dealing with challenges, which was not mentioned by NAWAC **in this context**.

d. In referencing Edwards et al. (2020), NAWAC stated that 'When weaning early, production gains in terms of piglets weaned per sow per year are offset by production losses in terms of reduced average daily gain'.

Appraisal:

- The data referred to by NAWAC were derived from a paper reported by Vega et al. (2012). NAWAC did not disclose that Edwards et al. (2020) also mentioned that early weaning in the Vega et al. study resulted 'in comparable weight of pigs produced/sow/year'. Later weaned piglets typically weigh more than earlier weaned animals; thus, bodyweight and age were confounded. Edwards et al. (2020) noted that heavier weaning weights *per se* can contribute to better post-weaning performance.
- In a more recent study, Faccin et al. (2020) showed that there was no difference in weight gain measured at a common age (164 d) for piglets weaned at 19, 22, 25, 28 days.
- Edwards et al. (2020) concluded 'that similar lifetime performance can be achieved over a wide range of weaning ages' with appropriate management.

Thus, a balanced interpretation of the science does not support NAWAC's statement.

iii. Robert et al. (1990)

In referencing Robert et al. (19990), NAWAC stated that 'Piglets weaned prior to 28 days of age had reduced feed intake and body weight and a weakened immune response'.

Appraisal:

- After examining a large body of scientific evidence, Edwards et al. (2020) concluded that earlier weaning poses a range of challenges, but crucially (as detailed above), the 'consequences for growth and susceptibility to disease, depend largely on the quality of management. With appropriate post-weaning nutrition, environmental control and hygiene, the detrimental short-term effects of weaning can be minimised, such that similar lifetime performance can be achieved over a wide range of weaning ages.'

Thus, the welfare risks highlighted by NAWAC in the Robert et al. (1990) paper can be managed.

iv. EFSA 2007

In referencing EFSA 2007, NAWAC stated that 'early weaning before four weeks affects piglet gastrointestinal processes causing diarrhoea and weight gain retardation. Weaning at 3 weeks causes belly nosing, frustration and injuries due to chewing at pen mates.

Appraisal:

- See section ii b for an evaluation of the effects of weaning between 21 and 28 days on belly nosing.
- EFSA developed its Opinion using research published up to 2006. Edwards et al. (2020), drawing on a greater body of (and more recent) science, acknowledged that early weaning poses a range of challenges to piglets and concluded that adverse effects can be minimised with appropriate post-weaning nutrition, environmental control and hygiene.
- Further, in referencing EFSA 2007, NAWAC stated that 'They recommended that weaning of piglets should not be carried out before they have a significant feed intake from creep feed and not before 4 weeks of age'. Edwards et al. (2020) came to a different conclusion 'that weaning at less than 25 days of age carries increased risk'.

Thus, a credible review of recent research by Edwards et al. (2020) does not support EFSA's opinion.

v. OIE Terrestrial Animal Code

In referencing the OIE Code, NAWAC stated 'that piglets should be weaned at three weeks or older, unless otherwise recommended by a veterinarian for disease control purposes.'

Appraisal:

- The OIE code is in line with:
    - The EU Directive 2001/93/EC which allows weaning from 21 days (albeit under special conditions), and
    - The conclusion by Edwards et al. (2020) that the physical, health and behavioural needs of piglets can be protected at weaning ages of less than 28 days. Note, Edwards et al. also stated that 'Data suggest that weaning at less than 25 days carries increased health risks.'

In summary, a critical appraisal of the science in NAWAC's evaluation of weaning age, together with additional information, shows that the weight of evidence supports an alternative proposal to that promulgated by NAWAC, that is:

- that the physical, health and behavioural needs of piglets can be protected at weaning ages of less than 28 days, as proposed by Edwards et al. (2020).

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Section: Space for weaner and grower pigs

NAWAC stated that it '*has carefully considered the science available to describe space allowance, and remains of the opinion that allowances should increase*'.

Brief Summary

The critique below shows that not all appropriate evidence was considered by NAWAC, with just six of about 80 potentially relevant papers referenced in the '[Evaluation of the Code of Welfare for Pigs]' document. Several of the papers referenced by NAWAC are scientifically flawed and weaknesses in them were not mentioned by NAWAC. Crucially and inexplicably, NAWAC did not appear to consider other credible papers that provided evidence counter to NAWAC's proposal ('*that allowances should increase*'). For example, NAWAC reported the results of a paper by Averós and colleagues (Averós et al., 2010a) showing that increases in space allowance were associated with increased in lying time, but did not mention another paper by Averós et al., also published in 2010 (Averós et al., 2010b), where lying time decreased as space allowance increased.

Counter to NAWAC's proposal, the balance of credible evidence in recent studies (with k values between 0.03 and 0.066), suggests that the welfare of weaner-grower-finisher pigs will not be improved demonstrably by increases in space allowance. This is consistent with earlier work analysed by Averós et al. (2010b), where pigs were kept under similar conditions (with enrichment). There is a dearth of recent, commercially relevant scientific information on the effects of space allowances on weaner-grower-finisher welfare at space allowances greater than 0.066. There is some evidence that the provision of enrichments (suspended and on-floor) has greater benefits for welfare than increases in space.

Evaluation

NAWAC noted that 'Space provided for growing pigs must allow them to express a wide range of their normal patterns of, not just lying down.' Further, NAWAC noted that 'Spoolder et al. (2012) proposed that, for pigs to cope with their housing conditions, they need sufficient static space (occupied by the body of the pig), activity space (for movement to different areas of the pen and behaviours relating to these), and their interaction space (for appropriate social behaviour)'. NAWAC did not mention other important points made by Spoolder et al. (2012):

- that it is very difficult to calculate activity and social space
- that space requirements should take account of the proportions of animals engaged in different activities at any point in time.

Spoolder et al. (2012) developed a model to calculate k values for the combined active+static space requirements of pigs at various temperatures based on the proportions of animals lying/not lying. At 23 °C, the model gives a **k value of 0.034** i.e., a space allowance of 0.74 m^2 for a 100kg pig. NAWAC has stated that at **k < 0.047** not all pigs can lie laterally, but it has been shown that pigs do not all lie down at the same time, and when lying not all pigs lie in the lateral position (e.g., Ekkel et al., 2003); Spoolder et al., 2012) even when sufficient space is available.

Regarding space for lying behaviour, Averós and colleagues summarised the effects of space allowance on the welfare of grower-finisher pigs in two papers (Averós et al., 2010a; Averós et al., 2010b) by conducting analyses of previously published papers. In one, Averós et al. (2010a) focussed on space allowance and lying time, whilst in the second they investigated the effects of space allowance (and pen enrichment) on a wider range of behaviours (including lying time). The NAWAC evaluation report mentioned the results of one Averós et al. paper only (Averós et al., 2010a) – where k values varied between 0.020 to 0.121. This paper showed that lying time decreased at space allowances below k=0.039 in pens with slatted floors, and below k=0.072 in pens with solid flooring.

The second Averós et al. paper (Averós et al., 2010b) came to an entirely different conclusion i.e., lying time **decreased** as space allowance **increased** across the range of k values from 0.023 to 0.486. Further, the time pigs spent in negative (e.g., biting, fighting) or positive behaviours (sniffing) were not affected by space allowance. Averós et al. (2010b) noted the disagreement between the two papers, but NAWAC did not. Averós and colleagues postulated that the presence of enrichments in one set of studies (Averós et al., 2010b) might have accounted for the differences between the two papers. This is consistent with more recent papers (as detailed below) showing that enrichment has a greater effect than space allowance on time spent lying (and other welfare enhancing activities). Thus, the conclusions of Averós (2010b) study should be taken into consideration, and even accorded priority, given the relevance of enrichments for weaner-grower-finisher pig welfare.

The studies that Averós et al. (2010a, b) used in their analyses were published between 13 and 61 years ago. There have been changes in grower-finisher pig genetics and management systems since then. A search of the literature on the Web of Science database revealed that about 80 papers have evaluated the effects of variation in space allowance on grower-finisher pig behaviour/welfare since 1961. To provide a more up-to-date perspective, the most relevant papers (n=11) published since Averós et al.'s (2010a, b) analyses were reviewed. Importantly, five of these studies were conducted in commercial pig production systems. All but two of the studies (Fu et al. 2016; Zeng et al., 2022) provided enrichment. Note, only two (Fu et al 2016; Scollo et al., 2014) of the 11 papers were referenced by NAWAC, and both have scientific shortcomings that limit their usefulness for understanding the effects of variations in space allowance on welfare.

In the Fu et al. (2016) experiment, groups of pigs were formed by mixing unfamiliar animals at 75kg (135 d of age) and then studied for a short period (15 d) only. Thus, the results would have been confounded by elevated levels of aggressive behaviour associated with establishing new social orders and the short growing period. Further, the k values at the end of the study were not presented, nor were they able to be calculated from the information provided. Thus, the Fu et al. (2016) results have little relevance to commercial practice and could not be used for calculating k values. NAWAC did not acknowledge these issues, and the Fu et al. (2016) data were excluded from my synthesis of the relation between k value and pig welfare derived from recent papers (see below).

The relevance of the Scollo et al. (2014) study referenced by NAWAC is also questionable as the method of feeding was atypical (animals were fed 1x/d at 4pm) and the pigs were observed whilst 18 to 20 h food deprived. The quantities of feed supplied was not disclosed but would appear to have been inadequate as the growth rates were less than 500g/d. Nevertheless, the Scollo et al. (2014) manuscript was not excluded from the 11 recent publications as the k values could be calculated.

Across the five studies conducted in commercial systems (Brandt et al., 2020; Jensen et al., 2010; Klaarborg et al., 2019, Schodl et al., 2021; Vermeer et al., 2017), k varied between 0.03 and 0.059, the flooring was at least partially slatted, and enrichment was provided. In four studies, the higher space allowances were combined with other factors known to enhance welfare e.g., smaller group sizes, more effective enrichment, greater trough space. In the fifth study (Vermeer et al., 2017), space (but not extra enrichment) was confounded with group size. Thus, the treatments represented a combination of different factors (systems), and space allowance was conflated with other variables.

There were no significant differences between space allowance/systems in levels of aggression, ear directed behaviour or manipulation of other pigs. In one study (Brandt et al., 2020), tail directed behaviour was greater in the systems with more space, but the incidence of tail lesions was lower. Based on a comprehensive welfare assessment, Brandt et al. (2020) concluded that 'the difference between systems was minor.' Klaarborg et al. (2019) reported no difference in tail directed behaviour between treatments, and Schodl et al. (2021) observed no differences in skin, tail or ear lesions, soiling, mortalities, or disease incidence between systems. Vermeer et al. (2017) reported no difference in tail damage between systems, a slightly lower incidence of skin lesions (3%) in the higher space system. Interestingly, enrichment had a much greater influence on the prevalence of skin lesions; being much lower (14%) in treatments with than without additional enrichment.

In summary, across the five studies in commercial settings, the welfare of grower-finisher pigs was similar in systems where space allowance together with other factors varied between treatments. Further, the confounding of space allowance with other factors means that any observed variation between systems cannot be attributed to space alone. In referencing Whittaker et al. (2012), NAWAC also highlighted the difficulty of disentangling the effects of space, group size and other factors, but NAWAC did not seem to consider it any further in their evaluation of the science.

In other respects, the Whittaker et al. (2012) review paper is not credible. NAWAC quoted Whittaker et al.'s conclusion that 'increased space is likely to reduce aggressive interactions and total skin lesion score and decrease physiological indicators of stress such as free plasma cortisol concentrations.' However, Whittaker et al. (2012) used 12 papers only, the **most recent** being 26 years old, no information on k values was presented, and there was no attempt to take account of confounding of space allowance with other variables.

For the five recent studies conducted under laboratory conditions (Caldas et al., 2020; Larsen et al., 2018; Li et al., 2021; Scollo et al., 2014; Zeng et al., 2022), k value varied between 0.031 and 0.066, the flooring was at least partially slatted in all but one (Caldas et al., 2020), and enrichment was provided in all but one (Zeng et al., 2022). Group size was confounded with space allowances in one study (Larsen et al., 2018); and enrichment was not confounded with space in any of these experiments. In three studies, enrichment and space were systematically varied.

Considering all five laboratory studies, the welfare of the pigs was similar across variations in space allowance on most parameters investigated: prevalence of fighting, manipulating or biting pen mates; time lying or active; stress levels; evidence of a negative mental state; and use of enrichments. In two studies, lesions were scored, and the results were inconsistent - Larsen et al. (2018) reported no difference in the risk of tail lesions between space allowances, whilst Scollo et al. (2014) observed slightly more lesions on the ears (2 vs 1) and total lesions (6 vs 3) at the lower space allowance. Scollo et al. (2014) reported slightly more sitting behaviour (5 vs 3%) at the lower space allowance. Note the caveat above regarding the Scollo et al. (2014) study.

In contrast with variations in space allowance, the presence of enrichments in the laboratory studies improved welfare (i.e., reducing fighting with suspended items (Li et al., 2021) and reduced risk of tail lesions with straw on the floor (Larsen et al., 2018)).

Summary

Counter to NAWAC's proposal, the balance of credible evidence in recent studies (with k values between 0.03 and 0.066), suggests that the welfare of weaner-grower-finisher pigs will not be improved demonstrably by increases in space allowance. This is consistent with earlier work analysed by Averós et al. (2010b), where pigs were kept under similar conditions (with enrichment). There is a dearth of recent, commercially relevant scientific information on the effects of space allowances on weaner-grower-finisher welfare at space allowances greater than 0.066. There is some evidence that the provision of enrichments (suspended and on-floor) has greater benefits for welfare than increases in space.

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Appendix C: Health and Safety Assessment

Report to David Baines, NZ Pork

Farrowing and Mating Systems, Indoor Pig Farming

Contents

Introduction

Purpose Statement

NZ Pork engaged with CORE Health and Safety Limited to undertake an assessment of working practices and systems across indoor pig farming farrowing and mating systems to identify the health and safety hazards and risks for workers and others who may be present within the workplace.

Criteria of assessment included considering current legislation, work practices, equipment, skilled labour resource and training.

Statement of scope

This report is written for Mr David Baines, Chief Executive, NZ Pork. Information obtained through workplace observations, employer(e) discussions and analysis of documents and relevant data available. Any recommendations that will be made are taking into consideration current New Zealand legislation, The Health and Safety at Work Act 2015 (HSWA)[i] - the health and safety law for New Zealand, effective April 2016. HSWA sets out the principles for businesses to provide a safe working environment, the Person Conducting a Business or Undertaking (PCBU) having the primary duty of care being that a business has the primary responsibility for the health and safety of workers and others influenced by its work. The purpose of the HSWA is to provide a balanced framework to secure the health and safety of both workers and workplaces.

In November 2020, a judicial review was taken by New Zealand Animal Law Association (NZALA) and SAFE against the National Animal Welfare Advisory Committee (NAWAC), the Minister for Primary Industries and the Attorney-General[ii]. Following this the High Court ruled the regulations and minimum standards regarding the use of farrowing crates and mating stalls were unlawful and invalid failing to comply with the Animal Welfare Act 1999, and with no prescribed time for phasing the crates out.

The following report aims to provide information on the risks associated when working during the mating, farrowing, lactation and weaning process within the existing indoor pig farming crate systems with direct comparison to indoor systems devoid of the crates and stalls.

Assessment

The Health and Safety at Work Act 2015 (HSWA) Section 36[iii] – Primary Duty of Care states

Primary duty of care

(1) A PCBU must ensure, so far as is reasonably practicable, the health and safety of—

(a) workers who work for the PCBU, while the workers are at work in the business or undertaking; and

(b) workers whose activities in carrying out work are influenced or directed by the PCBU, while the workers are carrying out the work.

(2) A PCBU must ensure, so far as is reasonably practicable, that the health and safety of other persons is not put at risk from work carried out as part of the conduct of the business or undertaking.

This is a broad overarching duty, requiring as is reasonably practicable, to provide and maintain, a work environment without risks to health and safety, safe plant, safe systems of work, training and supervision and the monitoring of health for the prevention of illness or injury. The PCBU must commit to providing the expected duty of care across all operations of the business, for not only their own workers but any other person present in the business, such as a veterinarian, or an electrician. There are many operational aspects involved in pig farming, this report focuses on the hazards and risks around farrowing and mating in an indoor environment.

The hierarchy of controls determines that if a risk can be eliminated or substituted it should be, where not practicable, so in the case of attending to piglet/sow welfare engineering controls should be considered such as physical barriers to protect a stockperson. The farrowing crate provides a safe working system assisting in HSWA section 36.

Currently 60% of pig farms across New Zealand are Indoor farms, all of which using a farrowing crate style system. Farms visited for assessment fall into the three categories: Indoor Pig Farm – farrowing crate and mating stall system, Indoor/Outdoor Pig Farm – farrowing and mating pen system, Outdoor Pig Farm – farrowing barn and mating pen system. The Indoor/Outdoor pen system and Outdoor farm held similar numbers of pigs and stockpersons; the Indoor farm held 30% more animals but the same number of stockpersons.

Points of difference for consideration surrounding indoor and outdoor systems:

Outdoor systems are limited due to restrictions due to local council regulation, RMA, environmental conditions, requiring a combination of both correct climate and soil conditions.

Outdoor systems have the capability to shut the sow outside of the farrowing barn, allowing a stockperson to access safely to provide for the welfare needs of the piglets. An Indoor pen system, without a farrowing crate does not provide any way to exclude the sow to allow stockpersons safety to enter and access the piglets.

Mating

The mating practice when utilising a mating stall requires the gilt/sow to be walked into the stall where food and water is present, a boar is then present in a laneway in front of the stall. This allows the stockperson to conduct artificial insemination in a controlled environment. In an open system the stockperson is exposed to higher risk as the sow and boar are both free to move at will and they need to be in close proximity to ensure successful mating, with close interaction at times from the stockperson.

Farrowing

In the experiment conducted by *Marchant, Jeremy. (2002)*[iv]*." Piglet and stockperson-directed sow aggression after farrowing and the relationship with a pre-farrowing, human approach test*", it was found that "Savaging of piglets and levels of stockperson-directed aggression were higher in the open pen system than in farrowing crates", the study involved 62 gilts held in either an open pen-based system or a farrowing crate. Reported that 8.1% showed dangerously aggressive behaviour towards humans, all attributed to the open pen system, reflecting 16.2% aggression[v] in the open pen system and 0% in a farrowing crate.

All farming systems visited, discussed, and emphasised the difference of farrowing behaviour between gilts versus sows. Gilts are young female pigs who are farrowing for the first time and are considered to be more likely to demonstrate higher levels of hostility towards both piglets and stockpersons, occasions may result in muzzling the gilt if found savaging the piglet(s). An indoor farrowing system where the gilt is held in a farrowing crate it makes the procedure to muzzle relatively easy, presenting low risk to stockperson safety, in a pen based or outdoor system this is not the case and is rarely done, being the compromise to protect the stockperson's health and safety.

Interventions to assist during (pre) farrowing for welfare of both the gilt/sow and piglet heightens the need for frequent interaction resulting in further risks for stockpersons. Within a farrowing crate system the confinement of the animal provides good protection to allow the stockperson to assist, in a pen based or outdoor system to assist it is necessary to enter the area with elevated risk to the stockperson. Activities are detailed on the risk register and summarised below for the following reasons:-

- The requirement (if necessary) to induce the sow
- The requirement (if necessary) to assist in prolapse, breaching complications, retained piglets in birth canal, removing placenta, and clamping of the umbilical cord if bleeding
- The requirement to inject or muzzle a sow presenting viciously / savaging
- The requirement to assist in the event of overlay / or to remove any piglet mortality

Post Farrowing

The welfare needs of the piglets and sow, husbandry and health practices, require stockpersons to frequently monitor, handle and assist post farrowing. Ongoing care is required for the piglets through their lifecycle, but the intense time critical and essential practices are undertaken in the first 7 days. The natural instinct of the sow to protect her litter during this time this can make the sow behaviour more defensive and sometimes aggressive towards a stockperson when conducting the tasks below:

- Iron Injections
- Drenching
- Vaccinations
- Teeth grinding/clipping
- Tail Docking
- Ear Notching
- Castrations
- Fostering
- Split Suckling
- Preventing crushing through overlay

Majority of the control methods within a farrowing crate environment are reliant on the sow being confined with no access the stockperson whilst they are conducting the above, resulting in the main risk being a crush injury of the hand/arm between the sow and the bars. An open pen-based system the stockperson is required to enter the pen area, there is no option to confine the sow, safety controls involve assessing the safest place to stand in the pen, stance, pig boards and how to quickly exit the pen, the main risk being attacked by the sow. Combining the level of risk, urgency to respond to the animal welfare needs, lack of escape route, whilst trying to remain safe has the potential to create an environment where the stockperson may act in haste, these may be contributing factors to an accident or injury.

Piglet squealing, regardless of reason, will alert a sow - who instinctively will become defensive or aggressive and the likelihood of attack to a stockperson in the immediate area is extremely high. In the farrowing crate system, the risk is minimal due to the confinement, in a pen-based system the risk is high.

Immediate post farrow activities described above, for a stockperson working in a pen-based system presents the most risk which may require a sacrifice to the litter to protect human health and safety.

Weaning in each system happens 28 days after farrowing, the removal of the sow in each system is an area of risk as they may demonstrate high levels of maternal aggression towards the stockperson.

Training

HSWA section 36 (3,f) (f), states *"the provision of any information, training, instruction, or supervision that is necessary to protect all persons from risks to their health and safety arising from work carried out as part of the conduct of the business or undertaking"*

The Welfare Code for Pigs, section 2; Stockmanship[vi], states *"Stock handlers need to be familiar with the risks that are characteristic of the production system in which they work". "Persons involved in the farming of pigs are encouraged to receive external training from accredited training providers where relevant."*

Training is critical to the success of good health and safety management within all workplaces and assists in promoting good mental health and wellbeing. All three farming systems acknowledged the importance of having trained and skilled stockpersons who demonstrate compassion towards the animals, understand their flights paths, good husbandry skills and understand the risks involved. Recruitment and retention of staff highlighted as difficult in the sector, more so for the outdoor systems often cited as concern of health and safety.

Availability of skilled workers within the industry is low and attracting people into the industry proven problematic, some farms recruiting from countries overseas with high level of pork production, such as the Philippines. Immigration New Zealand currently lists both Pig Farm Manager and Assistant Pig Farm Manager on the Regional Skill Shortage List[vii], for each region of New Zealand. With the impact of Covid-19 and the borders closed this reduces the pool of skilled resource further.

Regardless of the farming system applied, training of stockpersons is critical to ensure the hazards, risks and controls needed for health and safety in pig farming are understood. At present the entry level of training for the sector, through the Primary Industry Training Organisation (PRITO) is Level 3[viii], focusing on husbandry, with no focus on health and safety. With 60% of farms using a farrowing crate style system providing strong safety controls for stockpersons this may be reflective as to the focus of training being around animal welfare and husbandry and not human health and safety. If no time during the farrowing process permits temporary confinement in a crate system, stockpersons used to working only with these systems will be required to undergo training to adapt safely in a different environment.

Injury

Injuries across the Industry sector remain reasonably low, averaging at 117.2 incidents per annum over a five-year period. The data received from ACC can break down the injuries by territorial authorities but not as to whether it is an indoor / outdoor system. Regardless of which farming system is applied, each visited identified the areas of critical risk being attacked by a sow, slips trips and falls around pigs, being crushed, and deep lacerations from boar tusks at thigh level.

Table 3: New claims for work-related pig farming injuries by calendar year and accident location.

Accident location	2016	2017	2018	2019	2020
Northland	<4	<4	<4		<4
Auckland	4	4	<4	5	5
Waikato	18	16	18	29	20
Bay of Plenty	4	<4		<4	
Gisborne				<4	
Hawkes Bay	4	<4	<4	<4	<4
Taranaki	4	6	4	<4	5
Manawatū-Whanganui	19	14	9	13	9
Wellington	4	5	<4	6	<4
Marlborough	<4	<4		<4	
Canterbury	65	53	57	51	68
Otago	7	7	6	5	6
Southland				<4	<4
Total	**132**	**112**	**102**	**120**	**120**

Table 3: New claims for work-related pig farming injuries by calendar year and cause of injury.

Injury cause	2016	2017	2018	2019	2020
Workplace property or characteristics	36	23	12	14	11
Lifting, carrying, strain	25	16	14	20	18
Loss of balance or personal control	10	21	8	15	24
Struck by person or animal	11	9	15	8	11
Puncture	<4	<4	10	15	11
Twisting movement	8	8	7	7	12
Object coming loose or shifting	16	5	8	5	4
Pushed or pulled	5	4	6	11	6
Slipping, skidding on foot	<4	7	9	7	5
Other causes	17	..	13	18	18
Total	**132**	**112**	**102**	**120**	**120**

Table 2: New claims for work-related pig farming injuries by calendar year and injury type.

Primary injury diagnosis group	2016	2017	2018	2019	2020
Soft Tissue Injury	79	58	60	75	75
Laceration, Puncture Wound, Sting	26	19	22	22	20
Deafness	8	10	<4	6	4
Fracture/ Dislocation	6	6	7	<4	7
Other	13	19	..	..	14
Total	**132**	**112**	**102**	**120**	**120**

Common injuries acknowledged across the sector include: Crushing/Tissue damage – feet/arm/hand, Fractures/Strains/Sprains – feet/hand/arm/knee/back/ankle, Needlestick – hand/arm, Lacerations – hand/leg/arm, Amputations - finger

Comparatively, the data on cause of injury has been provided by the Health and Safety Executive (HSE) UK. Each year the largest reported cause of injuries to workers are by injured by animal, the second highest annually caused by slips/trips or falls on same level.

Table 2 Fatal and non-fatal injuries to workers (employees and the self-employed) in Great Britain, by detailed industry SIC 0146 Raising of swine-pigs and kind of accident 2015/16-2019/20p

Source: Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR)

		Number of fatal and non- fatal injuries		
		Workers	Of which…	
Year	**Kind of accident**		Employees	Self-employed
2015/16	Total	46	46	0
	Contact with moving machinery	2	2	
	Struck by moving, including flying or falling, object	2	2	
	Struck by moving vehicle	1	1	
	Strike against something fixed or stationary	3	3	
	Injured while handling, lifting or carrying	9	9	
	Slips, trips or falls on same level	9	9	
	Falls from a height	4	4	
	Drowning or asphyxiation	2	2	
	Exposure to, or contact with, a harmful substance	3	3	
	Injured by an animal	10	10	
	Other kind of accident	1	1	
2016/17	Total	43	43	0
	Contact with moving machinery	3	3	
	Struck by moving, including flying or falling, object	6	6	
	Struck by moving vehicle	1	1	
	Strike against something fixed or stationary	1	1	
	Injured while handling, lifting or carrying	5	5	
	Slips, trips or falls on same level	7	7	
	Falls from a height	3	3	
	Exposure to, or contact with, a harmful substance	2	2	

	Injured by an animal	9	9										
	Other kind of accident	6	6										
2017/ 18	Total	36	36	0									
	Contact with moving machinery	1	1										
	Struck by moving, including flying or falling, object	5	5										
	Strike against something fixed or stationary	1	1										
	Injured while handling, lifting or carrying	3	3										
	Slips, trips or falls on same level	6	6										
	Falls from a height	5	5										
	Exposure to, or contact with, a harmful substance	1	1										
	Injured by an animal	10	10										
	Other kind of accident	4	4										
2018/ 19r	Total	32	32	0									
	Contact with moving machinery	1	1										
	Struck by moving vehicle	1	1										
	Strike against something fixed or stationary	1	1										
	Slips, trips or falls on same level	6	6										
	Falls from a height	1	1										
	Trapped by something collapsing or overturning	2	2										
	Injured by an animal	18	18										
	Other kind of accident	2	2										
2019/ 20p	Total	42	40	2									
	Contact with moving machinery	1	1										
	Struck by moving, including flying or falling, object	5	5										
	Struck by moving vehicle	1	0	1									
	Strike against something fixed or stationary	3	3										
	Injured while handling, lifting or carrying	4	4										
	Slips, trips or falls on same level	10	10										
	Falls from a height	3	2	1									
	Injured by an animal	12	12										
	Other kind of accident	3	3										

Conclusion

Indoor pig farms currently represent 60% of the industry, utilising a farrowing crate for the gilt and sow. Mating stalls are used as common practice and allow stockperson to assist in close proximity safely. Gilts and sows awaiting to farrow and gilts that had recently farrowed were observed in the farrowing crate and in a pen-based system. Stockperson interaction around the gilts, piglets and sows were observed in both environments, processes and systems were assessed to determine levels of risk.

The risk register shows the residual risk once the controls have been applied for in both an indoor crate and pen-based system, and mating stalls and mating pens. Mating pens have a higher residual risk level simply due to the stockperson being required in close proximity to conduct artificial insemination with no barriers of protection from the sow or boar. Assessment results for the farrowing crate shows significantly lower levels of residual risk, due to the confinement in the crate, providing a physical barrier of protection to the stockperson, enabling health, welfare, and husbandry tasks to be conducted with easy access and low risk. Pen-based system has higher residual risk scores, reliant on the skills, competency, and fitness of the stockperson. This is due to the multiple interactions essential immediately after farrowing which demand the stockperson having to enter the pen being in close proximity with the gilt/sow, with no physical barrier and no ease of exit present.

The first week after farrowing there is significantly higher risk due to the likelihood of incident, by the combination of the intensity of activity around the sow and piglets and the sow's maternal defence instinct. It is during this timeframe that a system of confinement provides crucial protection to the stockperson of an indoor pig farm.

Currently it has not been identified as to what engineering controls are available to protect the stockperson's health and safety by removal of the farrowing crate. Consideration of the design, height and layout of a new system is essential to ensure a safe working environment will be provided for stockpersons.

Recommendations

For the purposes of the review it is recommended that a gilt or sow is confined to a farrowing crate or similar for the first five-seven days from farrowing to provide a safe controlled environment for the stockperson at a critical time.

Engineering controls to be assessed by industry to identify options to provide safety to stockpersons.

Industry training to be reviewed with PRITO to include health and safety strands at entry level to ensure stockpersons are educated as to the hazards, risks and controls in the workplace.

Industry to review best practice across the sector and develop Health and Safety guidance, applicable to each relevant style of pig farming.

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https://www.legislation.govt.nz/act/public/2015/0070/latest/DLM5976660.html

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Hazard Matrix

Risk	Insignificant (1) (No Treatment)	Minor (2) (First Aid)	Moderate (3) (Doctors/ER)	Major (4) (Disability)	Catastrophic (5) (Fatal)
	Consequence (Hazard Severity)				
Almost Certain (5)	Medium (5)	Medium (5)	High (15)	Extremely High (20)	Extremely High (25)
Likely (4)	Medium (4)	Medium (8)	High (12)	High (16)	Extremely High (20)
Possible (3)	Low (3)	Medium (6)	Medium (9)	High (12)	High (15)
Unlikely (2)	Low (2)	Low (4)	Medium (6)	Medium (8)	High (10)
Rare (1)	Low (1)	Low (2)	Low (3)	Medium (4)	Medium (5)

Likelihood (of event happening)

Most Effective	Extremely High (20 - 25)	Do not proceed with the task without authorisation from the manager. Put control measures in place to reduce the risk further and re-assess the task. Notify others of your task	Eliminate the risk
	High (10 - 16)	Do not proceed with the task. Put control measures in place to reduce the risk and re-assess the task. Notify others of your task	Isolate, Substitute, Engineering Controls
	Medium (4 - 9)	Make a plan and follow it. Read Instructions/training. Try and reduce the risk with other controls and re-assess. Notify others of your task	Isolate, Substitute, Training
Least Effective	Low (1 - 4)	Make a plan. Monitor and Assess the hazards. Try and reduce the risk further. Notify others. Wear PPE	Wear (PPE) Personal Protective Equipment

Eliminate the risk	Remove the risk from the workplace	Do this 1st
Substitute	Use a different tool, System or material to do the job	
Isolate	Put a physical barrier in place	
Engineering Controls	Use guarding and well designed systems	
Administrative	Use training to reduce the risk	
PPE	Wear Personal Protective Equipment	

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Indoor *Farrowing Crate* Risk Hazard Register — *Prepared By: Core HS Rob Markillie/Jane Grace*

Location: New Zealand — *Version: 1.2 26/2/2021*

Risk	Hazard		Initial Risk				Controls	Residual Risk		
Risk Identified	**Hazard Description**	**Hazard Consequence**	**Person at Risk**	**Likelihood**	**Consequence**	**Risk Rating**	**Controls Required**	**Likelihood**	**Consequence**	**Risk Rating**
Sow movement into crates	Maternity aggression from sow turning on stockperson. Slips, Trips, Falls	Mauling, Biting, Entrapment resulting in injury, Wounds, Physical Trauma, Major Trauma, Fracture, Disability	Stockpersons	4	4	16	Use of narrow passageways. Correct height walls. Pig boards. Experienced/trained empathetic/companionate stockpersons. High level of alertness. Emergency Planning	2	2	4
Early sow welfare before farrowing	Maternity Aggression. Slips, Trips, Falls, Biting	Wounds, Physical Trauma, Poisoning, Disability	Stockpersons	3	3	9	Confine sows movement through use of farrowing crate. Experienced empathetic/compassionate stockpersons. Emergency Planning	2	3	6
Teat condition check for general condition/milk	Maternity aggression from sow. Slips, Trips, Falls	Wounds, Physical Trauma, Disability	Stockpersons/ Vet	4	3	12	Experienced empathetic/compassionate stockpersons. High level of alertness. Clean crate floors. Sturdy Footwear. Low crate wall height access. No limbs through bars. Leave and come back to restless Sows. Emergency Planning	3	2	6
Inducing	Crushed limb from entrapment between sow and crate. Slips, Trips, Falls. Needle Stick	Wounds, Physical Trauma, Poisoning	Stockpersons/ Vet	3	3	9	Sow into crate. Limbs over bars not through bars. Experienced empathetic/compassionate stockpersons/vet. Emergency Planning	1	3	3
Breaching Complications	Maternity aggression from sow. Slips, Trips, Falls	Wounds, Physical Trauma	Stockpersons/ Vet	3	3	9	Experienced empathetic/compassionate stockpersons. High level of alertness. Clean crate floors. Sturdy Footwear. Low crate wall height access. Emergency Planning	1	3	3
Retained Piglets - Afterbirth	Maternity aggression from sow. Slips, Trips, Falls	Wounds, Physical Trauma	Stockpersons/ Vet	3	3	9	Experienced empathetic/compassionate stockpersons. High level of alertness. Clean crate floors. Sturdy Footwear. Low crate wall height access. Emergency Planning	1	3	3
Sow Prolapse	Maternity aggression from sow. Slips, Trips, Falls	Wounds, Physical Trauma	Stockpersons	3	3	9	Experienced empathetic/compassionate stockpersons. High level of alertness. Clean crate floors. Sturdy Footwear. Low crate wall height access. Emergency Planning	1	3	3
Removing Placenta - clearing airway	Maternity aggression from sow. Slips, Trips, Falls	Wounds, Physical Trauma	Stockpersons/ Vet	3	3	9	Experienced empathetic/compassionate stockpersons. High level of alertness. Clean crate floors. Sturdy Footwear. Low crate wall height access. Emergency Planning	1	2	2
Umbilical Chord Clamping - if bleeding	Maternity aggression from sow. Slips, Trips, Falls	Wounds, Physical Trauma	Stockpersons/ Vet	3	3	9	Experienced empathetic/compassionate stockpersons. High level of alertness. Clean crate floors. Sturdy Footwear. Low crate wall height access. Emergency Planning. Tool usage training	1	2	2
Checking for Overlay of Piglets	Maternity aggression from sow. Slips, Trips, Falls	Wounds, Physical Trauma	Stockpersons	3	3	9	Experienced empathetic/compassionate stockpersons. High level of alertness. Clean crate floors. Sturdy Footwear. Low crate wall height access. No limbs through bars. Leave and come back to restless Sows. Emergency Planning	2	3	6
Piglet Care - Colostrum - Split Suckling	Maternity aggression from sow. Slips, Trips, Falls	Wounds, Physical Trauma	Stockpersons	3	3	9	Experienced empathetic/compassionate stockpersons. High level of alertness. Clean crate floors. Sturdy Footwear. Low crate wall height access. Emergency Planning	2	3	6
Savaging - Removing piglet to creep/box area	Maternity aggression from sow. Slips, Trips, Falls. Burns	Wounds, Physical Trauma	Stockpersons	3	3	9	Experienced empathetic/compassionate stockpersons. High level of alertness. Clean crate floors. Sturdy Footwear. Low crate wall height access. Guarding around heat lamp if used. Emergency Planning	2	3	6
Removal of Mortality	Maternity aggression from sow. Slips, Trips, Falls	Wounds, Physical Trauma	Stockpersons	3	2	6	Experienced empathetic/compassionate stockpersons. High level of alertness. Clean crate floors. Sturdy Footwear. Low crate wall height access. Leave and come back to restless/aggressive sows Emergency Planning	2	2	4
Stomach feel of piglet to ensure feeding	Maternity aggression from sow. Slips, Trips, Falls	Wounds, Physical Trauma	Stockpersons/ Vet	2	3	6	Experienced empathetic/compassionate stockpersons. High level of alertness. Clean crate floors. Sturdy Footwear. Low crate wall height access. Emergency Planning	2	2	4

Fostering/Cross-Fostering	Maternity aggression from sow. Slips, Trips, Falls	Wounds, Physical Trauma, Disability	Stockpersons/ Vet	3	3	9	Experienced empathetic/compassionate stockpersons. High level of alertness. Clean crate floors. Sturdy Footwear. Low crate wall height access. No limbs through bars. Leave and come back to restless Sows. Emergency Planning	2	2	4
Encourage Sow to Stand/Uptake of Food	Maternity aggression from sow. Slips, Trips, Falls.	Wounds, Physical Trauma, Disability	Stockpersons	4	3	12	Experienced empathetic/compassionate stockpersons. High level of alertness. Clean crate floors. Sturdy Footwear. Low crate wall height access. No limbs through bars. Leave and come back to restless Sows. Emergency Planning	3	2	6
Sow Mastitis Antibiotic Injection	Maternity aggression from sow. Slips, Trips, Falls. Needle Stick	Wounds, Physical Trauma, Poisoning	Stockpersons/ Vet	3	3	9	Experienced/ trained/ empathetic/compassionate stockpersons/vet. High level of alertness. Clean crate floors. Low crate wall height access. Emergency Planning	2	3	6
Piglet Care - Iron Injection	Maternity aggression from sow. Slips, Trips, Falls. Needle Stick	Wounds, Physical Trauma, Poisoning	Stockpersons/ Vet	3	3	9	Experienced/ trained/ empathetic/compassionate stockpersons/vet. High level of alertness. Clean crate floors. Low crate wall height access. Emergency Planning	2	3	6
Piglet Care - Drenching (Scours)	Maternity aggression from sow. Slips, Trips, Falls.	Wounds, Physical Trauma	Stockpersons	3	3	9	Experienced/ trained/ empathetic/compassionate stockpersons/vet. High level of alertness. Clean crate floors. Low crate wall height access. Emergency Planning	2	3	6
Piglet Care - Vaccines	Maternity aggression from sow. Slips, Trips, Falls. Needle Stick	Wounds, Physical Trauma, Poisoning	Stockpersons/ Vet	3	3	9	Experienced/ trained/ empathetic/compassionate stockpersons/vet. High level of alertness. Clean crate floors. Low crate wall height access. Emergency Planning	2	3	6
Piglet Care - Teeth Grinding	Maternity aggression from sow. Slips, Trips, Falls. Biting	Wounds, Physical Trauma	Stockpersons	3	3	9	Experienced/ trained/ empathetic/compassionate stockpersons/vet. High level of alertness. Clean crate floors. Low crate wall height access. Emergency Planning. Tool usage training	2	3	6
Piglet Care - Tail Docking	Maternity aggression from sow. Slips, Trips, Falls. Needle Stick. Cuts. Burns	Wounds, Physical Trauma, Poisoning	Stockpersons/ Vet	3	3	9	Experienced/ trained/ empathetic/compassionate stockpersons/vet. High level of alertness. Clean crate floors. Low crate wall height access. Emergency Planning. Tool usage training	2	3	6
Piglet Care - Castration	Maternity aggression from sow. Slips, Trips, Falls. Cuts	Wounds, Physical Trauma, Poisoning	Stockpersons/ Vet	3	3	9	Experienced/ trained/ empathetic/compassionate stockpersons/vet. High level of alertness. Clean crate floors. Low crate wall height access. Emergency Planning. Tool usage training	2	3	6
Piglet Care - Ear Notching	Maternity aggression from sow. Slips, Trips, Falls.	Wounds, Physical Trauma	Stockpersons	3	3	9	Experienced/ trained/ empathetic/compassionate stockpersons/vet. High level of alertness. Clean crate floors. Low crate wall height access. Emergency Planning. Tool usage training	2	3	6
Weaning	Maternity aggression from sow. Slips, Trips, Falls.	Wounds, Physical Trauma	Stockpersons	3	3	9	Experienced/ trained/ empathetic/compassionate stockpersons/vet. High level of alertness. Clean crate floors. Low crate wall height access. Emergency Planning	2	3	6
Thermal Protection Maintenance (Crate temperature checks)	Maternity aggression from sow. Slips, Trips, Falls. Cuts. Burns	Wounds, Physical Trauma, Infection	Stockpersons	3	3	9	Experienced/ trained/ empathetic/compassionate stockpersons/vet. High level of alertness. Clean crate floors. Low crate wall height access. Use appropriate/effective equipment. Use a heat gun from outside the crate. Use effective/appropriate PPE. Wash hands. Clean PPE. Emergency Planning	2	3	6
Mucking out of crate	Maternity aggression from sow. Slips, Trips, Falls. Infection	Wounds, Physical Trauma, Zoonosis	Stockpersons	3	3	9	Experienced/ trained/ empathetic/compassionate stockpersons/vet. High level of alertness. Clean crate floors. Low crate wall height access. Use appropriate/effective equipment. Use a shovel. Use effective/appropriate PPE. Wash hands. Clean PPE. Emergency Planning	2	3	6
Stockpersons own health and hygiene (Zoonosis)	Maternity aggression from sow. Slips, Trips, Falls. Infection. Cuts	Wounds, Physical Trauma, Zoonosis, Death	Stockpersons	3	5	15	Experienced/ trained/ empathetic/compassionate stockpersons/vet. High level of alertness. Clean crate floors. Low crate wall height access. Use appropriate/effective equipment. Use effective/appropriate PPE. Wash hands. Clean PPE. Emergency Planning	2	3	6
Crate/Water/Feeder Maintenance	Maternity aggression from sow. Slips, Trips, Falls. Infection. Cuts	Wounds, Physical Trauma, Zoonosis	Stockpersons	3	3	9	Experienced/ trained/ empathetic/compassionate stockpersons/vet. High level of alertness. Clean crate floors. Low crate wall height access. Use appropriate/effective equipment. Use effective/appropriate PPE. Wash hands. Clean PPE. Emergency Planning	2	3	6

Stockperson Mental Health and Wellbeing	High Mortality Rate, Fatigue, Overworked, Undue Pressure from outside sources	Disability, Death	Stockpersons	4	5	20	Use of Proven Systems to reduce piglet mortality rates. Extra staff to reduce workload. Outside intervention with counselling or other resources	3	3	9

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Indoor *Farrowing Pen System* Risk Hazard Register

Prepared By: Core HS Rob Markillie/Jane Grace

Location: New Zealand

Version: 1.2 26/02/2021

Risk	Hazard		Initial Risk				Controls	Residual Risk		
Risk Identified	**Hazard Description**	**Hazard Consequence**	**Person at Risk**	**Likelihood**	**Consequence**	**Risk Rating**	**Controls Required**	**Likelihood**	**Consequence**	**Risk Rating**
Sow movement into the system	Maternity aggression from sow turning on stockperson. Slips, Trips, Falls	Mauling, Biting, Entrapment resulting in injury, Wounds, Physical Trauma, Major Trauma, Fracture, Disability, Death	Stockpersons	5	5	25	Use of narrow passageways. Correct height walls. Pig boards. Experienced/trained empathetic/companionate stockpersons. High level of alertness. Emergency Planning and escape route	3	3	9
Early sow welfare/husbandry before farrowing	Maternity Aggression. Slips, Trips, Falls	Mauling, Biting, Entrapment resulting in injury, Wounds, Physical Trauma, Major Trauma, Fracture, Disability, Death	Stockpersons	5	5	25	2 stockpersons to confine sow. Pig Board. Experienced empathetic/compassionate stockpersons. Emergency Planning and Escape route. Athletic Stockperson. High level of alertness. Sturdy footwear. Clean floors. Remove obstacles	4	4	16
Teat condition check for general condition/milk supply	Maternity aggression from sow. Slips, Trips, Falls	Wounds, Physical Trauma, Lacerations, Disability, Death	Stockpersons/Vet	5	5	25	2 stockpersons to confine sow. Pig Board. Effective/appropriate PPE. Experienced empathetic/compassionate stockpersons. Leave and come back to restless sows. Emergency Planning and Escape route. Athletic Stockperson. High level of alertness. Sturdy footwear. Clean floors. Remove obstacles	3	4	12
Inducing	Crushed limb from entrapment between sow and system walls. Slips, Trips, Falls. Needle Stick	Mauling, Biting, Entrapment resulting in injury, Wounds, Physical Trauma, Major Trauma, Fracture, Poisoning, Disability, Death	Stockpersons/Vet	5	5	25	2 stockpersons to confine sow. Pig Board. Experienced empathetic/compassionate stockpersons. Emergency Planning and Escape route. Athletic Stockperson. High level of alertness. Sturdy footwear. Clean floors. Remove obstacles	4	4	16

Breaching Complications	Maternity aggression from sow. Slips, Trips, Falls	Mauling, Biting, Entrapment resulting in injury, Wounds, Physical Trauma, Major Trauma, Fracture, Disability, Death	Stockpersons/Vet	5	5	25	2 stockpersons to confine sow. Pig Board. Experienced empathetic/compassionate stockpersons. Emergency Planning and Escape route. Athletic Stockperson. High level of alertness. Sturdy footwear. Clean floors. Remove obstacles	4	4	16
Retained Piglets - Afterbirth	Maternity aggression from sow. Slips, Trips, Falls, Infection	Mauling, Biting, Entrapment resulting in injury, Wounds, Physical Trauma, Major Trauma, Fracture, Zoonosis, Disability, Death	Stockpersons/Vet	5	5	25	2 stockpersons to confine sow. Pig Board. Experienced empathetic/compassionate stockpersons. Emergency Planning and Escape route. Athletic Stockperson. High level of alertness. Sturdy footwear. Clean floors. Remove obstacles	4	4	16
Sow Prolapse	Maternity aggression from sow. Slips, Trips, Falls	Mauling, Biting, Entrapment resulting in injury, Wounds, Physical Trauma, Major Trauma, Fracture, Zoonosis, Disability, Death	Stockpersons	5	5	25	2 stockpersons to confine sow. Pig Board. Effective/appropriate PPE. Wash hands. Experienced empathetic/compassionate stockpersons. Emergency Planning and Escape route. Athletic Stockperson. High level of alertness. Sturdy footwear. Clean floors. Remove obstacles	4	4	16
Removing Placenta - clearing airway	Maternity aggression from sow. Slips, Trips, Falls. Bites	Wounds, Physical Trauma, Zoonosis, Disability, Death	Stockpersons	5	5	25	2 stockpersons to confine sow. Pig Board. Effective/appropriate PPE. Wash hands. Experienced empathetic/compassionate stockpersons. Emergency Planning and Escape route. Athletic Stockperson. High level of alertness. Sturdy footwear. Clean floors. Remove obstacles	4	4	16
Umbilical Chord Clamping - if bleeding	Maternity aggression from sow. Slips, Trips, Falls	Wounds, Physical Trauma, Lacerations, Disability, Death	Stockpersons/Vet	5	5	25	2 stockpersons to confine sow. Pig Board. Effective/appropriate PPE. Wash hands. Experienced empathetic/compassionate stockpersons. Emergency Planning and Escape route. Athletic Stockperson. High level of alertness. Sturdy footwear. Clean floors. Remove obstacles	4	4	16
Checking for Overlay of Piglets	Maternity aggression from sow. Slips, Trips, Falls	Wounds, Physical Trauma, Disability, Death	Stockpersons	5	5	25	2 stockpersons to confine sow. Pig Board. Effective/appropriate PPE. Wash hands. Experienced empathetic/compassionate stockpersons. Emergency Planning and Escape route. Athletic Stockperson. High level of alertness. Sturdy footwear. Clean floors. Remove obstacles	4	4	16
Piglet Care - Colostrum - Split Suckling	Maternity aggression from sow. Slips, Trips, Falls	Wounds, Physical Trauma, Lacerations, Disability, Death	Stockpersons	5	5	25	2 stockpersons to confine sow. Pig Board. Effective/appropriate PPE. Experienced empathetic/compassionate stockpersons. Emergency Planning and Escape route. Athletic Stockperson. High level of alertness. Sturdy footwear. Clean floors. Remove obstacles	4	4	16

Savaging - Removing piglet to creep/box area	Maternity aggression from sow. Slips, Trips, Falls. Burns	Wounds, Physical Trauma, Lacerations, Disability, Death	Stockpersons	5	5	25	2 stockpersons to confine sow. Pig Board. Effective/appropriate PPE. Guarding around heat lamp if used. Experienced empathetic/compassionate stockpersons. Emergency Planning and Escape route. Athletic Stockperson. High level of alertness. Sturdy footwear. Clean floors. Remove obstacles	4	4	16
Removal of Mortality	Maternity aggression from sow. Slips, Trips, Falls	Wounds, Physical Trauma, Lacerations, Disability, Death	Stockpersons	5	5	25	2 stockpersons to confine sow. Pig Board. Leave and come back when sow less agitated. Use a long fork/grab from outside the system. Experienced empathetic/compassionate stockpersons. Emergency Planning and Escape route. Athletic Stockperson. High level of alertness. Sturdy footwear. Clean floors. Remove obstacles	2	2	4
Stomach feel of piglet to ensure feeding	Maternity aggression from sow. Slips, Trips, Falls	Wounds, Physical Trauma, Lacerations, Disability, Death	Stockpersons	5	5	25	2 stockpersons to confine sow. Pig Board. Effective/appropriate PPE. Experienced empathetic/compassionate stockpersons. Emergency Planning and Escape route. Athletic Stockperson. High level of alertness. Sturdy footwear. Clean floors. Remove obstacles	4	4	16
Fostering/Cross-Fostering	Maternity aggression from sow. Slips, Trips, Falls	Wounds, Physical Trauma, Lacerations, Disability, Death	Stockpersons/Vet	5	5	25	2 stockpersons to confine sow. Pig Board. Effective/appropriate PPE. Experienced empathetic/compassionate stockpersons. Emergency Planning and Escape route. Athletic Stockperson. High level of alertness. Sturdy footwear. Clean floors. Remove obstacles	3	4	12
Encourage Sow to Stand/Onto Food	Maternity aggression from sow. Slips, Trips, Falls.	Wounds, Physical Trauma, Disability, Death	Stockpersons	5	5	25	2 stockpersons to confine sow. Pig Board. Effective/appropriate PPE. Experienced empathetic/compassionate stockpersons. Leave and come back to restless sows. Emergency Planning and Escape route. Athletic Stockperson. High level of alertness. Sturdy footwear. Clean floors. Remove obstacles	4	4	16
Sow Mastitis injection	Maternity aggression from sow. Slips, Trips, Falls. Needle Stick	Wounds, Physical Trauma, Poisoning, Disability, Death	Stockpersons/Vet	5	5	25	2 stockpersons to confine sow. Pig Board. Effective/appropriate PPE. Experienced empathetic/compassionate stockpersons. Leave and come back to restless sows. Emergency Planning and Escape route. Athletic Stockperson. High level of alertness. Sturdy footwear. Clean floors. Remove obstacles	3	4	12
Piglet Care - Iron Injection	Maternity aggression from sow. Slips, Trips, Falls. Needle Stick	Wounds, Physical Trauma, Poisoning, Disability, Death	Stockpersons/Vet	5	5	25	2 stockpersons to confine sow. Pig Board. Effective/appropriate PPE. Experienced empathetic/compassionate stockpersons. Leave and come back to restless sows. Emergency Planning and Escape route. Athletic Stockperson. High level of alertness. Sturdy footwear. Clean floors. Remove obstacles	3	4	12

Piglet Care - Drenching (Scours)	Maternity aggression from sow. Slips, Trips, Falls.	Wounds, Physical Trauma, Disability, Death	Stockpersons	5	5	25	2 stockpersons to confine sow. Pig Board. Effective/appropriate PPE. Experienced empathetic/compassionate stockpersons. Leave and come back to restless sows. Emergency Planning and Escape route. Athletic Stockperson. High level of alertness. Sturdy footwear. Clean floors. Remove obstacles	3	4	12
Piglet Care - Vaccines	Maternity aggression from sow. Slips, Trips, Falls. Needle Stick	Wounds, Physical Trauma, Poisoning, Disability, Death	Stockpersons/Vet	5	5	25	2 stockpersons to confine sow. Pig Board. Effective/appropriate PPE. Experienced empathetic/compassionate stockpersons. Leave and come back to restless sows. Emergency Planning and Escape route. Athletic Stockperson. High level of alertness. Sturdy footwear. Clean floors. Remove obstacles	3	4	12
Sow Mastitis	Maternity aggression from sow. Slips, Trips, Falls. Needle Stick	Wounds, Physical Trauma, Poisoning, Disability, Death	Stockpersons/Vet	5	5	25	2 stockpersons to confine sow. Pig Board. Effective/appropriate PPE. Experienced empathetic/compassionate stockpersons. Leave and come back to restless sows. Emergency Planning and Escape route. Athletic Stockperson. High level of alertness. Sturdy footwear. Clean floors. Remove obstacles	3	4	12
Piglet Care - Teeth Grinding	Maternity aggression from sow. Slips, Trips, Falls. Biting	Wounds, Physical Trauma, Lacerations, Disability, Death	Stockpersons	5	5	25	2 stockpersons to confine sow. Pig Board. Effective/appropriate PPE. Tool usage training. Experienced empathetic/compassionate stockpersons. Leave and come back to restless sows. Emergency Planning and Escape route. Athletic Stockperson. High level of alertness. Sturdy footwear. Clean floors. Remove obstacles	3	4	12
Piglet Care - Tail Docking	Maternity aggression from sow. Slips, Trips, Falls. Needle Stick. Cuts. Burns	Wounds, Physical Trauma, Poisoning, Disability, Death	Stockpersons/Vet	5	5	25	2 stockpersons to confine sow. Pig Board. Effective/appropriate PPE. Tool usage training. Experienced empathetic/compassionate stockpersons. Leave and come back to restless sows. Emergency Planning and Escape route. Athletic Stockperson. High level of alertness. Sturdy footwear. Clean floors. Remove obstacles	3	4	12
Piglet Care - Castration	Maternity aggression from sow. Slips, Trips, Falls. Cuts	Wounds, Physical Trauma, Lacerations, Disability, Death	Stockpersons/Vet	5	5	25	2 stockpersons to confine sow. Pig Board. Effective/appropriate PPE. Tool usage training. Experienced empathetic/compassionate stockpersons. Leave and come back to restless sows. Emergency Planning and Escape route. Athletic Stockperson. High level of alertness. Sturdy footwear. Clean floors. Remove obstacles	3	4	12
Piglet Care - Ear Notching	Maternity aggression from sow. Slips, Trips, Falls.	Wounds, Physical Trauma, Lacerations, Disability, Death	Stockpersons	5	5	25	2 stockpersons to confine sow. Pig Board. Effective/appropriate PPE. Tool usage training. Experienced empathetic/compassionate stockpersons. Leave and come back to restless sows. Emergency Planning and Escape route. Athletic Stockperson. High level of alertness. Sturdy footwear. Clean floors. Remove obstacles	3	4	12

Weaning	Maternity aggression from sow. Slips, Trips, Falls.	Wounds, Physical Trauma, Disability, Death	Stockpersons	5	5	25	2 stockpersons to confine sow. Pig Board. Effective/appropriate PPE. Experienced empathetic/compassionate stockpersons. Leave and come back to restless sows. Emergency Planning and Escape route. Athletic Stockperson. High level of alertness. Sturdy footwear. Clean floors. Remove obstacles	3	4	12
Thermal Protection (Pen Temperature) Maintenance	Maternity aggression from sow. Slips, Trips, Falls. Cuts. Burns	Wounds, Physical Trauma, Disability, Death, Infection	Stockpersons	5	5	25	2 stockpersons to confine sow. Pig Board. Effective/appropriate PPE. Use a heat gun from outside the pen. Experienced empathetic/compassionate stockpersons. Leave and come back to restless sows. Emergency Planning and Escape route. Athletic Stockperson. High level of alertness. Sturdy footwear. Clean floors. Remove obstacles	3	4	12
Mucking out of Pen - Pen Hygiene	Maternity aggression from sow. Slips, Trips, Falls. Infection. Cuts. Allergies	Wounds, Physical Trauma, Zoonosis, Disability, Anaglyphic, Death	Stockpersons	5	5	25	2 stockpersons to confine sow. Pig Board. Effective/appropriate PPE. Use a long rake from outside of pen. Experienced empathetic/compassionate stockpersons. Leave and come back to restless sows. Emergency Planning and Escape route. Athletic Stockperson. High level of alertness. Sturdy footwear. Clean floors. Remove obstacles	2	5	10
Pen Layout and Condition	Slips, Trips, Falls	Wounds, Physical Trauma, Disability, Death, Infection	Stockpersons	5	5	25	Athletic Stockperson. High level of alertness. Sturdy footwear. Clean floors. Remove loose obstacles	3	5	15
Stockpersons own Health and Hygiene (Zoonosis)	Maternity aggression from sow. Slips, Trips, Falls. Infection. Cuts. Allergies	Wounds, Physical Trauma, Zoonosis, Disability, Analyphaxics, Death	Stockpersons	5	5	25	2 stockpersons to confine sow. Pig Board. Effective/appropriate PPE. Experienced empathetic/compassionate stockpersons. Leave and come back to restless sows. Emergency Planning and Escape route. Athletic Stockperson. High level of alertness. Sturdy footwear. Clean floors. Remove obstacles	3	5	15
Pen Water/Feeder Maintenance	Maternity aggression from sow. Slips, Trips, Falls. Infection. Cuts	Wounds, Physical Trauma, Lacerations, Disability, Death	Stockpersons	5	5	25	2 stockpersons to confine sow. Pig Board. Effective/appropriate PPE. Experienced empathetic/compassionate stockpersons. Leave and come back to restless sows. Emergency Planning and Escape route. Athletic Stockperson. High level of alertness. Sturdy footwear. Clean floors. Remove obstacles	3	4	12
Stockperson Mental Health and Wellbeing	High Mortality Rate, Fatigue, Overworked, Undue Pressure from outside sources	Disability, Death	Stockpersons	4	5	20	Extra staff to reduce workload. Outside intervention with counselling or other resources	3	5	15

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Indoor *Mating Crate* Risk Hazard Register

Location: New Zealand

Prepared By: Core HS Rob Markillie/Jane Grace

Version: 1.2 26/02/2021

Risk	**Hazard**		**Initial Risk**				**Controls**	**Residual Risk**		
Risk Identified	**Hazard Description**	**Hazard Consequence**	**Person at Risk**	**Likelihood**	**Consequence**	**Risk Rating**	**Controls Required**	**Likelihood**	**Consequence**	**Risk Rating**
Sow movement in/out of mating crates	Aggression from sow turning on stockperson. Slips, Trips, Falls	Mauling, Biting, Entrapment resulting in injury, Wounds, Physical Trauma, Major Trauma, Fracture	Stockpersons	4	4	16	Use of narrow passageways. Correct height walls. Pig boards. Experienced/trained empathetic/companionate stockpersons. High level of alertness. Emergency Planning and Escape routes	2	2	4
Boar movement	Boar Aggression. Slips, Trips, Falls, Biting, Tusking	Wounds, Physical Trauma, Disability	Stockpersons	4	4	16	Confine Boar movement through use of narrow passageways. Pig Boards. Experienced empathetic/compassionate stockpersons. Emergency Planning and escape route. Shorten Tusk size. Alert Stockperson. Approach from the right angle. Experienced and competent stockperson	2	4	8
Insemination	Crushed limb from entrapment between sow and crate. Slips, Trips, Falls. Needle Stick	Wounds, Physical Trauma, Poisoning	Stockpersons/Vet	3	3	9	Limbs over bars not through bars. Observe outside of crate until ready. Trained/Experienced empathetic/compassionate stockpersons/vet. Emergency Planning	2	2	4
Crate/Feeder maintenance	Crushed limb from entrapment between sow and crate. Slips, Trips, Falls.	Wounds, Physical Trauma	Stockpersons	3	3	9	Limbs over bars not through bars. Trained/Experienced empathetic/compassionate stockpersons/vet. Emergency Planning. Clean floors. Sturdy Footwear	2	2	4
Boar Welfare and Husbandry	Boar Aggression. Slips, Trips, Falls, Biting, Tusking	Wounds, Physical Trauma, Disability	Stockpersons/Vet	3	5	15	Confine boar if needed. Pig boards. Trained/Experienced empathetic/compassionate stockpersons. Emergency Planning and Escape route. Clean floors. High level of alertness. Athletic stockperson Sturdy Footwear	3	3	9
Sow Welfare and Husbandry	Aggression from sow. Slips, Trips, Falls.	Wounds, Physical Trauma	Stockpersons/Vet	3	3	9	Experienced empathetic/compassionate stockpersons. Pig boards. High level of alertness. Clean crate floors. Sturdy Footwear. Emergency Planning	2	2	4

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Indoor *Mating Pen System* Risk Hazard Register — *Prepared By: Core HS Rob Markillie/Jane Grace*

Location: New Zealand — *Version: 1.2 26/02/2021*

Risk	Hazard		Initial Risk				Controls	Residual Risk		
Risk Identified	Hazard Description	Hazard Consequence	Person at Risk	Likelihood	Consequence	Risk Rating	Controls Required	Likelihood	Consequence	Risk Rating
Sow movement in/out of mating pens	Aggression from sow turning on stockperson. Slips, Trips, Falls	Mauling, Biting, Entrapment resulting in injury, Wounds, Physical Trauma, Major Trauma, Fracture	Stockpersons	4	4	16	Use of narrow passageways. Correct height walls. Pig boards. Experienced/trained empathetic/companionate stockpersons. High level of alertness. Emergency Planning and Escape routes	3	3	9
Boar movement	Boar Aggression. Slips, Trips, Falls, Biting, Tusking	Mauling, Biting, Entrapment resulting in injury, Wounds, Physical Trauma, Major Trauma, Fracture, Disability, Death	Stockpersons	4	5	20	Confine Boar movement through use of narrow passageways. Pig Boards. Experienced empathetic/compassionate stockpersons. Emergency Planning and escape route. Shorten Tusk size. Effective and appropriate PPE. High level of alertness. Athletic stockperson. Approach from the right angle. Experienced and competent stockperson	3	3	9
Insemination	Aggression from sow turning on stockperson. Crushed limb from entrapment between sow and Pen. Slips, Trips, Falls. Needle Stick	Mauling, Biting, Entrapment resulting in injury, Wounds, Physical Trauma, Major Trauma, Fracture, Disability, Death	Stockpersons/Vet	4	5	20	2 Stockpersons to confine sow. Trained/Experienced empathetic/compassionate stockpersons/vet. Observe outside of pen until ready. Emergency Planning and Escape route. Athletic person. High level of alertness. Clean floors. Sturdy Footwear	3	4	12
Crate/Feeder maintenance	Crushed limb from entrapment between sow and pen. Slips, Trips, Falls.	Mauling, Biting, Entrapment resulting in injury, Wounds, Physical Trauma, Major Trauma, Fracture, Disability, Death	Stockpersons	4	5	20	Solve from outside the pen if possible. 2 stockpersons to confine sow. Trained/Experienced empathetic/compassionate stockpersons. Emergency Planning and Escape route. Clean floors. High level of alertness. Athletic stockperson Sturdy Footwear	3	4	12
Boar Welfare and Husbandry	Aggression from boar. Slips, Trips, Falls	Mauling, Biting, Entrapment resulting in injury, Wounds, Physical Trauma, Major Trauma, Fracture, Disability, Death	Stockpersons/Vet	4	5	20	Solve from outside the pen if possible. 2 stockpersons to confine boar. Trained/Experienced empathetic/compassionate stockpersons. Emergency Planning and Escape route. Clean floors. High level of alertness. Athletic stockperson Sturdy Footwear	3	4	12
Sow Welfare and Husbandry	Aggression from sow. Slips, Trips, Falls	Mauling, Biting, Entrapment resulting in injury, Wounds, Physical Trauma, Major Trauma, Fracture, Disability, Death	Stockpersons/Vet	4	5	20	Solve from outside the pen if possible. 2 stockpersons to confine sow. Trained/Experienced empathetic/compassionate stockpersons. Emergency Planning and Escape route. Clean floors. High level of alertness. Athletic stockperson Sturdy Footwear	3	4	12

Appendix D: Factors to consider in the design and management of a farrowing system

The objectives of different farrowing systems – indoor and outdoor

A) Produce a number of healthy, heavy weaners at weaning
B) Wean a healthy sow in good condition

Factors to consider in the design and management of a farrowing system

1. The sow has a sense of separation and isolation from others in keeping with her preference to have her own nest site for farrowing
2. Ability for the sow to express nesting behaviour before farrowing
3. The sow can stand up, sit and lie down comfortably and make full postural adjustments
4. Freedom from injury (both sows and piglets)
5. There is space behind the sow for piglets to be born safely
6. Provision of farrowing rails or sloping walls to reduce overlaying of piglets by the sow
7. Piglets have a retreat area
8. Thermal comfort for sows and piglets
9. Ability to comfortably suckle (both sows and piglets). Piglets have ready access to the sow's udder and the sow can lie down to present her udder to the piglets
10. Access for stockpersons to attend to the needs of sows and piglets
11. Feeding to maintain sow body condition, match sow nutrient intake with milk production to support piglet growth rates with sow nutrient intake
12. Ease of handling: moving sows into the housing system, weaning, piglet handling
13. Allow 'all in – all out' management
14. Facilities are easy to clean
15. Nonslip flooring
16. Accommodation is of robust construction to withstand frequent cleaning, is pig proof and has a good life expectancy
17. Cost effective building and fittings
18. Safe for sows, piglets and staff

Feeding requirements

19. Feeder design - there are different options to suit varying preferences and requirements
20. Allow high levels of an appropriate diet to be fed to sows
21. Access to water at all times
22. Providing creep feed to piglets
23. Minimise feed wastage
24. Minimise buildup of old feed for sow

Temperature requirements

25. Create a temperature differential for sows and piglets. Sows require 18-20°C, piglets require 30°C plus at birth
26. Ability to control the thermal environment as lactation progresses: ventilation
27. Heating source provided may be heaters, heat lamps/bulbs, under floor heating or heat pads assisted by covered creep areas and creep boxes
28. Providing insulation (e.g., outdoor huts)
29. Dry straw and bedding in outdoor systems
30. Provision of draught barriers (solid pen divisions)

Flooring

31. Comfortable lying surface, non-slip walking and standing surfaces
32. Raised slatted floors allow good drainage for a dry lying area and reduce buildup of manure
33. Easy to clean while still occupied
34. Constructed of heavy-duty material for the sow in various forms, cast-iron, concrete (slates/solid), plastic-coated wire; plastic slats and panels for piglets.
35. Construction materials need to be easy to clean and disinfect, are quick to dry, allow access to sunshine outdoors

Farrowing crate

36. Design to minimise crushing and overlaying of piglets by the sow
37. Encourage sows to change posture slowly
38. Angled to flare out at the bottom
39. Adjustable width
40. Allow staff access to the rear of the sow to provide farrowing assistance

Outdoor huts

41. Straw availability critical – amount and type; topped up as required
42. Internal guard rails or sloping walls for piglet protection
43. Earthen or wooden floor
44. Door in centre or to one side – covered or uncovered
45. Window or vents for ventilation
46. Skids and hooks for movement to relocate for each batch
47. ‘Fenders’ to keep piglets inside the hut for the first week
48. Stakes to stop hut blowing over, sited away from prevailing wind/rain

Appendix E: Literature review: Determining the space requirements of growing pigs

NAWAC's 2010 Code Report

NAWAC's Code report in 2010 outlined some key findings in the available literature in relation to space requirements for grower-finisher pigs. The subsequent minimum standard was determined using a k value of 0.030, based on the space allowance that Edwards et al. (1998) found led to optimal performance on slatted floors. This k value has also been used to calculate the minimum space allowance in other countries such as Australia and England. The EU also uses a k value of 0.030 as the basis of calculating the minimum space allowance for pigs within specific weight bands (EU Council Directive 91/630/EEC).

'K' varies between 0.018 and 0.047 to represent the static space that pigs require according to various lying positions:

0.018 = Sternal lying

0.025 = Lying semi-laterally with legs folded under the body

0.033 = Half recumbency lying

0.047 = Fully lateral recumbency plus space between front and back legs

Static space represents the animal's physical size. There are additional requirements for dynamic space which is the area needed for non-locomotor movements, and space for and social interaction. As well as the area needed for the animal's physical dimensions, movement and behaviour, space requirements are influenced by the type of flooring, presence of bedding, temperature and humidity.

Growing pigs are usually moved to larger pens as they grow. Depending on the farm this may happen between two and four times before they reach their finishing weight. When pigs are first moved into a pen, they have more than the minimum space allowance. This decreases over time as the pigs grow into the space provided. This increase in size and relative decrease in space requires the pigs to be moved to a larger pen to ensure adequate space is provided. Immediately before pigs are moved, at a space allowance determined using a k value of 0.030, the space provided may start to have a slight impact on feed intake and other production measures. However, this period of constraint represents a very short period of time at the end of the production phase (days) when the group of pigs is also most settled.

Codes of welfare set minimum standards that detail specific actions that need to be taken to meet the obligations in the Animal Welfare Act (1999). The current minimum standard addressing space allowance is based on the point at which performance is affected. NAWAC has noted that this must be based on welfare outcomes rather than performance and that this must take the physical health and behavioural needs of pigs including opportunities to display normal patterns of behaviour into consideration.

In the work NAWAC used when setting the minimum standard for the space allowance for grower-finisher pigs (Edwards et al., 1988), an economic analysis indicated profitability was adversely affected when k was below 0.027. NAWAC stated that in their view more space was required for the locomotor and social needs of pigs to be met. Thus, the recommended best practice in the 2010 and 2018 Code was a k value of 0.047.

There are interacting requirements with space in the current Code of Welfare for Pigs (2018). Regulation 24 addresses shelter and a dry lying area, requiring that:

(a) the pig has access at all times to a ventilated shelter that provides protection from extremes of heat and cold; and
(b) the pig has access at all times when it is not in a farrowing crate to a dry area that is large enough to allow the pig to stand up, turn around, and lie down in a natural position; and
(c) faeces or urine do not accumulate in any area in which the pig is kept to an extent that may pose a threat to the health or welfare of the pig.

Minimum standard No. 6 (Housing and equipment) currently states that:

(a) Housing systems must be designed, constructed and maintained in a manner that provides suitable (comfortable) temperatures, fresh air, and hygienic conditions.
(cd) Faeces or urine must not be allowed to accumulate in any area in which the pig is kept to an extent that may pose a threat to the health or welfare of the pigs.
(e) The risk of injury, disease or stress for pigs must be minimised by appropriate design, construction and maintenance of housing and equipment.

Minimum standard No. 7 (Temperature) currently states:

(c) Ventilation control or other measures must ensure housed pigs do not become overheated or cold stressed.

Literature

Welfare and space allowance

The evaluation of the welfare of grower-finisher pigs in the context of space may be based on indicators relevant to their health and productivity, their ability to express highly motivated behaviours, and their affective state. As has been the foundation of most of the scientific literature on this subject, sufficient space will result in healthy pigs that have a good feed intake and average daily gain, low morbidity in terms of injury and disease, and low mortality. Aggression and other behaviour problems will be minimal, and their thermoregulatory needs will be met.

The area provided should enable species-specific behaviours associated with resting, feeding dunging and interacting with pen mates in addition to their static space requirements. Sufficient space should prevent negative affective states such as hunger and thirst, discomfort, and pain. The provision of enrichment or occupational material will promote positive affective states associated with exploration and activity, improving the quality of the space available to pigs.

Most studies investigating the effect of space allowance on pigs don't generally serve to determine what the minimum space required per pig is, but how much space pigs will use when given the opportunity. There are two predominant methods by which the effects of different space allowances are investigated. The first method uses one pen size but changes the number of pigs in each pen to achieve different space allowances per pig in the same total area. This is not reflective of what happens on farms. One study calculated that pigs in groups of 80 would be expected to have 36% more unused space per individual pig than pigs in a group of 20 (McGlone and Newby 1994). Whilst each pig takes up space in a pen, they also contribute free space to the total communal area available. Studies using this methodology are potentially confounded by comparing different group sizes as well as different space allowances without an ability to separate these effects. The area of unused space per pig increases in proportion to group size.

Other than changing group size to alter space allowance, the other common method used is to keep pigs at a constant space allowance by modifying the pen dimensions weekly in line with pig growth. This is not reflective of what happens on farms. Unlike most experimental situations, pigs are not moved to a slightly bigger pen every week to keep them near the minimum space allowance throughout. As already mentioned, initially a higher space allowance is provided which pigs grow into over time. This means that the minimum space allowed is only reached for a short period (a matter of days) at the end of a production stage. The effect of temporary space restriction on productivity and welfare is not understood and has not been examined scientifically.

Lying and thermoregulatory behaviour

Although pigs predominantly lie fully recumbent, the space they occupy is on average half of a fully recumbent pig due to space-sharing as a group when lying together. Ekkel 2003 showed that, on average, 60% of the lying animals appear to lie down in a fully recumbent position. As a group, there is a mixture of pigs lying fully recumbent on their side, semi-lateral, sternal, and some that are standing. Space allowance should be considered with this in mind. Pigs at different ages (from weaners to finishers) spent ~70% of the time at rest regardless of space allowance indoors and they share the lying space with one another. As pigs grow older, overlying behaviour reduces and lateral lying increases.

Lying behaviour is related to the effective temperature of the pigs' environment, but also to their normal behaviour. Research investigating interactions between metabolism and pig behaviour has shown that comfort behaviour under thermoneutral conditions is represented by pigs lying together and touching one another – described as looking like "cigars in a box" (Geers 2007). Early experiments have shown that growing pigs preferred to huddle together at night than operate a switch to turn on a radiant heat source, suggesting that pigs prefer to keep warm through having contact with one another whilst resting (Baldwin 1974).

Van Putten (2000) described the lying behaviour of pigs thus:

"Pigs are sound sleepers, packed tightly together like spoons in a canteen of cutlery. However, this seems of less importance during the rest in the early afternoon than during the one in the night. There are obvious reasons for this behaviour. It does keep all members of the group warm in cold days, and it offers more protection from predators than sleeping apart. Nevertheless, pigs try to find a resting-place with protection from the rear and - even more important - with a good view of the area in front. I am elaborating on this because, for our pigs, these priorities have not really changed since they were domesticated."

A group of pigs lying laterally without contact with one another is an indicator of heat stress. This is a behavioural adaptation to high temperature that may be accompanied by panting, drinking more water, lying in the dunging area and reducing their feed intake to reduce heat production (Hillmann et al., 2004; Spoolder et al., 2012; Nannoni et al., 2020).

Though pigs may be provided with enough space to meet their static, dynamic and activity requirements; they may not utilise the available space if the environment does not meet their needs. Pigs that are too cold are less physically active and less interested in engaging in behaviours such as exploration, investigation and play as these are energetically expensive. Smaller pigs such as weaners have a very narrow interval between their lower and upper optimal temperature thresholds (Larsen et al., 2018). When cold, pigs spend more time lying sternally to minimise their contact with the floor, seek contact with other pigs through huddling and increase their feed intake (Nannoni et al., 2020).

K values in the literature

The k value (in the equation "m^2/pig = k x LW(kg)$^{0.67}$") may change depending on the temperature, humidity, type of flooring, presence of bedding, and group size. It may also vary depending on the indicators used to determine k. Whilst most indicators relate to performance, there are studies that have investigated physiological indicators (e.g. cortisol, immune function, adrenal function), behaviour (e.g. time budgets, feeding behaviour, aggression) and other parameters (e.g. lesion scores, treatment records, lameness scoring). There is evidence that behavioural and physiological responses of pigs may be negatively impacted at a higher space allowance than that which affects their performance (e.g. ADG, FCR, feed intake) (Averós et al. 2010; Meunier-Salaün 1987, Callahan et al. 2017).

A metanalysis of 21 studies investigating the performance of nursery and grower-finisher pigs at different space allowances estimated the critical k value to be between 0.0317 – 0.0348 (Gonyou et al. 2006). Below these values the average daily gain was reduced. Others have reported similar results with k values below 0.034 (Meunier-Salaün 1987; Street and Gonyou 2008; Wolter et al, 2000). Ekkel et al (2003) confirmed Petherick's (1983) suggestion that a k of 0.033 should be a starting point for discussions on space requirements for growing pigs. Brown et al (2018) found that feed efficiency was greatest at a k of 0.0335 and pigs at lower space allowances (below 0.0335) spent less time feeding but compensated by increasing the frequency of feeding events. ADG was greatest at a space allowance of k = 0.039 and lowest at a k of 0.023. The ADG at a space allowance of 0.030 and 0.035 were intermediate (Brown et al., 2018). These findings suggest that ADG is reduced at a k of 0.0335.

The European Food Safety Authority (EFSA) (2005) proposed that under thermoneutral conditions the minimum floor area required by growing pigs is equivalent to a k value of 0.036. This enables space for resting, exploration, social and dunging behaviours and is calculated using the below assumptions:

- k = 0.033 for a group with 80% of pigs lying down (Ekkel et al., 2003).
- k = 2 * 0.019 = 0.038 for the remaining 20 % of active pigs. This was calculated by doubling the k-value of 0.019 estimated by Petherick (1983) for sternal lying based on an assumption that exploration, social interactions and walking to the feeder or dunging area requires at least twice that amount of space.
- k = 0.0019 was estimated to be the minimal space required to allow a pig to strictly separate the dunging from the resting area (assuming that a group of 10 pigs

would require approximately one body space of k=0.019 for dunging and not having to lie in their excrement).

The final k-value of 0.036 was calculated as: 80% * 0.033+20% * 0.038+0.0019 = 0.036.

The underlying assumptions for the above proposal have not been quantified experimentally. This is a notional approach based on daily behaviours performed by pigs. Indeed, some studies have suggested higher minimum k values to provide for behaviour and performance such as was reported by Averós et al. 2010. This study proposed a minimum k of 0.039 for fully slatted floors and suggested that a k of 0.047 overestimates the spatial needs of pigs as it does not take into account the distribution of behaviour over time, the different lying postures, space sharing and the social and behavioural dynamics within the group.

Temperature and ventilation

The climactic environment required by pigs to maintain a constant and adequate body temperature varies according to the pig's size, the structure of the building in which they are kept, feeding levels, air speed at pig level and other sources of heating. Under thermoneutral conditions no additional energy is needed for pigs to maintain the balance between heat production and heat loss. Heat production depends on metabolism and is affected by feed intake, feed composition, production, activity and stocking density. Conversely heat loss depends on convection, conduction, radiation and evaporation (Nannoni et al., 2020).

Pigs will lie in the warmest area and establish a dunging area that is located away from where they rest, often in a relatively cooler section of a pen. Young pigs are highly sensitive to the influence of air speed. Air speed differences and localised draughts influence the areas selected for dunging and sleeping (Randall et al., 1983). Draughts in the pig's lying area have been observed to cause aberrant dunging behaviour.

The optimal temperature for pigs during the first week following weaning is approximately 28°C. This is because daily feed intake is low during this week as piglets transition to a new diet, and this reduced feed intake leads to fat loss and hence temporarily reduced thermal insulation. Temperature fluctuations of as little as 3°C have been shown to increase post-weaning scours (Le Dividich 1981). The pigs themselves generate heat, and this is accounted for when the temperature and ventilation rates are set. However, a small number of pigs in a large lying area, even if it was covered or kennelled, would not sufficiently maintain a warm lying area.

A warm air temperature in the lying area and a relatively cool temperature in the dunging area is achieved in a system with mechanical ventilation by maintaining a stable airflow pattern irrespective of the ventilation rate and temperature of the ventilating air (Randall et al., 1983). These ventilation rates (expressed as m^3 per hour per kg LWT) are adjusted over time as the pigs get older. One of the challenges to ensuring a stable air flow is the size of a room or building in which pigs are housed. The minimum number of air changes per hour will depend on room design, air inlet placement, manure system and subsequent manure gases etc. In many common systems the minimum figure of 1.5 air changes per hour is used to maintain even air quality and to avoid pockets of over-ventilated and under-ventilated areas in the room.

If the room is beyond a certain size relative to the number of pigs present at the start of a growing stage this may mean that minimum air changes per hour becomes the greater priority above minimum ventilation rate per kg liveweight. In cold weather this higher ventilation rate can both increase the risk of cold incoming air "dumping" on the pigs and require substantially more supplementary heating to maintain room temperature within the pigs' comfort zone. Furthermore, where there is a small number of pigs in a large space that is difficult to keep at a consistent temperature, there will also be pockets of over- and under-ventilation influenced by where the pigs choose to position themselves. To counteract chilling, the additional heating required increases operational costs and often reduces air quality.

Ventilation must fulfil several requirements – to control air temperature and relative humidity, keep concentrations of manure gases such as ammonia and hydrogen sulphide, airborne pathogens and endotoxins below desirable thresholds, maintain a comfortable environment for pigs and control the speed at which air passes over pigs. Relative humidity is challenging to measure, so air temperature is used to determine the ventilation rate. However, this may conflict with the aforementioned requirements, as humidity and odour levels can rise in cold weather when it is necessary to maintain optimum temperature and minimise the rapid passing of air over the pigs.

In warm temperatures (>20 - 25°C, depending on liveweight), pigs will make behavioural adaptations to increase the evaporative and respiratory heat loss. If pigs are still too warm after making behavioural adjustments, they will reduce their feed intake. Pigs on partly slatted floors may also alter their dunging behaviour as they prefer to use the cooler slatted area for resting. This has implications in terms of negative consequences for pig health and welfare due to poor hygiene, and additional labour required for cleaning. Concrete slatted floors are 2 to 4°C cooler than a solid concrete floor in the same room, and straw bedding can increase the temperature by up to 8°C (Huynh et al., 2004; Verstegen and van der Hel, 1974). In pens where part of the floor is solid concrete and part is plastic slats, pigs choose to spend the vast majority of their time lying on the plastic slats due to the thermal properties of this flooring type, creating challenges for keeping the solid portion of the pen clean.

Pen soiling and hygiene

Once introduced to a new pen or space, pigs will investigate their environment to establish its layout, including the location of feeders/troughs and drinkers as well as preferential lying and dunging areas. As mentioned, pigs will lie down in an area that is relatively warm and free of draughts, with the dunging area located away from where they rest. Their motivation for this is to keep their lying and feeding areas clean and to site the dunging area in a place that has the least activity (Randall et al., 1983). A clean and dry lying area is important to ensure thermal comfort and hygiene and reduce the risk of disease transmission. Pigs prefer to urinate and defecate close to a wall or pen partition, often in a corner. They need to feel safe in their dunging area as pigs adopt an unstable posture, particularly when dunging, and are more vulnerable in this position to being disrupted or otherwise bothered by their pen mates (Randall et al. 1983; Guo et al 2015). Dunging patterns are often established very early on after pigs enter the pen. Once a certain part of the pen is soiled by a few pigs the other pigs in the pen will tend to perpetuate and escalate dunging in that area.

Pen soiling may occur due to inadequate thermoregulation (from both high and low temperatures), draughts, and the pen design. Where pigs change their resting behaviour in response to an inadequate thermal environment, they may begin dunging in the area previously designated for lying. Likewise, if the pigs' preferences change regarding the suitability of the dunging area, or their environment is changed (e.g. the size or dimensions of the pen), this can lead to soiling other areas of their pen (Nannoni et al., 2020). Pen soiling has been found to compromise hygiene and air quality, disturb the pigs' resting behaviour and increase agonistic interactions (Aarnink et al., 1996; Hillmann et al., 2004; Smulders et al., 2006).

The main cause of pen soiling is inadequate thermoregulation particularly when the lying area is too warm or too draughty. Additionally, the pen design and layout can have consequences if for example a wet feeding system leads to spillage on a solid floor, or if the dunging area is used for activity, creating disturbances in a part of the pen where pigs require a safe calm environment (Nannoni et al., 2020). Pen shape may contribute to this.

A long rectangular pen may encourage pigs to dung along a side, which does not properly allow separation of the dunging and lying/activity/feeding areas. In this scenario, pigs are unable to properly separate their eliminative behaviour from other pigs which may be resting or engaging in activity (Randall et al. 1983). Long narrow pens make it difficult for pigs to reach dunging areas and drinkers, leading to soiling of the lying area. Previous recommendations have been to avoid using pens that are longer than twice the pen's width.

Where a large amount of space is provided, pigs may establish multiple lying areas, with some choosing to make the lying area of other pigs their dunging place. Excessive space allowance may result in pigs not being motivated to move away from the other pigs to perform their excretory behaviour (Larsen et al., 2018). With too abundant space in the resting area it has been observed that pigs often defecate in unoccupied corners or against walls (Aarnink et al., 1993). Young pigs may choose to dung in the middle of the pen, as this is perceived to be far enough away from the lying area. As the pigs get older this often continues once this behavioural pattern has become established.

The consequences of poor hygiene can be significant if this impacts pig health, and therefore welfare. Poor hygiene may eventuate if pigs begin dunging in their lying area as outlined above, which is often the result of an inadequate temperature. A study investigated the effect of moderate, chronic cold stress immediately post-weaning on piglets that were inoculated with an enterotoxigenic strain of *E. coli*. In the group subjected to the greatest cold stress (15°C), 14% of piglets died. All presented with scouring, weight loss and poor condition prior to death (Wathes et al 1989). The rate of scouring was highest in the group kept at 15°C (nearly 70% of all pigs), and approximately 50% of the pigs kept at 20°C showed evidence of scouring. None of the piglets kept at 30°C showed evidence of scours.

Deep litter systems, particularly those with larger group sizes (100-500 pigs) pose certain challenges with respect to establishment of dunging patterns early on in the growing phase, which will then be perpetuated by other pigs in the pen. With sawdust as bedding, initial placement can exclude desired dunging areas as long as there is an ability to add sawdust through the growing phase. Frequently this will be sufficient to establish robust dunging patterns in the pen. With straw-based systems this is less easy to control. Pigs move straw around the pen to a greater extent and can often choose to start dunging along a side wall or next to a feed pad on one side of the building. Once started the damage is done. The fewer the pigs in a large straw-based pen the greater the chances that the pigs will start to dung in an undesirable position e.g. next to the feed pad, simply due to the forces outlined above, in particular the distance that a pigs is willing to walk to defaecate or urinate.

Consequences of increasing the space allowance on existing New Zealand farms

All in all out (AIAO) and mixing stress

One of the most effective strategies to minimise the spread of disease on pig farms is to practice all in all out (AIAO) management. This approach maintains batches of pigs that are moved together through each stage of production. These pigs are effectively the same age and weight, making it easier to meet their nutritional, spatial and thermal requirements. Moving pigs as a batch enables to facilities to be cleaned and disinfected before the next cohort of pigs is introduced. This breaks the cycle of pig disease and reduces the pathogen load in the pigs' environment. It is one of the mainstays of good biosecurity, animal health, and welfare.

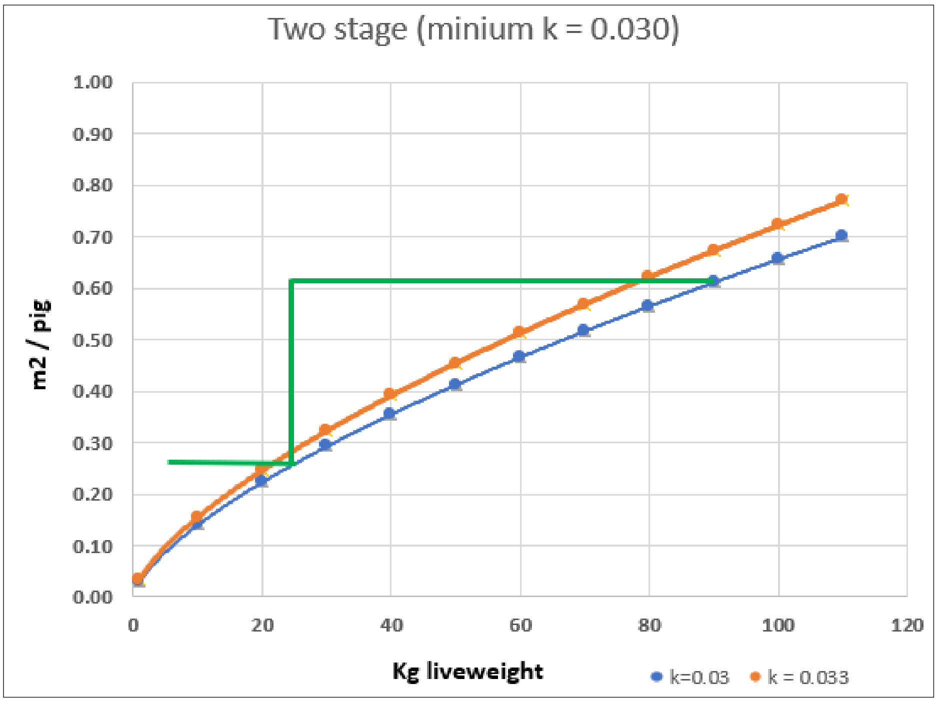
The consequences of breaching an AIAO routine are that there is inadequate cleaning and disinfection between batches of pigs, and there is potential mixing of different age groups of pigs. An investigation of on-farm factors related to pleurisy in pigs found that an absence of AIAO herd management was the most important factor associated with increased pleurisy (Jäger et al., 2012). Keeping pigs with an age difference of more than one month in the same airspace and repeated moving and mixing during the rearing phase were also significant risk factors.

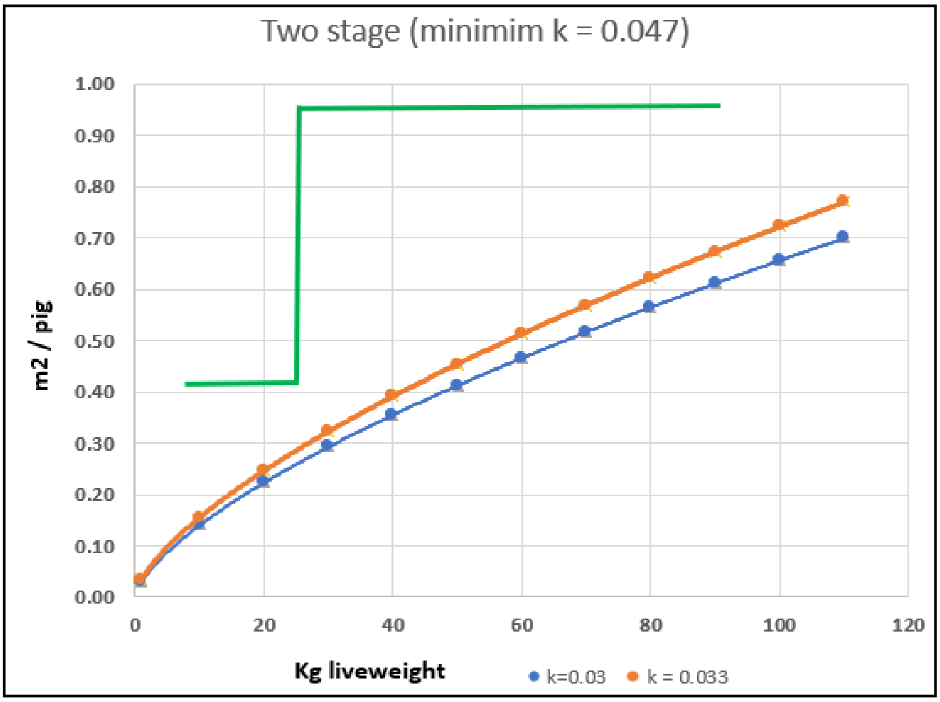
If significantly more space is required for grower-finisher pigs in New Zealand (such as the proposal of at least 56% more space in the current NAWAC draft code), many farmers will increase the number of stages (and therefore movements) of pigs to make more efficient use of available space. With a greater number of movements, cleaning and disinfection is less likely to be done to an effective standard and may not be possible at all if there is no ability to leave pens empty for long enough to do so. The combination of stress, movements, change in the pigs' environment and the potential mixing unfamiliar pigs will lead to stress and immune challenges, impacting pig growth health and welfare.

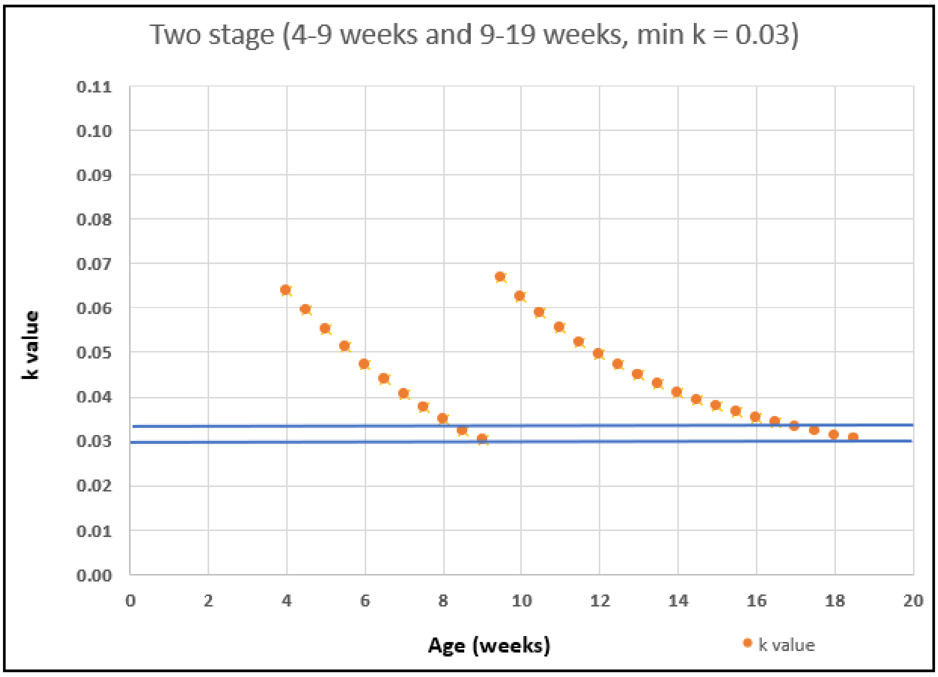
Not only may unfamiliar pigs be mixed, but pigs of different ages may need to be mixed. Where the space allowance becomes constrained at the end of a weaner production stage, the larger pigs in that batch may need to be removed and placed into a group of growers in the next production phase before the growers have been shifted. Even where more moves are implemented to meet this requirement but it is possible to avoid mixing pigs at each move, every move in itself is a source of stress to the pigs, even when they move to a pen that is very similar to the pen they came from. This stress reduces feed intake, slows growth and further congests the growing space available. A common saying in the pork industry is "every time you move a pig you add to the pig's life and subtract from your own life", illustrating the additional stress on the pigs of every move and the substantial challenges it creates for the farm staff.

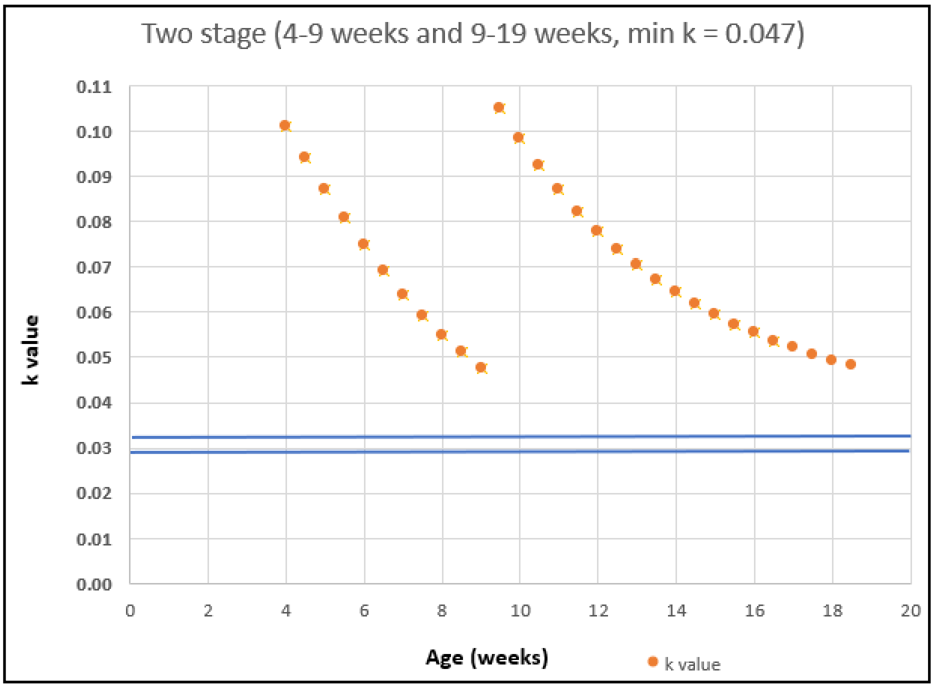
Challenges created by too much space at the start of each phase – New Zealand scenarios

As an illustration, the differences in square metres per pig and in k value per pig between the current code requirements (k of 0.03) and NAWAC's proposed k of 0.047 are outlined in the graphs below. The effect is shown for a hypothetical 2-stage production system that minimises space to the limit at each stage, with weaners from 7-25kg and finishers from 25-90kg.









This increased space at the start of each phase will mean that in indoor mechanically ventilated systems (which provide the best welfare in terms of keeping the pigs in their thermal comfort zone) there will be negative consequences of the higher space option. One of these consequences is due to an inability of the pigs to generate enough heat to keep warm to make the system operate optimally. Additionally, in partly slatted systems there will be an increased risk of aberrant dunging patterns developing. Similarly, in deep litter systems the very low stocking density will be very likely to result in dunging behaviours commencing in an undesirable part of the pen (e.g. close to the feed platform and lying area). This will have negative welfare consequences later in the stage as dunging patterns will encroach on the lying area, forcing pigs to either lie in the colder draughtier area or else lie in a moist soiled area of the pen.

Hypothetical examples of k = 0.03 vs k = 0.047

Example 1 – Indoor mechanically ventilated fully-slatted system, weaners 7-25kg, finishers 25-90kg.

In a hypothetical example of such a system with the space provided as per the graphs above (in a typical New Zealand winter minimum temperature), the calculated amount of supplementary heating required in the weaner phase is substantially higher in the k=0.047 scenario. The higher requirement for heating is due to minimum air changes taking priority over the 0.03 m^3/kg/hour figure, and greater heat loss from conduction loss through the shell of the building the pigs are in. This additional heating would be expensive to run, demanding on the environment, and can reduce air quality while increasing temperature variation across the room.

In the same scenario in hot weather, the larger room dimensions mean that at maximum ventilation rates the actual air speed at pig level is calculated to be slower in the k=0.047 example than in the k=0.03 scenario due to a greater room space to move the air across at the maximum ventilation rate. Air speed at pig level is the most important parameter that assists the pig to remain comfortable and avoid heat stress.

Example 2 – In a typical 22m x 10m shelter that could house approximately 240 pigs from 10 to 19 weeks old under the k=0.03 requirement (with allowance for dunging area).

The stocking rate would have to be reduced to around 174 pigs under the k=0.047 requirement. A smaller number of pigs in the pen at the start of the phase would mean that under k=0.03 their lying space would occupy around 27% of the space in the shelter while at k=0.047 it would occupy 19% of the space in the shelter. This difference would increase the risk of the pigs starting an aberrant dunging pattern that would be impossible to rectify in that pen and negatively impact on animal welfare due to the dunging area being too close to the lying area.

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Appendix F: Estimated costs for a 400 sow farrow to finish farm to adopt NZPork's alternative proposals

Typical indoor Canterbury pig farm scenario: 400 sow farrow to finish unit

This scenario maintains a 400 sow herd with all progeny reared on farm and sold as bacon weight pigs at 70 kg deadweight.

Key physical assumptions

This farm would be described as using good management and husbandry practices, feeding well balanced diets at recommended levels to stock of improved genotypes of high health status. While there is no 'standard' farm, as there are indoor and outdoor breeding operations, the post weaning facilities will be indoor, either in environmentally controlled or naturally ventilated sheds with slatted dunging areas or in naturally ventilated sheds using either sawdust or straw deep litter bedding. Because the size of the pigs changes as they grow in the post weaning stage (8kg-95kg in 15-16weeks) the pigs will be housed in different facilities in 1,2 or 3 stages, known as weaner or nursery area followed by growing and finisher sheds. The finishing pens will be substantially larger than weaner pens. This is described as a multistage system. In the post weaning area, a wean to finish housing system is larger and this is where the weaner pigs are introduced to a pen in which they stay until sold.

Sow productivity is measured in weaners/sow/year and this scenario is looking at 26.89 piglets weaned per sow per year. Sows are typically mated on a weekly basis or on some farms batches are mated on a 2 or 3 week cycle. Breeding occurs all year round with sows being mated, weaned and farrowed on a 1, 2 or 3 week cycle. Sows are usually culled at weaning, on age or for low productivity and the annual replacement rate is typically over 45%.

Piglets are weaned at 3-4 weeks of age and transferred from the farrowing (maternity) facility to a nursery facility where they will be housed for 4 weeks. The pigs are then transferred to larger pens to accommodate them for the growing period for 5 and subsequently to the finishing period which for another 7 weeks. In addition, there is a n extra weeks accommodation to allow for cleaning and spelling between batches of pigs. Therefore, pigs are sold at around 19-20 weeks of age at a carcass weight of 70 kg dead weight. Replacement female stock is bred on farm or purchased and will be on hand for 8 weeks prior to their first mating and introduction into the herd. High use of artificial insemination means an essential requirement is the weekly supply of semen to be delivered on site. In addition, replacement breeding both males and females are delivered on site at least monthly to maintain the herd size and parity balance of the herd. A number of boars will be on hand to mate and 'stimulate' the sows where artificial insemination is used.

Mortality rates of sows are typically 6% and that of post weaned pigs is 3.5%.

At any time of the year similar numbers of stock will be on hand, and matings, farrowings weaning and sales will all occur on a regular (weekly) basis.

The accommodation of the facility is designed to match the pig flow and as such all pens are likely to be occupied apart from cleaning and spelling (few days) between batches. Therefore, the numbers of stock on hand remain reasonably constant all year round.

Table 1: Assumptions of the example farm:

Sow herd size (sows and mated gilts)	400
Litters/sow/year	2.35
Number of boars	6
Replacement rate % Sows Boars	 45 50
Duration of stay of gilts (months)	2
Number of gilts on hand	29
Breeding stock mortality rate%	6
Number of culls per year	169
Number of culls per week	3
Weaned pigs produced per/sow/year	26.89
Total weaners produced annually	10,756
Weaning age of piglets (weeks)	4
Post weaning mortality %	3.5
Age at transfer to grower shed	8 weeks
Age at transfer to finisher shed	12 weeks
Total sales of progeny /annum	10,400
Sales of progeny/week	200
Age at sale (weeks)	19
Average deadweight at sale (kg)	70
Herd FCR (Feed: meat Ratio)	3.3

The price paid to the farmers is based on a classification grid with the return per kg dependant on the back fat (measured at P2) and weight of the carcass (head on/feet on). The pig meat price can vary throughout the year. The price is market driven, based on supply and demand in the New Zealand market of numbers and volume of pigs and competing food proteins, volume and price of imported pig meat and the value of the NZ$.

The price per kg usually averages less than the top price on the classification schedule and in the example it is 8 cents/kg less than the top price of $3.95. The weekly sales allow pig farmers to have up to date actual data on average sale weights, classification profile, and a track record of weekly sales numbers. The cull stock are classed as choppers or manufacturing and are paid on a weight basis. From the price per kilogram multiplied by the weight of the carcass the following deductions are taken. They will include NZPork Levy $3.50, meat inspection $3 and the PigCheck health inspection $0.17. There may be a per head freight cost to transport pigs to the abattoir.

Feed usage

Assumptions below based on 2,431 tonnes of proprietary purchased of feed /annum averaging $625/tonne, which includes a $15 freight delivery charge. Feed is based on locally grown cereal crops (barley and wheat,) and these prices vary year to year and within the year depending competition from other farming sectors (price goes up in a drought). Protein feed ingredient prices are variable throughout the year, with imported products such as soya meal and fishmeal dependant on international availability and NZ$ and locally produced products such as milk powders, meat and bone meal, blood meal dependant on availability. Please note that the costs used are 2021 figures and they have increased since then.

Given the assumptions in Table 1 above, a base farm budget can be determined from which other scenarios can be developed taking account of accommodation changes that may be required in the forthcoming Code of Welfare (Pigs).

Table 2 The financial impact upon the 400 sow farrow to finish unit described above. The changes include increases to the size of a farrowing pen (to 5.75m^2) and a reduced sow herd if the farm is expected to operate with the same accommodation. Also modelled is an increase in space for growing pigs using a k value of 0.034. The reduced sow herd reflects the herd size to accommodate the post weaning pigs in the existing facilities for either a multi-stage (3 stage) facility or a wean to finish example for post weaning accommodation.

	Bottom line to cover debt servicing, taxation, depreciation and capital items $	**Total pig sales per year**	**Annual bottom line reduction $**	**Capital cost to maintain herd size. Retro fit 67 farrowing pens $**	**Capital cost to build 23 new farrowing pens $**	**Loose mating area capital cost $**	**Breeding herd Total capital cost $**	**No. staff including owner operator**	**Breeding herd $ Extra cost/loss**	**$ Grower multi stage. Capital cost 0.034**	**$ Grower Wean to finish. Capital cost k of 0.034**
Base herd 400 sows	336,433	10,566		269,005	335,110	76,107	680,222	4	680,222	217,327	1,026,319
Less 3% mortality	290,991	10,222	45,441	269,005	335,110	76,107	680,222	4	725,663	217,327	1,026,319
Less 6% mortality	244,018	9,867	92,415	269,005	335,110	76,107	680,222	4	772,637	217,327	1,026,319
				67 pens retrofit	**16**						
Sow herd 375 Multi stage	291,123	9,904	45,310	269,005	236,000	71,350	576,355	4	621,665		
Less 3% mortality	248,423	9,582	88,010	269,005	236,000	71,350	576,355	4	664,365		
Less 6% mortality	202,845	9,238	133,588	269,005	236,000	71,350	576,355	4	709,943		
				60 pens retrofit							
Sow herd 266 wean to finish	179,742	7,026	156,691	240,900		50,611	291,511	3	448,202		
Less 3% mortality	149,453	6,797	186,980	240,900		50,611	291,511	3	478,491		
Less 6% mortality	117,123	6,553	219,310	240,900		50,611	291,511	3	510,821		

Table 3 Demonstrates the financial effect for the 400 sow farrow to finish unit described above with increases to the farrowing pen area to 5.75 m^2 and of a reduced sow herd if the farm is expected to operate with the same accommodation incorporating space in the post weaning area of 0.047 x Liveweight $^{0.67}$

The reduced sow herd reflects the herd size to accommodate the post weaning pigs in the existing facilities for either a multi 3 stage facility or a wean to finish example for post weaning accommodation.

	Bottom line to cover debt servicing, taxation, depreciation and capital items $	**Total pig sales**	**Annual bottom line reduction $**	**Capital cost to maintain herd size. Retro fit 67 farrowing pens $**	**Capital cost to build 23 new farrowing pens $**	**Mating area capital cost $**	**Breeding herd Total capital cost $**	**No. of staff including owner operator**	**$ Extra cost/loss**	**$ Grower multi stage. Capital cost 0.047**	**$ Grower Wean to finish. Capital cost 0.047**
Base herd 400	336,433	10,566		269,005	335,110	76,107	680,222	4	680,222	923,639	1,672,832
Less 3% mortality	290,991	10,222	45,441	269,005	335,110	76,107	680,222	4	725,663	923,639	1,672,832
Less 6% mortality	244,018	9,867	92,415	269,005	335,110	76,107	680,222	4	772,637	923,639	1,672,832
				56 pens retrofit							
Sow herd 271 Multi stage	208,957	7,159	127,476	224,840		51,562	276,402	3	403,878		
Less 3% mortality	178,100	6,926	158,333	224,840		51,562	276,402	3	434,735		
Less 6% mortality	145,162	6,678	191,271	224,840		51,562	276,402	3	467,673		
				45 pens retrofit							
Sow herd 199 wean to finish	111,652	5,256	224,781	180,675		37,863	218,538	2	443,319		
Less 3% mortality	88,993	5,086	247,440	180,675		37,863	218,538	2	465,978		
Less 6% mortality	64,806	4,903	271,627	180,675		37,863	218,538	2	490,165		

Table 3 below demonstrates the financial effect for the 400 sow farrow to finish unit described above with increases to the farrowing pen area to 5.75 m² and of a reduced sow herd if the farm is expected to operate with the same accommodation incorporating space in the post weaning area of 0.072 x Liveweight $^{0.67}$

The reduced sow herd reflects the herd size to accommodate the post weaning pigs in the existing facilities for either a multi 3 stage facility or a wean to finish example for post weaning accommodation.

	Bottom line to cover debt servicing, taxation, depreciation and capital items $	**Total pig sales**	**Annual bottom line reduction $**	**Capital cost to maintain herd size. Retro fit 67 farrowing pens $**	**Capital cost to build 23 new farrowing pens $**	**Loose mating area capital cost $**	**Breeding herd Total capital cost $**	**No. of staff including owner operator**	**Breeding herd.$ Extra cost/loss**	**Grower multi stage. Capital cost 0.072 $**	**Grower Wean to finish. Capital cost 0.072 $**
Base herd 400	336,433	10,566		269,005	335,110	76,107	680,222	4	680,222	2,281,931	3,392,618
Less 3% mortality	290,991	10,222	45,441	269,005	335,110	76,107	680,222	4	725,663	2,281,931	3,392,618
Less 6% mortality	244,018	9,867	92,415	269,005	335,110	76,107	680,222	4	772,637	2,281,931	3,392,618
				40 pens retrofit							
Sow herd 177 Multi stage	73,586	4,676	262,847	160,600		33,677	194,277	2	457,124		
Less 3% mortality	53,431	4,523	283,002	160,600		33,677	194,277	2	477,279		
Less 6% mortality	31,918	4,361	304,515	160,600		33,677	194,277	2	498,792		
				30 pens retrofit							
Sow herd 130 wean to finish	18,262	5,256	318,171	120,450		24,735	145,185	1.5	463,356		
Less 3% mortality	3,459	5,086	332,974	120,450		24,735	145,185	1.5	478,159		
Less 6% mortality	-12,341	4,903	348,774	120,450		24,735	145,185	1.5	493,959		

APPENDIX G: **Comparison of welfare standards (Mating stalls, Farrowing crates, Castration, Space for growing pigs, Tail docking, Manipulable material and Weaning age): NZ vs. Exporting countries**

Last Updated June 2022 based on April 2022 Imports Report - last 16 months to April 2022 (source - NZ Pork)

Rank	Country	Subsidy?	Max. days allowed in a mating or gestation stall*	Max. days allowed in farrowing crate post farrowing**	Min. size (m^2) of Farrowing crate or pen	Is Castration carried out?	Min. space for growing pigs (k value)	Is manipulable material required?	Is tail docking allowed?***	Min. weaning age****	% imports from this country	Cumulative % imports
1	Germany (1)	Yes	28	Unlimited	6.5	Yes, with pain relief	0.03	Yes	Yes, without pain relief if under 7 days	21 d with caveats	24%	24%
2	USA (2)	Yes	Entire length of pregnancy	Unlimited	Not specified	Yes, without pain relief	No minimum	No	Yes, no age limit and no pain relief required	None	15%	39%
3	Poland	Yes	28	Unlimited	Not specified	Yes, without pain relief	0.03	Yes	Yes, without pain relief if under 7 days	21 d with caveats	14%	53%
4	Spain	Yes	28	Unlimited	Not specified	Yes, without pain relief	0.03	Yes	Yes, without pain relief if under 7 days	21 d with caveats	12%	65%
5	Australia (3)	No	42	28	3.2 (crate) 5.6 (pen)	Yes. Pain relief required if over 21 days	0.03	No	Yes, without pain relief if under 7 days	None	6%	71%
6	Canada	Yes	35	42	Not specified	Yes with pain relief	0.034 with caveats	Yes	Yes, pain relief required at all ages	None	6%	77%
7	Finland (4)	Yes	28	Unlimited	Not specified	Yes with pain relief	Average k value of 0.044	Yes	No	21 d with caveats	5%	82%
8	Denmark	Yes	28	Unlimited	Not specified	Yes with pain relief	0.03	Yes	Yes, between 2 – 4 days old and without pain relief	21 d with caveats	5%	87%
9	Sweden (5)	Yes	0	0	6.0	Yes with pain relief	Average k value of 0.044	Yes	No	28 days	5%	92%
10	Netherlands (6)	Yes	4	Unlimited	Not specified	Yes, without pain relief	0.035	Yes	Yes, without pain relief if under 7 days	21 d with caveats	5%	97%
New Zealand Current		**No**	**7**	**28**	**Not specified**	**No**	**0.03**	**No**	**Yes, without pain relief if under 7 days**	**None**	-	-

Welfare Standards KEY:	Below NZ	Same/similar to NZ	Beyond NZ

Notes: Appendix G

1	Germany	In Germany legislation was passed in 2020 that states gestation stalls will be banned from 2028 and farrowing crates will be banned from 2035.
2	USA	Arizona, California, Colorado, Florida, Maine, Massachusetts, Michigan, Oregon and Rhode Island are the only US States that have phased out or banned the use of gestation stalls to varying degrees. Many of these states are not considered significant areas for pig production.
3	Australia	Sows may be confined in a gestation stall from weaning until 5 days post-mating (~9 days in total), but this is by voluntary agreement. The legal upper limit is 6 weeks. Most of the industry is compliant with the voluntary agreement (approx. 80%). Castration must be carried out by a veterinarian if over 21 days. Farrowing crate and creep area must be 3.2m2, farrowing pens must be 5.6m2.
4	Finland	Finland has greater space requirements for growing pigs than the EU directive requires and calculates it differently (not with a k value), as: 0.17 m2 + (weight kg/130). This translates to an average k value of 0.044 from 10kg – 110kg (k value range = 0.040 – 0.053). Growing pigs are generally kept in groups of 10 – 15.
5	Sweden	Sows can be confined in a farrowing crate temporarily post-farrowing, but the maximum period of confinement that is allowed is not defined. Sweden appears to use the same calculation as Finland for growing pig minimum space. Growing pigs are generally kept in groups of 8 – 10.
6	Netherlands	Sows may be confined in a gestation stall for 4 days post-mating. Whether or not the sows can be confined between weaning and mating is not specified.
*	The terms "mating stall" and "gestation stall" are both used, as New Zealand only permits stalls for the purpose of mating, not gestation. Other countries refer to them as gestation stalls as sows are housed in the stalls after mating, during part or all of a sow's pregnancy.	
**	Maximum period allowed in farrowing crates applies to the post-farrowing (lactation) period only as most countries do not specify the maximum amount of time that a sow may be housed in a farrowing crate before giving birth. In New Zealand this is limited to a maximum of 5 days pre-farrowing.	
***	In the EU, routine tail docking is not permitted however it is often a routine procedure. Since 2016, pain relief must be provided at tail docking at any age in Canada. In Ireland tail docking is not permitted unless recommended by a veterinarian on welfare grounds.	
****	In the EU the Directive states: "No piglets shall be weaned from the sow at less than 28 days of age unless the welfare or health of the dam or the piglet would otherwise be adversely affected. However, piglets may be weaned up to seven days earlier if they are moved into specialised housings which are emptied and thoroughly cleaned and disinfected before the introduction of a new group and which are separated from housings where sows are kept, in order to minimise the transmission of diseases to the piglets." Piglets are commonly weaned at under 28 days. Technically the (absolute) minimum weaning age is 21 days.	

Appendix H: Details of countries with farrowing crate prohibitions, transition periods and subsidies.

Country	Farrowing system requirements	Transition period	Subsidies and specific funding
Sweden	The minimum area for a farrowing pen is 6m^2 in total, providing a lying area of 4 m^2 for the sow. During the week before farrowing sows and gilts must have access to litter which allows them to carry out nest building behaviour. The sow's freedom of movement may be confined during the first days after farrowing by the use of a gate or similar construction if she shows aggressive or abnormal behaviour.	13 years. Introduced in 1994, came into force in 2007.	Producers have access to the 'Sow Money' scheme, regional subsidies, government payouts for specific disease events, compensation for surgical castration and immunocastration. Access to EU Common Agricultural Policy payments (CAP).
Switzerland	Minimum space is 5.5m^2 and at least 2.25 m^2 must be solid floor in the lying area for sow and piglet. Sufficient long straw or other material suitable for nest building is required in the days before farrowing. The sow may be restrained in isolated cases (for up to 3 days).	10 years. A ban on farrowing crates was announced in 1997, came into force in 2007.	Farmers are eligible for 'direct payments' as well as payments related to land size, crops/ agricultural land use etc. There are specific payments associated with keeping pigs. Direct payments are awarded (per stock unit) and generally represent a third of pig producers' income.
Norway	The minimum area is 6m^2. From 3 days before the expected farrowing date, the sow should have free access to enough hay, straw or other material to build a nest. Nervous or aggressive sows can be crated from the birth of the first piglet until they are 7 days old.	8 years. A two-stage approach was used starting with introducing temporary confinement from 3 days pre until 7 days post- farrowing between 1996 and 2003. Since 2003, temporary confinement is only allowed in certain circumstances farrowing, for up to 7 days.	Each agricultural holding in Norway on average receives support worth nearly €62,000 each year. Overall, subsidies to farms represent around 60% of gross farm income. Subsidies are mainly based on output, species and area farmed. These are in addition to investment and tax allowances for agriculture which provides an assured income to farmers.
Germany	The minimum farrowing pen size is 6.5m^2. Sows may be restrained for a maximum of 5 days post farrowing.	15 years. Introduced in 2020, comes into force in 2035.	Farmers in Germany are eligible for the EU CAP payments in the form of direct payments (income support). Government funding was available to cover up to 40% of expenses, with a maximum limit of €500,000 per farm, to transition. Germany is also exploring a change to building laws specifically to assist pig farmers with making changes.
Austria	Pen size must be ≥5.5 m², with 50% as a designated lying area for sows and piglets. Minimum of 1/3 solid floor. Restraint of the sow permitted for the critical period of a piglets' life, said to be from 1 day pre-farrowing to 5 days post-farrowing).	13 years. Introduced in 2020, comes into force in 2033.	Austrian farmers are eligible for 'basic payments' under the EU CAP (Common Agricultural Policy). The maximum payment that will be granted to any one farmer under the Basic Payment Scheme is capped at €150,000.00. Improved subsidy system covers 35% of the cost of transitioning to farrowing pens, up to €400,000 per farm.