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

A report prepared by the National Animal Welfare Advisory Committee (NAWAC)

Contents

1. Executive Summary

- The Five Domains Model (Model) was used as an analytical tool to assess options for farrowing and mating management systems for pigs.
- The expert panel undertaking the analysis consisted of the pigs sub-committee of the National Animal Welfare Advisory Committee (NAWAC) and a NZ Pork representative. The panel used a modified Delphi process to arrive at group decisions.
- The Model is designed to facilitate the assessment and grading of animal welfare indicators, incorporating mental experiences (negative and positive) that matter to the animal, referred to as affective states.
- A list of animal-based welfare indicators and the associated affective states for both sow and piglet were generated based on current and available peer-reviewed scientific literature. The panel described a range of management system scenarios for both pre-farrowing to weaning and mating and used the Model to assess pig welfare in each system.
- The assessment suggests:
    - 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.
        - One indicator for piglets (near-miss crushing) had equivalent risk (moderate) for both outdoor and indoor loose farrowing systems.
    - Sows and piglets in outdoor and indoor group housed systems have the greatest opportunity for positive experiences.
    - Mating systems with voluntary stalls and confined, un-enriched (barren), environments have the highest risk of moderate/high negative impacts on affective state of sows.
- In conclusion, it was considered that:
    - 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.
    - While the risk to affective state of piglets from near-miss crush injury is greater in indoor systems when sows are loose, it is not dissimilar from the risk to piglets born outdoors and may be reduced by management and pen design.
    - The negative impacts of exposure to adverse weather conditions on the affective state of pigs managed outdoors may require mitigation.
    - Systems that provide space, complexity and opportunities for appropriate social interactions are more likely to provide pigs with positive experiences.

2. Introduction

As part of its process to provide advice to the Minister on standards that might apply to the use of farrowing crates and mating stalls, the NAWAC Pigs Sub-committee conducted a thorough review of options for farrowing and mating management. Using the Five Domains Model (the Model) (Mellor et al., 2020), the committee analysed representative scenarios for their potential to influence the welfare state of both sows and piglets. This information was then used to inform NAWAC in its deliberations, alongside its review of scientific literature, good practice, and available technology (NAWAC Pigs Code Report, 2021).

This report describes the methods used to develop the assessment framework following the principles of the Model, the results obtained by its application and associated discussion. This is followed by conclusions and a discussion about possible limitations of the Model.

2.1 Background on the Five Domains Model

The Model was originally formulated in 1994 to identify and grade negative welfare impacts of research, teaching, and testing procedures for sentient animals. It has since been used to assess the welfare of a range of species in a range of situations, including working dogs (Littlewood & Mellor, 2016), farm animals (Mellor et al., 2009), sport animals (Mellor & Burns, 2020), zoo animals (Sherwen et al., 2018) and wildlife and pest animals (Beausoleil et al., 2012; Beausoleil & Mellor, 2015; Beausoleil et al., 2016). It has also been used to assess suffering and animal cruelty that have led to court prosecutions (Ledger & Mellor, 2018).

The Model was designed to facilitate the assessment and grading of animal welfare impacts in a systematic, comprehensive, transparent and justifiable manner, focussing not only on factors which can compromise welfare, but additionally on those which can ultimately improve welfare. Throughout its 25-year history, the Model has been regularly reviewed and updated to include the latest developments in animal welfare science. The most recent update to the Model includes detailed guidance on how to evaluate the negative and/or positive impacts of an animal's experiences arising from its interactions with its environment, humans (e.g. stockpeople) and other non-human animals (Mellor et al., 2020).

The model is predicated on the understanding of animal welfare as a state within the animal itself that arises due to the integration of its various mental experiences, both negative and positive, at a point in time. Mental experiences that have valence (i.e. are negative or positive) matter to the animal and are also referred to as 'affective experiences' or 'affects'. In other words, an animal's welfare reflects how it is experiencing its world and life, and its overall welfare will vary over time on a continuum from very poor to very good as those experiences vary.

This understanding aligns most closely to the 'affective state' orientation to welfare, according to which good welfare can be achieved when animals have few, minor and/or transient negative mental experiences *and* have frequent and meaningful positive experiences. Other approaches to welfare relate predominantly to the animal's 'biological functioning' (e.g. health and productivity) or the 'naturalness' of the way the animal is kept (Fraser et al., 1997; Dwyer, 2009; Hemsworth et al., 2015). Emphasis is placed on the 'affective state' orientation for different reasons: first, affective experiences most directly link the animal's welfare state with its own perceptions and interpretations of various features of its world (Fraser, 2008); second, affective experiences and biological functioning are dynamically related.

In accordance with this, the structure of the Five Domains model reflects the understanding that mental experiences arise due to processing of sensory information gathered about its physical state (internal bodily processes/biological functioning) and its external environment (Mellor et al., 2020). As shown in Figure 1 below, the link between the animal's physical state/behavioural interactions and its affective state is a fundamental feature of the model and one of its key strengths for transparent justification of the conclusions drawn about overall welfare state.

According to the Model, evidence of impacts on, or opportunities for, the animal is organised into four physical/functional domains which relate to its (1) Nutrition and hydration, (2) Physical environment, (3) Health or functional status, (4) Behavioural interactions. This evidence is provided by a range of qualitative or quantitative physical, physiological, pathophysiological, biochemical, immunological, neurological and behavioural indicators. This information is then used cautiously to *infer* the animal's likely mental/affective experiences, which are most relevant to its welfare state, to derive Domain 5: Mental Experiences.

Negative experiences such as thirst, hunger, breathlessness or pain arise in Domain 5 from factors that disturb or disrupt the internal stability of the body (evidence in Domains 1-3) or when the animal is stopped from achieving strongly motivated behavioural goals to interact with the environment and other animals, e.g. fear or frustration (evidence in Domain 4). Positive experiences such as pleasures of eating or thermal comfort may arise when the animal has opportunities to maintain or restore its internal physical stability (Domains 1-3) or when it can achieve its goals, e.g. pleasure and safety of companionship (Domain 4). Assessments in Domain 4 may also reflect the extent to which the "agency" of the animal (its engagement in voluntary, goal-directed behaviours) is restricted or enhanced by resources provided.

2.2 Indicators for scientific assessment of welfare state

Mental or affective experiences are, by definition, internal and subjective and thus cannot be directly assessed. Thus, various measurable or observable indicators must be used to *infer* the likely associated mental experience (Dawkins, 2003). Some caution is required when applying these inferences. In

humans, indicators can be directly validated by asking the person what they are experiencing when they express the indicator. In non-human animals, validation of indicators relies on a variety of information including: a) scientific understanding of the cause and effect of disease, dysfunction or disruption to the animal's internal physical state, b) consistency among a variety of different indicators, such as expression/presence of behavioural *and* physiological measures, in the same situation, c) understanding of the nervous system pathways leading from sensory inputs to the generation of specific mental experiences such as pain, fear or breathlessness and d) the effects of actions known to cure the disease, resolve the internal dysfunction or disruption or remove the external stimulus (Beausoleil & Mellor, 2017).

Animal-based indicators represent the *outcome* of the animal's perception and interpretation of its world and thus provide the strongest justification for inferring mental experiences and overall welfare state. Examples of animal-based indicators include behavioural and physiological responses to environmental features. In contrast, resource- and management-based indicators such as the space provided or the capability of stockpeople represent *risks* to the animal's welfare (inputs or alerting indicators) but do not provide direct evidence that resources and management activities influence the animal's mental state (Harvey et al., 2020). Thus, animal-based indicators are preferred for Five Domains assessments of welfare state whenever feasible.

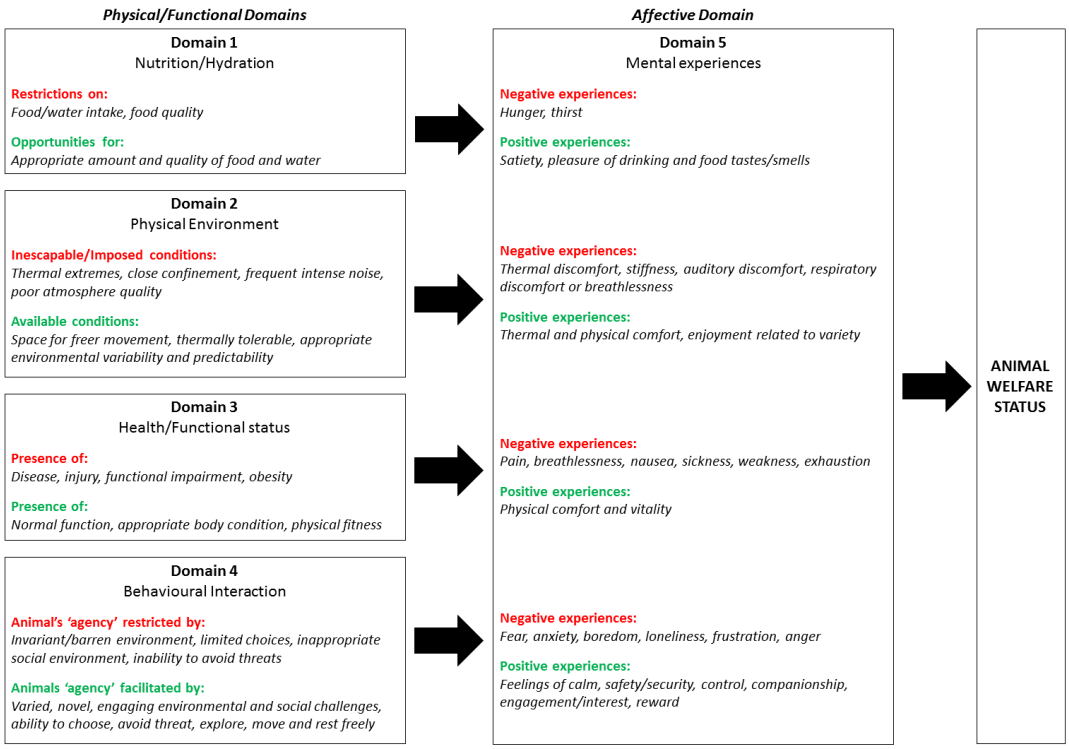

Figure 1. The generic diagram of the Five Domains model for assessment of animal welfare with examples of relevant features of the animal's physical/functional state or environment (Domains 1-4) and the associated negative or positive mental/affective experiences inferred in Domain 5. Taken together, these mental experiences represent the overall welfare state of the animal. Adapted from Mellor & Beausoleil, 2015.

3. Methods

The Five Domains Welfare assessment was undertaken by an informed panel following a modified stepwise Delphi process to arrive at group decisions. The informed panel consisted of the NAWAC pig subcommittee (6 members) and a representative from NZ Pork. In preparation for the Five Domains Assessment, the panel met for a workshop on 26 February 2021. A representative of World Animal Protection (WAP) was also present at this workshop but declined the opportunity for further involvement in the assessment citing ethical conflicts. The workshop was facilitated by Associate Professor Ngaio Beausoleil from the Animal Welfare Science and Bioethics Centre (School of Veterinary Science, Massey University), who has twelve years' experience in the evolution and applications of the Model.

Associate Professor Beausoleil explained the underlying philosophy and structure of the Model, presented examples of its application, and discussed some nuances of the approach. This included establishing the processes to be used for deciding ratings. A different rating scale is needed for enhancements because the reference points and animal-based indicators for rating negative impacts and positive enhancements are necessarily different (Mellor, 2015; Mellor & Beausoleil, 2015). The benchmark for grading impacts is the occurrence of negative experiences and their minimisation; traditional indicators such as stress hormones or fear behaviours are observed/measured when negative experiences are occurring and are not observed/measured when they are absent. This means such indicators reflect only the portion of the welfare continuum from negative state to neutral state. Thus, indicators of negative affects cannot be used to infer the occurrence of positive experiences.

In contrast, the extent to which animals may have positive experiences is generally reflected through their behavioural choices to utilise available opportunities. This expression of 'positive affective engagement' represents the animal's response to its internal motivations to undertake behaviours that are *rewarding* (i.e. expression of agency or voluntary goal-directed behaviours). Frequent expression of reward-related behaviours, where that is possible, would thus enhance welfare state past neutral into the positive end of the continuum. Because the field of animal welfare science has tended to focus on suffering (negative experiences) and its alleviation, there are fewer validated indicators of positive experiences currently available (Edgar et al., 2013).

Associate Professor Beausoleil then facilitated a discussion to develop a list of animal-based indicators of IMPACTS (associated with negative affective states) and ENHANCEMENTS (associated with positive affective states) for sows and piglets from pre-farrowing to weaning, and for sows during the week following weaning as they are mated for their next reproductive cycle.

The NAWAC Pigs subcommittee also identified a range of system scenarios for the analysis enabling the likelihood that the relevant IMPACTS and ENHANCEMENTS would occur to be scored for sows and piglets separately. These system scenarios are presented in Table 1.

Following the workshop, panel members worked individually with the lists and scenarios from the workshop. They developed ratings for both IMPACTS and ENHANCEMENTS for sows and piglets relevant to farrowing systems, and for sows relevant to mating systems, and estimations of likelihood for IMPACTS and ENHANCEMENTS to occur in the defined system scenarios. These assessments were assigned based on each panel member's understanding developed from reading the scientific literature, experiences gained during farm visits and conversations with pig welfare and industry experts.

The panel next collaborated in over ten meetings where scores were shared, discussed, challenged, and defended, and developed into an agreement on overall ratings. Most ratings reached consensus within the panel; however, some panel members had differing views on the scoring of some indicators. This was an iterative process allowing additional information to be obtained where there were information gaps, for example using New Zealand industry statistics and local expert veterinary knowledge.

3.1 Rating the severity/intensity of IMPACTS based on animal-based indicators

Panel members first considered each animal-based indicator and rated it for its IMPACT on affective state using the following procedure:

- The impact on animal welfare was described and qualitatively rated for intensity/severity by considering effects in each of the physical/functional Domains (1 to 4) with ratings assigned as None, Low, Moderate, or High (Beausoleil et al., 2016).
- Using these physical/functional ratings, each panel member considered the likely associated affective experiences inferred in Domain 5; multiple specific qualities of 'affect' were possible for each indicator. For example, the presence of 'lameness' could influence access to feed (Domain 1) which could lead to hunger (Domain 5) the health/physical state of the animal (Domain 3) which could lead to pain (Domain 5), and the behavioural interactions of the animal with the environment or other animals (Domain 4) which could lead to frustration (Domain 5). The scientific bases for the validity of these inferences of resultant affective experiences is described in Appendix A.
- The estimated duration of the impact was also considered (Minutes, Hours, Days or Weeks).
- Following this, the intensity/severity ratings from Domains 1-4 and the estimated durations were integrated into an overall IMPACT rating. This was based on the highest impact score from Domains 1-4 alongside its duration, and modifying it if considered appropriate (e.g. a moderate impact lasting weeks could be revised up to high impact, whereas a moderate impact

lasting minutes could be revised down to a low impact). The overall IMPACT rating was assigned as Low, Moderate, or High.

- Confidence for the indicator resulting in the inferred affected states was rated as "low" if there was limited scientific literature to support the inference. However, these indicators were still included in the analysis as all were considered possible, based on the available literature, and understanding of animal welfare.

3.2 Rating the significance of ENHANCEMENTS based on animal-based indicators

Each panel member next rated the animal-based indicators of ENHANCEMENTS using the following procedure:

- For each indicator, the significance of ENHANCEMENT was qualitatively rated by considering the behavioural utilisation of opportunities likely to be rewarding in each of the physical/functional Domains (1 to 4) on a scale from 1 to 3 where 1 = low and 3 = high significance.
- From these physical/functional significance ratings, the likely associated affective experiences were inferred in Domain 5; multiple specific qualities of 'affect' were possible for each indicator. For example, observed interactions with nesting material could influence thermoregulation and alleviate pressure on joints and abrasion of skin (Domain 2) which could lead to thermal and physical comfort (Domain 5) and facilitate maternal interactions with piglets (Domain 4) which could lead to feelings of maternal affection and security for her litter (Domain 5). The scientific bases for the validity of these inferences of resultant affective experiences is described in Appendix B.
- The estimated duration of the ENHANCEMENT was considered (Minutes, Hours, Days or Weeks).
- Each panel member then assigned an overall ENHANCEMENT significance rating for the indicator (1, 2, 3), integrating the significance of enhancements rated in Domains 1-4 and the estimated duration of those ENHANCEMENTS.
- As above, confidence for the indicator resulting in the inferred affected states was rated as "low" if there was limited scientific literature to support individuals experiencing these affective states in relation to the specific indicator.

3.3 Estimation of Likelihood of IMPACTS and ENHANCEMENTS in the different system scenarios

For each scenario, the relative *risk* or Likelihood of the described IMPACTS and ENHANCEMENTS occurring was evaluated. The scales for assigning Likelihood were also approached slightly differently for IMPACTS and ENHANCEMENTS. The observation/measurement of IMPACT indicators is much

better understood in both the industry and scientific literature, whereby evidence of the occurrence of negative affective experiences is often routinely recorded or well-studied. Thus, for IMPACT indicators, the proportion of individual animals affected in different management scenarios can be used to evaluate the Likelihood, at a population level, of animals experiencing negative affective states for a specified scenario.

In contrast, evidence of the occurrence of positive affective experience is not as widely understood by the industry or within the scientific literature, as this is an emerging field in animal welfare science. Thus, for ENHANCEMENT indicators, the panel used qualitative discussions to determine what they felt was the Likelihood, at a population level, of animals experiencing a positive affective state for specified scenarios. Evidence such as resource provision, known behavioural and neuropathological responses to environmental conditions, and highly motivated behaviours were used to inform these qualitative discussions. The panel considered ENHANCEMENTS in relation to behavioural choices that were likely to lead to positive affective experiences (as described above).

Panel members individually considered these Likelihoods for each system scenario as follows:

- The Likelihood of an IMPACT occurring in each system scenario was estimated as None (no animals likely to experience impact), Low (<10% of animals likely to experience impact), Moderate (11 to 30% of animals likely to experience impact), High (>30% of animals likely to experience impact). Where no direct data were available, the estimation was made qualitatively by considering system features such as the degree of confinement and access to various resources.
- The Likelihood of an ENHANCEMENT occurring was estimated by considering a relative degree to which the system was likely to result in animals to expressing reward-related behaviours resulting in positive affective experiences. The degree of Likelihood for each system scenario was estimated as None, * Low, ** Moderate, and *** High.

Table 1. System scenarios rated in the Five Domains welfare assessment for a) pre-farrowing to weaning and b) the week following weaning where mating occurs.

a) Pre-farrowing to weaning

Scenario	*Description*
A. Outdoor farrowing	Farrowing outdoors in a paddock. Typical insulated huts provided. Plentiful (~6-10 kg) nesting material provided 2 days pre-farrowing and topped up daily.
B. Group housing indoors	Large barn with deep straw bedding/litter. Sows grouped several days prior to farrowing. Nest boxes available down the sides of the barn for sows to choose to nest in.

C.	*Individual pens indoors*	Designed pen of at least 6.5m^2. No crate. Separate dunging (slatted floor) and lying/nesting (solid floor) areas. Example: Swiss FAT pens[1]. Plentiful nesting material (15-20 kg) provided 2 days pre-farrowing and topped up daily. Heated piglet creep provided.
D.	*Temporary crating plus*	6.5m^2 pen. Separate dunging (slatted floor) and lying/nesting (solid floor) areas. Swing sided crate available. Example: SWAP[2] pen. In this scenario the sow is shut in the crate post-nesting and is in the crate for 3.5 days total. Some straw (1-2kg) available in a 'self-serve' rack 2 days pre-farrowing and topped up daily. Heated piglet creep provided.
E.	*Temporary crating*	Swing-sided crate provided of the same footprint as a conventional crate area. Example: 360 Freedom Farrower[3] (4.3m^2). Fully slatted floor. Sow is crated 5 days pre-farrowing and side is opened 10 days post-farrowing. Manipulable material is provided, in the form of a hessian sack attached to the crate. Heated piglet creep provided.
F.	*Current state*	Conventional crate system (3.6m^2). Sow is introduced to the crate 5 days before farrowing and stays until piglets are weaned (total 30 days). Fully slatted floor. Heated piglet creep provided.
Assumptions:		• Duration is from entering the farrowing area through to weaning only. Weaning age is 25 days. • Hyperprolific sow lines are used. • Cross-fostering is not occurring (cross-fostering is common practice on-farm however it was deemed too complicated to include in the analysis) • Stockpeople are experienced and competent. Tail docking and vaccination/injections for piglets are carried out on day 2. • Sows are fed *ad libitum* as per normal farm practice during this period. • All other minimum standards (outside of MS 10) are met. • Any crates used are large enough for the sow - they meet current regulatory requirement of not touching both sides/ends simultaneously. • Pens/huts are built to recommended specification. • Piglets are fully sentient from birth. • While it was acknowledged that the management system during gestation affects animals going into farrowing and has great influence on the welfare of sows, this was not taken into account. • It was assumed that sows were going into the farrowing system healthy with no previous injuries.

b) Mating

Scenario		*Description*
A.	*Natural mating*	Sows are kept in a group outdoors. No stall/restraint for breeding – they are run with a boar.
B.	*Artificial insemination (AI) with no restraint*	AI is performed in a pen rather than a stall. They are otherwise kept outdoors, in a paddock with a communal shelter.
C.	*2 hours in stall - outdoors*	Sows are restrained in a stall for the time to perform AI – in this scenario, 2 hours. They are otherwise kept outdoors, in a paddock with a communal shelter.

[1] Swiss Free Farrowing FAT pens: https://www.freefarrowing.org/farrowing-systems/individual-farrowing-pens/fats/

[2] Danish Free Farrowing SWAP pens: https://www.freefarrowing.org/farrowing-systems/temporary-crating/swap/

[3] 360° Freedom Farrower pens: https://www.freefarrowing.org/farrowing-systems/temporary-crating/360-farrower

D. 2 hours in stall - indoors	Sows are restrained in a stall for the time to perform AI – in this scenario, 2 hours. They are otherwise kept in indoor group housing pen indoors. Part of the floor in the group housing is solid and contains rooting material (straw/sawdust).
E. Voluntary stalls	A large group pen is provided with a row of stalls down each side that the sows enter and leave at will. They are only locked in a stall for the time to perform AI – in this scenario, 2 hours. They are fed in the stalls. The floor is concrete, and the pen is barren.
F. 7 days in a stall	Maximum allowable under current state. The sows go from the farrowing system to a mating stall for the full 7-day period. The floor is fully slatted.
Assumptions:	• Consider the experience of a sow (2nd parity+), not a gilt. • Duration is a 7-day period from exiting the farrowing accommodation only. • Group size: 25. Group is intact for the 7 days (no additional animals/mixing after the group is first constituted). • Sows enter the mating period in a lean condition. They are fed *ad libitum* as per normal farm practice. • Stockpeople are fully competent in the performance of AI. • All other minimum standards (outside of MS 11) are met. • Stalls, where used, meet current regulatory requirement of being large enough for sow to be able to stand without contact with any side of the stall. • While it was acknowledged that the management system during the farrowing and suckling period affects the welfare of sows after weaning, this was not taken into account. It was assumed that sows were going into the mating system healthy with no previous injuries.

4. Results and Discussion

4.1 Pre-farrowing to weaning

4.1.1. Supporting evidence for rating IMPACTS on sow welfare

The IMPACTS on sow welfare during the farrowing period and the Likelihoods of those impacts that differ among system scenarios are presented in Table 2.

High and moderate IMPACTS were estimated to have a higher Likelihood of arising in scenarios E (Temporary crating) and F (Current management). Many of these impacts were also judged to be moderately likely in scenario D (Temporary crating plus). Indicators of these IMPACTS tended to cluster in Domain 2 (slipping and gait, up/down movement), Domain 3 (pressure sores, skin lesions, physiological stress response, long farrowing duration) and Domain 4 (abnormal redirected/repetitive behaviours, aversion to piglets). The associated negative affective experiences were inferred in Domain 5 to be pain and weakness/fatigue associated with impacts in Domains 2 and 3 and frustration, boredom, helplessness, anxiety or fear associated with impacts in Domain 4.

The panel considered that the Likelihood of occurrence of the negative affective states of pain, stress, frustration, boredom and anxiety is higher in systems where the sow is restricted in terms of space and the ability to move freely, to explore, forage and undertake nest building and maternal behaviour. In contrast, systems that provide greater behavioural freedom such as outdoor and group housing were considered to have a lower Likelihood of exposing sows to these IMPACTS.

In a semi-natural setting, pigs are typically active for most of the day and spend a large proportion of time undertaking foraging and exploratory behaviours (Stolba & Wood-Gush, 1989). This can be used as a basis for understanding the potential negative effects of restricting sows' behavioural interactions in Domain 4. In some indoor conditions, pigs can still carry out some normal behaviours[4], however, the environment is often restrictive in terms of amount of space available as well as providing no, or very limited, resources that pigs can interact with to express normal foraging and exploratory behaviours. In addition, the diet is typically provided in fixed and sometimes restricted ways (e.g. for dry sows - not included in this assessment), which is likely to lead to thwarted foraging behaviour.

[4] Normal behaviours in the context of this report are those that form part of the natural behavioural ecology (related to food acquisition, social interactions, breeding, and rearing young) as observed in wild or semi-wild populations.

Table 2. The IMPACT ratings and their inferred affective states, for sow-based indicators, and the Likelihood of their occurrence for each farrowing system scenario considered. No indicators were rated as having "low" confidence for inferred affective states.

Sow impact	Impact rating	Inferred affective states	Housing System					
			A Outside	B Group housing	C Pens	D Temporary crating plus	E Temporary crating	F Current
ARB[1]	high	*frustration, boredom, helplessness, depression anxiety, hypervigilance*	low	low	moderate	high	high	high
Up/down movement	high	*pain, frustration, anxiety, hunger*	none	none	none	low	high	high
Pressure sores	high	*pain, discomfort*	none	none	none	low	low	moderate
Clinical hyperthermia	high	*thermal discomfort, malaise, breathlessness, exhaustion, weakness*	low	none	none	none	none	none
Aversive response to piglets	high	*fear, anxiety, frustration, rage/anger*	low	low	low	moderate	moderate	moderate
Slipping and gait	moderate	*anxiety, discomfort, pain*	none	none	none	low	high	high
Skin lesions	moderate	*pain, discomfort, itchiness*	low	low	low	moderate	moderate	moderate
Long farrowing duration	moderate	*weakness, exhaustion, fatigue, pain*	low	low	low	moderate	high	high
Poor sow hygiene	moderate	*skin irritation, pain, discomfort, frustration*	none	none	none	low	low	low
Sunburn	moderate	*pain, skin irritation*	moderate	none	none	none	none	none
Long term chilling	moderate	*thermal discomfort, chilling*	low	none	none	none	none	none
Aversive response to sow	moderate	*fear, anxiety, frustration, rage/anger*	low	moderate	none	none	none	none
Short term heating	low	*thermal discomfort, malaise, lethargy*	moderate	moderate	low	low	low	low
Short term chilling	low	*thermal discomfort, chilling*	moderate	none	none	none	none	none

[1] Abnormal repetitive/redirected behaviour

Severe restrictions in an animals' environment have been shown to lead to expression of abnormal redirected or repetitive behaviours (ARBs) which have been suggested to be indicators of negative affective states, such as frustration, boredom and depression (Mason & Burn, 2018; Meagher, 2018; Vice, 2019). These behaviours are typically seen in barren environments, for example bar biting by periparturient sows is more common and more frequent in crates compared to pens containing manipulable material (Cronin et al., 1994; Damm et al., 2003). Vacuum nest building behaviour (e.g. pawing at the ground, bar biting) performed by sows in crates prior to farrowing is another example of an ARB related to thwarted nest building behaviour which is associated with stress (Lawrence et al., 1994; Jarvis et al., 1997; Jarvis et al., 2001; Damm et al., 2003). Further work dissociating the effects of space and substrate demonstrated that space restriction *per se* induced elevated hypothalamic-pituitary-adrenal (HPA) activity which is indicative of physiological stress (Jarvis et al., 2002). Therefore, providing sows with environments that allow for freedom of movement and the expression of motivated behaviours (e.g. nest building, maternal care, exploration etc), as is the case for scenarios A (Outside) and B (Group housing), is likely to result in lower incidences of ARB's and associated frustrated, bored, helpless or depressed affective states.

Nest building requires both suitable material and space. When the environment does not allow sows to carry out nest building behaviour, they are also at risk of longer farrowing durations. Farrowing was on average over 90 min longer in sows with restricted space and with no nesting material compared to sows with more space and straw bedding (Oliviero et al., 2010). Shorter farrowing duration and lower percentage of stillbirths were also found when sows had straw as nest-building material, compared to sows with peat or no specific material (Rosvold & Andersen, 2019). In addition, during farrowing, sows provided with straw or peat as nesting material showed a lower frequency of negative communication (i.e. pushing, threatening barks, biting) towards piglets compared to controls without nesting materials (Rosvold et al., 2019). Providing straw as a nest-building material also resulted in a higher proportion of sow-initiated nursing bouts and successful nursing bouts (i.e. with milk let-down) than for sows with access to peat and or in the control treatment without materials (Rosvold et al., 2019). Crated sows will show bar biting and restless behaviour even if they have the same amount of straw as sows in pens, thus indicating that having access to space is an important part of fulfilling nest-building behaviours (Andersen et al., 2014). Sows in crates also had restricted opportunity to carry out appropriate maternal behaviour including nose-to-nose contact (Portele et al., 2019), which is typically undertaken during parturition (Gundlach, 1968; Jensen, 1986), and there was a greater risk of piglet-savaging behaviour or the sow not interacting appropriately with her piglets (Cronin et al., 1996; Jarvis et al., 1998).

As indicated by resource provision, the prevalence of ARBs, long farrowing duration, and aversive response to piglets, the panel concluded that nesting behaviours are highly restricted in scenarios E (Temporary crating), and F (Current management), and moderately in scenario D (Temporary crating plus), which all involve elements of confinement to a crate. Temporary crating plus was considered to

moderately restrict nesting behaviour due to the differences in space allowance and nesting material restricting the completion of a full nest. Scenarios D, E, and F are also most likely to have greater impact on farrowing duration and aversion to piglets, potentially leading to affective state impacts of pain, weakness, fatigue, exhaustion (long farrowing duration), fear, anxiety and frustration (aversion to piglets).

Partially or fully slatted floors are common in many pig farms as they allow for easier management of hygiene in the system and reduce the risk of disease outbreaks. However, these flooring surfaces affect sow locomotion and may reduce the ability to move freely (slipping and gait), particularly in respect to plastic and cast iron slats (Pedersen & Ravin, 2008). Slatted flooring in comparison with solid or bedded floors has been reported to be associated with lameness and poor claw health (Jørgensen, 2003; Heinonen et al., 2006; KilBride et al., 2010; Cador et al., 2014).

Floors that are wet and slippery can lead to a change in gait pattern (Thorup et al., 2007) and difficulty when the sow is changing position from lying to standing (up/down movement) which may result in the sow moving cautiously due to the fear of slipping. Sows in farrowing crates compared to loose housing had greater difficulties when lying down during the first day post farrowing, and this damaging motion, i.e., pressure and slipping, was related to a higher frequency of limb lesions (Boyle et al., 2002). In addition, if sows can move more freely, they are better able to see and control where they are placing their feet. In general, outdoor conditions provide pigs with a suitable walking surface (KilBride et al., 2010), however, weather conditions and soil type, and the presence of stones and mud, can result in sub-optimal walking surfaces when pigs are managed outdoors. Scenarios A (Outside) and B (Group housing) were rated by the panel as providing a more suitable walking surface for sows compared to the other scenarios which have solid concrete or slatted flooring.

Lesions, such as shoulder lesions, can be influenced by environmental factors such as lying surface, ambient temperature and housing conditions, as well as sow factors, such as age, body condition score post farrowing, health status, lameness, weaning weight of the litter, lactation length, sow behaviour, breed and genetics (Ocepek et al., 2016; Rioja-Lang et al., 2018). Sows kept outdoors had a lower prevalence of limb and body lesions compared to sows housed indoors (KilBride et al., 2009a). When sows were managed indoors, there was an increased risk of lesions in sows housed on slatted floors compared with those housed on solid concrete floors with bedding (KilBride et al., 2009b). The floor type in farrowing pens has been associated with the risk of developing limb and body lesions. In a study of 383 lactating sows in an experimental unit, the lowest prevalence of limb wounds occurred in sows housed on solid concrete floors with straw bedding and the prevalence increased as the proportion of the pen floor that was slatted increased (Edwards et al., 1986). Scenarios E (Temporary crating)t, F (Current management) and to some extent scenario D (Temporary crating plus) were considered to have a higher Likelihood of pressure sores and skin lesions compared to the other systems due to a lack of

bedding, so sows in these systems were considered more likely to experience pain associated with these injuries.

Thermal impacts (Domain 2) were judged to be more likely in scenario A (Outside). Clinical hyperthermia in sows was considered to have a High IMPACT but only a Low Likelihood in scenario A (Outside) compared to None in the other scenarios. Likewise, sunburn was considered to have Moderate IMPACT, and a Moderate Likelihood in scenario A (Outside) but None in the other scenarios. Other IMPACTS of Moderate Likelihood in scenario A (Outside) were long- and short-term chilling and short-term heating.

Farrowing sows have a thermoneutral zone of 18˚C to 20˚C (Silva et al., 2009). Regulation of body temperature can be challenging in outdoor conditions, with sows being at risk hyperthermia in hot conditions and when solar radiation levels are high. These impacts can be mitigated by providing cooling strategies such as shade, sprinklers or wallows. Warm weather is more problematic for lactating sows, considering high feed intake and metabolic activity to support milk production, while dry sows may be more susceptible to cold stress because of their restricted feed level. Effects of cold weather can be mitigated in outdoor systems by providing sufficient bedding (Edwards et al., 2014), and insulated shelter.

In indoor farrowing systems, temperatures are usually controlled, at least to some extent, by the ventilation system. However, the panel considered that there was still some Low or Moderate risk of short-term heating in indoor systems. Individual preferences are not accounted for, so sows confined in crates do not have an opportunity to thermoregulate by seeking out different microclimates, while pen systems may allow the sow to seek more desirable areas and reduce the likelihood of thermal discomfort.

Scenario B (Group housing) differed from the others in the Likelihood of aversive responses to other sows (moderate Likelihood) which was inferred to reflect fear and/or anxiety in Domain 5.

There were several other impact indicators that the panel considered to have similar Likelihoods in all scenarios, and these are presented in Table 3. Four had a High IMPACT rating (aversive response to humans, lameness, MMA (Metritis, Mastitis and Agalactia) and birthing difficulties) and three were Moderate (eye/nose irritations, loss in BCS, and long-term heating). Most of these impacts were judged to occur in less than 10% of animals in all scenarios (i.e. Low likelihood; aversion to humans, lameness, MMA, birthing difficulties, respiratory/ocular irritation and long term chilling). The genetic background of modern sows can result in individuals that are more likely to be at risk of lower body condition scores due to higher utilisation of resources for lactation. Therefore, deviations in body condition were rated as Moderate IMPACT and a High Likelihood across all systems. The above IMPACTS are unlikely to be related to features of the system itself but may be a response to animal management strategies across all scenarios.

Table 3. The IMPACT ratings and inferred affective states, for sow-based indicators that were rated as having similar Likelihoods of occurrence for the farrowing system scenarios considered. Indicators with *(low)* confidence for inferred affective state are identified.

Sow impact (*confidence*)	Impact rating	Inferred affective states	Housing System					
			A Outside	B Group housing	C Pens	D Temporary crating plus	E Temporary crating	F Current
Aversive response to human	high	*fear, anxiety, panic*	low	low	low	low	low	low
Lameness	high	*pain, discomfort*	low	low	low	low	low	low
Mastitis-Metritis-Agalactia (MMA)	high	*pain, malaise, sickness*	low	low	low	low	low	low
Birthing difficulty	high	*pain, frustration, discomfort, malaise*	low	low	low	low	low	low
Eye/nose irritations and coughs	moderate	*pain, discomfort, breathlessness, itchiness*	low	low	low	low	low	low
Deviation in BCS *(low)*	moderate	*malaise, hunger, weakness*	high	high	high	high	high	high
Long term heating	moderate	*thermal discomfort, malaise, lethargy*	low	low	low	low	low	low

4.1.2. Supporting evidence for rating ENHANCEMENTS on sow welfare

The significance of ENHANCEMENTS for sows during the farrowing period, and degree to which each system scenario was considered likely to result in positive affective states are presented in Table 4. ENHANCEMENTS of Moderate to High significance were estimated to be more likely in scenarios A (Outside), B (Group housing), and to a lesser extent C (Pen housing). Indicators for ENHANCEMENTS are predominantly clustered in Domain 4 (behavioural interactions). Examples of the associated positive affective experiences that were inferred in Domain 5 were pleasure, satiety, curiosity, thermal comfort, affectionate sociability and calm.

System scenarios which provide sows with the ability to move freely, and a more complex environment, were rated as providing greater Likelihood for ENHANCEMENTS potentially linked to positive affective states. In contrast, systems that included both short- and long-term crating that restrict sows' movement and opportunity to engage with the environment in a way that is rewarding, were considered unlikely to provide the potential for associated positive affective states.

Of particular importance to the sow during the pre-farrowing phases is undertaking nest building activities, where the sow uses different types of nesting materials when given access to them (Rosvold et al., 2019). Herskin et al. (1998) showed that sows behaved with more care towards their piglets if they were provided with nest building opportunities compared to those without. Moreover, Yun et al. (2014) also established a correlation between the duration of prepartum nestbuilding behaviour and carefulness of sows towards their offspring during early lactation, and suggested that the release of oxytocin, as a driver of maternal characteristics, might be the explanation for the link. Oxytocin is known to modulate maternal nurturing behaviour, including the parent-child relationship in humans (Ross & Young, 2009), and encourage maternal reactivity of sows towards their offspring (Yun et al., 2014). In addition, oxytocin also plays a role in decreasing stress hormone levels, blood pressure, and heart rate, and thus contributes to stabilising the condition of postpartum sows (Uvnas-Moberg & Petersson, 2005). It has therefore been suggested that active nestbuilding behaviour of prepartum sows, possibly due to elevated circulating oxytocin concentrations, could improve maternal carefulness behaviour in early lactation (Yun et al., 2013; 2014). Scenario A (Outside) was considered to have a High likelihood, while scenarios B (Group housing) and C (Pens) were considered to have Moderate likelihood of ENHANCEMENT for nest building behaviours, and the associated positive affective states of pleasure, engagement, and feeling in control. Scenario D (Temporary crating plus) provided small amounts of straw as nesting material was rated Low as this system provides only limited opportunities for nest building behaviours compared to a system where no nest building material was available.

Table 4. The ENHANCEMENT ratings and their inferred affective states, for sow-based indicators, and the Likelihood of their occurrence for each farrowing system scenario considered. 'None' represents no Likelihood for the ENHANCEMENT, while *, ** and *** represent Low, Moderate and High Likelihood.

Sow enhancement *(low confidence)*	Significance rating	Inferred affective states	Housing System					
			A Outside	B Group housing	C Pens	D Temporary crating plus	E Temporary crating	F Current
Eating a variety of foods	2	*satiety, pleasure, gastrointestinal pleasure*	*	none	none	none	none	none
Foraging behaviour	3	*curiosity, pleasure, engaged by activity, interested, pleasantly occupied*	**	none	none	none	none	none
Exploration behaviour	3	*curiosity, pleasure, engaged by activity, interested, pleasantly occupied*	***	**	*	none	none	none
Utilisation of surfaces/areas	3	*physical and thermal comfort, calm, sense of being in control, confident,*	***	**	*	none	none	none
Nest building behaviour	3	*pleasure, in control, engaged by activity*	***	**	**	*	none	none
Wallowing	3	*pleasure, thermal comfort*	***	none	none	none	none	none
Friendly sow-sow interactions	3	*affectionate sociability, group rewards, calm, confident*	***	***	none	none	none	none
Nose to nose contact and other interactions (piglets)	3	*affectionate sociability, maternal rewards, calm, confident, feels in control*	***	***	***	*	none	none
Approach human for friendly interaction	2	*calm, confident, feels in control*	*	*	*	*	none	none

Sufficient space is important to allow the sow to have separate areas with different functions: a secluded and dry, soft place to rest/nest, the opportunity to eat without competition, an area with rooting material and foraging opportunities, and one for elimination, (Ekkel et al., 2003; Špinka, 2009). Several indicators for ENHANCEMENTS also required space for them to be expressed such as exploration and foraging behaviours, utilisation of different surfaces/areas, and wallowing, These are predominantly clustered in Domain 4 (behavioural interaction with the environment) and are likely to reflect positive affective states of curiosity, pleasure, engaged by activity, interest, pleasant occupation and thermal comfort in Domain 5. The panel considered that scenarios A (Outside) and B (Group housing) offer increased space and more complex environments so had greater Likelihood for these ENHANCEMENTS occurring.

Social interactions (Domain 4) promote positive affective states of affectionate sociability, maternal rewards, calm, confident, and feelings of control in Domain 5. Scenarios A (Outside) and B (Group housing) were rated with a High Likelihood of ENHANCEMENT for the sow from social interactions with conspecifics.

Scenarios A (Outside), B (Group housing) and C (Pens) were rated as having a High Likelihood of ENHANCEMENT through social interactions with piglets while Scenario D (Temporary crating plus) was rated as having a Moderate Likelihood due to the sow being in a crate for 3.5 days post-nesting which is a critical period for important maternal behaviour.

The panel considered that although there were potential benefits of ENHANCEMENT from providing opportunities that might be measured by the indicator "Approach human for friendly interaction", this was of uncertain benefit to the sow, and all systems were rated with a similar Likelihood.

4.1.3. Supporting evidence for rating IMPACTS on piglet welfare

Ratings for IMPACTS on piglets until weaning and their Likelihoods in the system scenarios are presented in Table 5.

The panel considered the Likelihood of IMPACTS on the affective state of piglets to be least in Scenarios B (Group housing) and C (Pens), each rated with only one Moderate IMPACT (non-fatal crushing). The Likelihood of non-fatal crushing was rated by the panel as Moderate for all loose farrowing systems, and Low for the confined systems. The associated negative affective experiences (Domain 5) for piglets during and after near-miss crush injury were inferred as pain, panic, breathlessness, chilling, overheating, malaise and discomfort from Domains 2 and 3, and frustration, boredom, helplessness, depression, anxiety, fear or insecurity associated with impacts in Domain 4. While the Likelihood of near-miss crush injury is greater in indoor systems when sows are loose, it is not dissimilar to the risk for piglets born outdoors and may be reduced by management and pen design.

Scenarios A (Outside), D (Temporary crating plus), E (Temporary crating), and F (Current management) accounted for the greater proportion of Moderate or High Likelihoods for IMPACTS that were rated as Moderate or High.

Newborn piglets are very susceptible to cold stress immediately after birth, and this can increase their risk of other impacts on their welfare such as starvation and crushing. The IMPACT rating of long-term chilling of piglets was considered by the panel to be High.

Scenario A (Outside) was considered to pose greater thermoregulatory challenges to piglets with four IMPACTs clustering in Domain 2 (long-term chilling, short- and long-term heating, and sunburn) and all rated as having Moderate Likelihood. Short-term chilling likewise had a Moderate Likelihood of occurrence, but this applied in all the system scenarios. Indoor scenarios with heated piglet creep areas where piglets can rest and maintain normal body temperature were rated by the panel as having a Low Likelihood of IMPACTS from other thermoregulatory indicators.

Indicators of IMPACTS with Moderate and High Likelihoods for scenarios D (Temporary crating plus), E (Temporary crating) and F (Current management) related to greater levels of confinement and tended to cluster in Domain 3 (lameness/foot/leg issues) and Domain 4 (ARBs, lack of maternal attention, aversive response to other piglets). This likely reflects the greater restrictions on piglets in these scenarios of space and ability to move freely, engage in maternally-directed behaviours (e.g. nursing, nose-nose communication), to explore (Chaloupková et al., 2007), forage (Schrey et al., 2019) and avoid aversive interactions with other piglets (Verdon et al., 2019).

Table 5. The IMPACT ratings and their inferred affective states, for piglet-based indicators, and the Likelihood of their occurrence for each farrowing system scenario considered. Indicators with *(low)* confidence for inferred affective state are identified.

Piglet impact *(confidence)*	Impact rating	Inferred affective states	Housing system					
			A Outside	B Group housing	C Pens	D Temporary crating plus	E Temporary crating	F Current
ARB[1] *(low)*	high	*frustration, boredom, helplessness, depression*	low	low	low	moderate	moderate	moderate
Non-fatal crushing	high	*pain, fear, panic, breathlessness*	moderate	moderate	moderate	low	low	low
Lameness/Foot/Leg Issues	high	*pain*	low	low	low	moderate	moderate	moderate
Long term chilling	high	*thermal discomfort, feeling cold*	moderate	low	low	low	low	low
Long term heating	moderate	*thermal discomfort, malaise, overheating*	moderate	low	low	low	low	low
Sunburn	moderate	*pain, skin irritation*	moderate	none	none	none	none	none
Vocalisations[2]	moderate	*frustration, hunger, anxiety, insecurity*	low	low	low	moderate	high	high
Aversive response to piglets *(low)*	moderate	*fear, anxiety, insecurity*	low	low	low	moderate	moderate	moderate
Short term heating	low	*overheating, malaise, discomfort*	moderate	low	low	low	low	low

[1]Abnormal repetitive/redirected behaviours

[2] Due to lack of maternal attention

Piglets are dependent on the sow to provide colostrum and milk until weaning; however, the sow, the system (including pen design) and management skills all influence piglet mortality. Non-fatal crushing is likely to be associated with affective states of panic, fear and different types of pain, and the risk of this impact occurring was rated as higher in systems where the sow is free to move around due to the greater risk of crushing the piglets. In contrast, in systems where the sow is not able to carry out nest building behaviour, sows are less likely to respond to piglet vocalisations and provide maternal care (Yun et al., 2014), which is likely to be associated with piglets experiencing fear, anxiety and insecurity. The panel rated the affective state of the piglets represented by vocalisations due to lack of maternal attention as the only IMPACT on piglet welfare with High Likelihood and this was in scenarios E (Temporary crating) and F (Current management).

Slatted or concrete floors without sufficient bedding are associated with lameness and hoof and leg problems in piglets, and associated pain (Zoric et al., 2008; 2009; KilBride et al., 2009a) These indicators associated with Domain 2 were rated by the panel as more likely to occur in the indoor scenarios D (Temporary crating plus), E (Temporary crating) and F (Current management) that have limited, or no, bedding material.

Abnormal redirected/repetitive behaviours have been recorded in pre-weaning piglets, including belly nosing and face biting, which could result in negative affective states such as anxiety, fear, frustration and helplessness. The panel rated scenarios D (Temporary crating plus), E (Temporary crating) and F (Current system) as having Moderate Likelihood of ARBs in piglets, and their associated affective states.

Fifteen indicators of IMPACTS for piglets were rated as having similar Likelihood in all scenarios and these are presented in Table 6. Seven were considered to have High IMPACT, and six to have Moderate IMPACT. Most were only Low Likelihood, except for scours and short-term chilling (discussed above) which were both considered to have Moderate Likelihood.

Table 6. The IMPACT ratings and inferred affective states, for piglet-based indicators that were rated as having similar Likelihoods of occurrence among farrowing system scenarios. No indicators were rated as having "low" confidence for inferred affective states.

Piglet impact	Impact rating	Inferred affective states	Housing system					
			A Outside	B Group housing	C Pens	D Temporary crating plus	E Temporary crating	F Current
Dead by trampling	high	*pain, panic*	low	low	low	low	low	low
Savaged	high	*pain, fear, panic*	low	low	low	low	low	low
Low Colostrum intake	high	*hunger, weakness, fatigue*	low	low	low	low	low	low
Starvation	high	*hunger, fatigue, weakness, malaise*	low	low	low	low	low	low
Face lesions	high	*pain, hunger, malaise*	low	low	low	low	low	low
Scours	high	*malaise, weakness, sickness, discomfort*	moderate	moderate	moderate	moderate	moderate	moderate
Pneumonia	high	*pain, breathlessness*	low	low	low	low	low	low
Aversive response to human	moderate	*fear, anxiety, panic*	low	low	low	low	low	low
Dead by overlay	moderate	*pain, panic, breathlessness*	low	low	low	low	low	low
Skin lesions	moderate	*pain*	low	low	low	low	low	low
Eye/ nose irritations and coughs	moderate	*irritation, pain*	low	low	low	low	low	low
Poor piglet hygiene	moderate	*skin irritation, pain, discomfort*	low	low	low	low	low	low
Hypothermia	moderate	*thermal discomfort, malaise, chilling*	low	low	low	low	low	low
Short term chilling	low	*chilling, discomfort*	moderate	moderate	moderate	moderate	moderate	moderate

4.1.4. Supporting evidence for rating ENHANCMENTS on piglet welfare

Ratings for the significance of ENHANCEMENTS for piglets until weaning, and the degree to which each system scenario was considered to provide opportunities for these are presented in Table 7.

As for sows, ENHANCEMENTS of Moderate or High significance for piglets were considered more likely in scenarios A (Outside), B (Group housing) and to a lesser extent C (Pens). These enhancements provide opportunities for positive affective states such as curiosity, pleasure, pleasant occupation, engagement by an activity, calm, confident, in control, play, and excitement.

Features of environments that can increase piglet activity and play behaviours are space, environmental complexity, and environmental enrichment. Thus, piglets in outdoor housing settings play more (Johnson et al., 2001) and are more engaged in active and foraging and explorative behaviour (Cox & Cooper, 2001; Hötzel et al., 2004) compared to indoor housed piglets (in farrowing crates with or without straw on concrete floors). It has also been shown that environmental enrichment enhances object play during lactation and reduces stress at weaning (Yang et al., 2018) and has more long-term benefits in terms of piglets being reared with enrichment being less aggressive (Chaloupková et al., 2007). The scenarios considered most likely to support these behaviours and associated positive affective states were A (Outdoors), B (Group housed), and C (Pens), i.e. the loose farrowing systems.

In addition, there is evidence that piglets in systems that facilitate pre-weaning mixing of animals, such as outdoor housing, learn social skills which benefit them in the longer term, enabling them to form stable dominance hierarchies more rapidly during future encounters with unfamiliar cohorts at weaning (D'Eath, 2005).

Table 7. The ENHANCEMENT ratings and their inferred affective states, for piglet-based indicators, and the Likelihood of their occurrence for each farrowing system scenario considered. 'None' represents no Likelihood for the ENHANCEMENT, while *, ** and *** represent Low, Moderate and High Likelihood.

Piglet enhancement (*low confidence*)	Significance rating	Inferred affective states	Housing system					
			A Outside	B Group housing	C Pens	D Temporary crating plus	E Temporary crating	F Current
Foraging behaviour	3	*curiosity, pleasure, engaged by activity, interested, pleasantly occupied*	**	*	none	none	none	none
Exploration behaviour	3	*curiosity, pleasure, engaged by activity, interested, pleasantly occupied*	***	**	*	none	none	none
Utilisation of surfaces/areas	3	*physical and thermal comfort, calm, sense of being in control, confident,*	***	**	*	none	none	none
Nose to nose contact and other interactions, and sow/piglet vocalisation	3	*affectionate sociability, calm, confident, feels in control*	***	***	***	*	*	*
Play behaviour	3	*playfulness, excitement, pleasures*	***	**	*	*	*	*
Approach human for friendly interaction	2	*calm, confident, feels in control*	*	*	*	*	*	*

4.1.5. Conclusions: Sow and piglet welfare in farrowing systems

Figures 2a and b display counts of indicators for IMPACTS and ENHANCEMENTS for sow and piglet welfare in the farrowing system scenarios rated by the panel.

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 plus), 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.

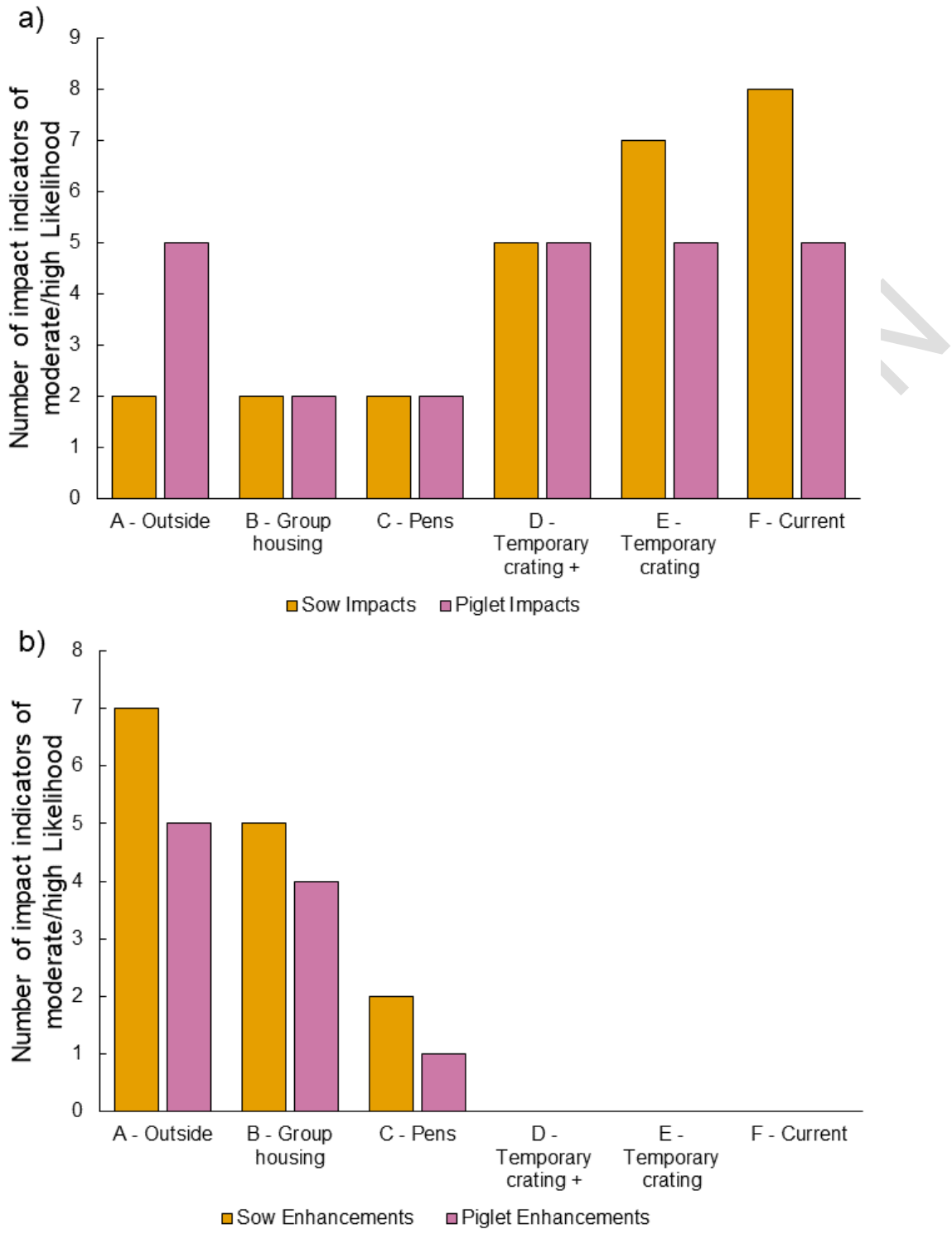

Figure 2. a) Counts of indicators associated with negative affective states that were rated as Moderate or High IMPACT and Moderate to High Likelihood for sows (orange columns) and piglets (magenta column) for each system scenario. **b)** Counts of indicators associated with positive affective states that were rated as Moderate or High ENHANCEMENT and Moderate to High Likelihood (** and ***) for sows (orange columns) and piglets (magenta columns) for each system scenario.

4.2 Mating systems

4.2.1. Supporting evidence for rating IMPACTS on sow welfare during mating

Table 8 presents the panel's ratings for IMPACTS on sows during the mating period and the Likelihoods of those impacts for each mating system scenario considered (Table 1b).

Indicators of high or moderate IMPACTS during the week of mating were considered more likely to arise in scenarios D (2 hours in stall – indoors with straw), E (Voluntary stalls), and F (Current – 7 days in a stall). Indicators of these IMPACTS tended to cluster in Domain 2 (slipping and gait, up/down, poor hygiene), Domain 3 (pressure sores, skin lesions, sow/sow riding injuries and Domain 4 (abnormal repetitive behaviour, aversion to sows). The associated negative affective experiences were inferred in Domain 5 to be anxiety, frustration, hunger, fear, boredom, helplessness, depression, and pain.

IMPACTS occurring during the mating period were considered by the panel to be largely dependent on the system in which the sows are managed. Higher levels of confinement in the mating system scenarios were considered to have similar IMPACTS as discussed above for farrowing scenarios (e.g. ARBs, thermal challenges, injuries associated with the system, poor sow hygiene). The general negative effects of restricted space, barren environment and flooring without bedding also applies to scenarios D (2 hours in stall – indoors with straw), E (Voluntary stalls) and F (Current – 7 days in stall). Some factors may exacerbate the Likelihood of IMPACTS for sows, in particular effects of increased aggressions when sows are on heat, and the risk of injuries when sows are riding each other. Injuries associated with other sows and lameness were rated as more likely to occur in systems where space is restricted in a group situation (i.e. they cannot escape or hide from aggressions) and the flooring surface may be slippery.

In scenarios where Artificial Insemination (AI) is performed (all except Scenario A (Natural mating)), the Likelihoods of the sow having an aversive response to humans were rated higher in scenarios B, C and D than the other systems (E and F) as the procedure may increase the potential for aversive or negative interactions with humans (i.e. an interaction where the pig is required to be confined, moved, or handled involuntarily), which are further compounded by the need to move animals while they are displaying oestrous behaviours. Positive handling and training of the sows may reduce the potential aversiveness of the procedure but is unlikely to result in a positive experience unless the sows are voluntarily participating.

While the artificial insemination systems also involve contact with boars, this is managed through a barrier (e.g. a gate or a fence) that may allow nose-to-nose contact as well as vocalisations and odour (pheromone exposure). Scenario A (Natural mating) was the only mating system where injuries associated with the boar were considered possible. These were rated as High IMPACT and Moderate Likelihood. Excessive mating behaviour can cause superficial injuries of the skin (e.g. tears, abrasions),

as well as well as more serious injuries such as muscle tears, bone fractures, and spinal cord injuries (Levis et al., 2011) and the indicator was associated with pain.

Table 8. The IMPACT ratings and inferred affective states for sow-based indicators and the Likelihood of their occurrence for each mating system scenario considered. No indicators were rated as having "low" confidence for inferred affective states.

Sow impact	Impact rating	Inferred affective states	Mating system					
			A Natural mating	B AI outdoors no restraint	C 2 hours in stall - outdoors	D 2 hours in stall - indoors	E Voluntary stalls	F Current - 7 days in a stall
ARB[1]	high	*frustration, boredom, helplessness, depression*	low	low	low	low	moderate	high
Lameness	high	*pain*	low	low	low	moderate	moderate	low
Up/down movement	high	*pain, frustration, anxiety, hunger*	none	none	none	low	moderate	high
Injury associated with boar	high	*pain*	moderate	none	none	none	none	none
Sow/sow riding injuries	high	*pain*	low	low	low	moderate	moderate	none
Clinical hyperthermia	high	*overheating, malaise, discomfort*	low	low	low	none	none	none
Aversive response to sow	high	*fear, anxiety*	moderate	moderate	moderate	high	high	none
Aversive response to human	high	*fear, anxiety*	low	moderate	moderate	moderate	low	low
Skin lesions	moderate	*pain*	low	low	low	moderate	moderate	moderate
Slipping and gait	moderate	*anxiety*	low	low	low	moderate	high	moderate
Poor sow hygiene	moderate	*skin irritation, pain*	none	none	none	low	moderate	low
Long term chilling	moderate	*chilling, discomfort*	low	low	low	none	none	none
Short term heating	low	*overheating, discomfort*	moderate	moderate	moderate	low	low	low
Short term chilling	low	*chilling, discomfort*	moderate	moderate	moderate	none	none	none

[1] Abnormal repetitive/redirected behaviour

Long-term heating was rated as having moderate impact, but the risk was rated as being similar and Low in all scenarios (Table 9) and is therefore not discussed further.

Table 9. The IMPACT ratings and inferred affective states, for sow-based indicators that were rated as having similar Likelihoods of occurrence for each mating system scenario considered. No indicators were rated as having *(low)* confidence for inferred affective states.

Sow impact	Impact rating	Inferred affective states	Mating system					
			A Natural mating	B AI outdoors; no restraint	C 2 hours in stall - outdoors	D 2 hours in stall - indoors	E Voluntary stalls	F Current 7 days in a stall
Long term heating	moderate	*overheating, malaise, discomfort*	low	low	low	low	low	low

4.2.2. Supporting evidence for rating ENHANCMENTS on sow welfare during mating

Table 10 presents the ENHANCEMENTS considered for sows during the mating period, and the Likelihood that each mating system scenario was considered to provide positive affective experiences.

As for IMPACTS in the mating period, the panel's ratings for ENHANCEMENTS were considered largely dependent on the housing system. Likelihoods for ENHANCEMENTS of Moderate (**) and High (***) significance were considered more likely in scenarios A (Natural mating), B (AI outdoors no restraint) and C (2 hours in stall – outdoors). Indicators of these ENHANCEMENTS were predominantly clustered in Domain 4 (behavioural interactions). Examples of the associated positive affective experiences that were inferred in Domain 5 were satiety, pleasure, curiosity, pleasantly occupied, physical and thermal comfort, calm, satiety, affectionate sociability and confident.

The outdoor mating system scenarios A (Natural mating), B (AI outdoors no restraint) and C (2 hours in stall – outdoors) that allow greater social contact with other sows and boars, increased space for environmental interactions, and safe walking surfaces which were considered to provide greater Likelihood of ENHANCEMENTS.

Table 10. The ENHANCEMENT ratings and their inferred affective states, for sow-based indicators, and the Likelihood of their occurrence for each mating system scenario considered. None represents no Likelihood for enhancement, while *, ** and *** represent Low, Moderate and High levels of Likelihood for engagement. No indicators with *(low)* confidence for inferred affective state were identified.

Sow enhancement	Significance rating	Inferred affective states	Mating system					
			A Natural mating	B Artificial insemination no restraint	C 2 hours in stall - outdoors	D 2 hours in stall - indoors	E Voluntary stalls	F Current 7 days in a stall
Eating a variety of foods	2	*satiety, pleasure, gastrointestinal pleasure*	*	*	*	none	none	none
Foraging behaviour	3	*curiosity, pleasure, engaged by activity, interested, pleasantly occupied*	**	**	**	none	none	none
Exploration behaviour	3	*curiosity, pleasure, engaged by activity, interested, pleasantly occupied*	***	***	***	none	none	none
Utilisation of surfaces/areas	3	*physical and thermal comfort, calm, sense of being in control, confident,*	***	***	***	none	none	none
Pre-mating courtship with boar *(low)*	2	*pleasure, affectionate sociability*	***	*	*	*	*	*
Friendly sow/sow interactions *(low)*	3	*affectionate sociability, group rewards, calm, confident*	***	***	***	*	*	none
Approach human for friendly interaction *(low)*	1	*calm, confident, feels in control*	*	*	*	*	*	*

4.2.3. Conclusions: IMPACTS and ENHANCMENTS on sow welfare during mating

Figure 3 displays counts of indicators for IMPACTS and ENHANCEMENTS for sow welfare in the mating system scenarios rated by the panel.

It shows that the mating system scenarios rated with more IMPACTS on affective state of Moderate or High Likelihood are D (2 hours in stall – indoors with straw), 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 with straw) 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.

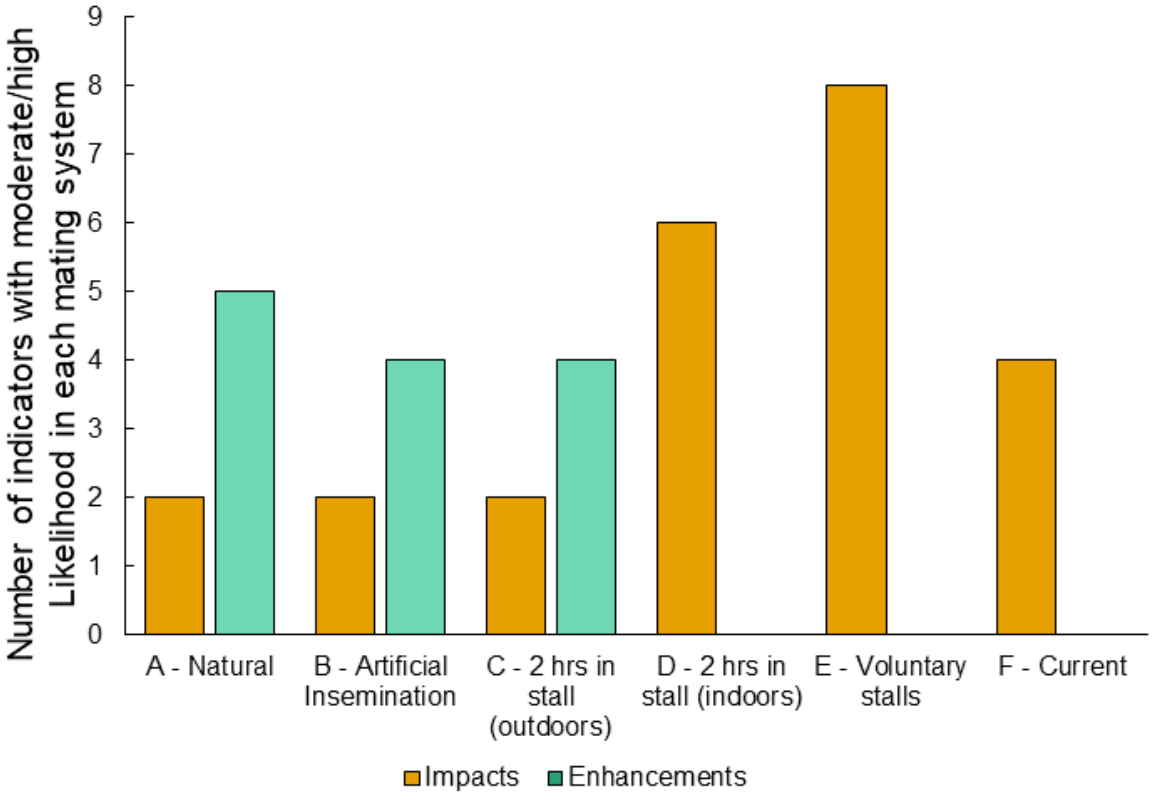

Figure 3. Count of indicators associated with negative affective states that were rated as having Moderate or High IMPACTS and with Moderate or High Likelihood (orange columns) and of indicators associated with positive affective states that were rated as Moderate or High ENHANCEMENTS and with greater (** and ***) Likelihood (green columns) for sows for each mating system scenario.

5. Discussion of Limitations of the Five Domains Model

The assessment using the Five Domains model was undertaken as a part of a wider review of systems for farrowing and mating management. The Model was used as a framework to explore systematically and comprehensively the welfare risks (IMPACTS) to pigs, as well as opportunities for positive experiences (ENHANCEMENTS) in a range of system scenarios.

Caution must be used when interpreting the evaluation, because the gradings allocated are derived qualitatively and because any resulting ranks are relative only, i.e. they relate to the systems described in the specific evaluation (Beausoleil & Mellor, 2015; Mellor & Beausoleil, 2015). To illustrate, although numerical grades were sometimes assigned (e.g. *, ** and *** for ENHANCEMENTS) implying a degree of precision, they are ordinal only, that is, designating the number two to a measure does not indicate that its impacts are twice as high as a designation of one. Similarly, the interval between a Low and Moderate IMPACT is not necessarily the same as the interval between a Moderate and High IMPACT.

The analysis undertaken for this report has pushed the use of the Model far beyond how it has previously been applied (Beausoleil & Mellor, 2015; Beausoleil et al., 2016; Mellor & Beausoleil, 2015). The use of the Model in this analysis adapted from assessing the welfare of a singular animal at a particular instance, to a group of animals in a theoretical setting, an exercise that the panel found challenging. The number of system scenarios compared was complicated further by the distinct timelines associated with each, comparing two groups of animals (sows and piglets) and separating mating scenarios from specific housing scenarios. The analysis highlighted the contrasting system trade-offs for sows and piglets that have resulted from intensive farming and genetic selection, which made interpretation of the results challenging.

It is also important to acknowledge that the inferences to affective state in Domain 5 cannot be directly extrapolated to empirical observation (Wemelsfelder, 2001). This is not a limitation, as such, but requires users of the Model to carefully justify those inferences and provide an indication of the strength of the evidence on which they are based. For some proposed affective states there is currently insufficient scientific evidence and the inferences must be interpreted cautiously. However, the application of the Model also requires users to systematically collate evidence of the physical/functional IMPACTS/ENHANCEMENTS on which such inferences are based. This clear delineation of observable/measurable evidence allows readers to judge for themselves the basis of inferring affective states, as well as satisfying those aligning most strongly to the physical/functional orientation to understanding and assessing animal welfare.

Due to the limited scientific data around positive affective states for sows and piglets, the panel deliberated whether ENHANCEMENT scores should be resource-based and consider only the

provisions given to the animals in each scenario i.e. potential opportunities to experience positive affective states. However, the panel decided that scores should be animal-based and would consider the Likelihood of these positive affective states occurring. This decision means that the IMPACT and ENHANCEMENT indicators are scored in an equivalent manner, but also that all the ENHANCEMENT indicators come with a caveat of "low confidence" from the panel. The panel recognised that animal welfare discussions are increasingly focussing on positive affective states and considered it to be valuable to score the Likelihood of actual positive affective experiences for the animals. However, the panel also recognised that this scoring may be more likely to become quickly outdated as new empirical evidence on positive affective states is published. It is important to note, that the panel considered the ENHANCEMENT indicator data to be important, but that the IMPACT indicator data be more relevant to the current discussions around farrowing crates in the Code of Welfare review.

In addition to these general considerations, specific limitations identified during the process include:

- Lack of relevant scientific and industry data about prevalence and duration of certain IMPACTS, to determine Likelihood of occurrence within the system scenarios.
- Lack of scientific data to support inferences of IMPACTS and ENHANCEMENTS (i.e. negative and positive affective states) for pigs. Where relevant these were declared as low confidence and identify information gaps providing direction for future research to improve pig welfare (Beausoleil et al., 2016).
- Lack of validated indicators of positive affective states for pigs, and the potential benefits of providing opportunities for ENHANCEMENTS within the system scenarios.

Some features of the environment, conditions or resources provided to animals identified in the initial workshop were considered important to reflect the welfare state of the animals but were difficult to assess using the framework because:

a) a suitable animal-based indicator could not be identified, or
b) an associated affective state could not be identified, or
c) the impact was likely to occur outside the period of interest, or
d) the indicator was too closely related to other animal-based indicators

These measures for the sow were oxytocin levels (a and b), physiological measures of stress (d), impact of noise (a), and physical fitness (d), and for the piglet were physiological measures of stress (b and d), impact of noise (b), physical fitness (b and d), and effects of social development on cognition (c).

The panel also noted that some elements of the IMPACT assessment may under-estimate sow welfare because it was necessary to assume that sows coming into farrowing systems had no carry-over effects from the previous dry period or prior farrowing, and likewise that sows moving into the mating system

had no carry-over effects from their recent farrowing. It was acknowledged that pre-existing conditions might exacerbate the negative effects of some of the IMPACTS.

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Appendix A: Evidence supporting inferred affective states for IMPACT indicators

Table 11. The inferred affective states for sow-based IMPACT indicators and the rationale of their occurrence considered. References are provided for both affective state rationale (References) and for differences between housing conditions (Example references for housing condition). Indicators marked as *(Low confidence)* are those that the panel considered the evidence for inferred affective state to be minimal.

Indicator	Description	Inferred Affective state	Rationale	References
Abnormal repetitive/redirected behaviour (ARB)	Sham chewing, bar biting, dog sitting, tongue rolling, teeth grinding, bar, drinker, trough biting and floor licking, vacuum nestbuilding	Frustration, boredom, helplessness, depression, anxiety, hypervigilance	The expression of abnormal repetitive or redirected behaviour is considered evidence of the animal's experience of inappropriate physical and/or social environments and/or inadequate nutrition.	Mason 1991; Mason & Latham 2004;
Example references for housing condition	Cronin et al., 1994; Lawrence et al., 1997; Damm et al., 2003; Yun & Valros 2015; Yun et al., 2015; Edwards et al., 2019; Bolhuis et al. 2018			
Difficult up/down movement	Difficulty getting up and down from lying, for example: latency to move after stimulated to rise from lying, number of attempts to get up/down, duration of attempts to get up/down.	Pain, frustration, anxiety, hunger	Difficulties in movement may lead to thwarted opportunities to engage in motivated behaviours (e.g. getting up, feeding, engaging with environment, social interactions). Abnormal repetitive behaviours are observed in pigs with restricted appetitive and consummatory phases of feeding behaviour, indicating an experience of frustration. It may also lead to inability to effectively move away from aversive stimuli (e.g. aggressive sow, stockperson, leading to anxiety. *See "Lameness" for further evidence on pain and discomfort*	Bonde et al 2004; Boyle et al., 2002; Rushen 1985
Example references for housing condition	Devillers et al. 2019; Marchant and Broom 1996; Bonde et al. 2004;			

Pressure sores	Broken skin on shoulder, ulcers	Pain, discomfort	Severe shoulder lesions in sows are manifested as ulcers and are common in the first weeks of lactation because of increased lying time. Pain and discomfort from ulcers can affect maternal behaviour. Moderately sized ulcers (~3 cm) result in decreased lying time, more frequent postural changes and increased standing in sows; these provide behavioural evidence of pain and discomfort.	Boyle et al., 2002; Larsen et al. 2015
Example references for housing condition	Larsen et al. 2015; Rioja-Lang et al. 2018			
Clinical hyperthermia	Elevated respiration rate (panting), body temperature, reduced feed intake, open mouth panting, shade seeking, wallowing, morbidity, collapse, death	Thermal discomfort, malaise, breathlessness, exhaustion, weakness If severe, this leads to organ failure which may cause nausea, dizziness, confusion, pain/discomfort	Due to pigs' inability to sweat, they are susceptible to heat stress, which can affect health and welfare. Sows with cooling pads have lower respiratory rates, spend more time lying and lying laterally (behaviours indicating comfort), and have lower heart rates that controlled sows; physiological and behavioural evidence of discomfort associated with heat stress. Heat stressed sows reduce food intake by up to 40% and decrease lactation.	Black et al. 1993; Muns et al. 2016; Parois et al. 2018
Example references for housing condition	Muns et al., 2016; Malmkvist et al., 2012; Spoolder et al., 2012; Barnett et al. 2001; Baxter et al., 2011			
Aversive response to piglets	Attacking piglets including savaging, 'bark', refusing to nurse piglets	Fear, anxiety, frustration, rage/anger	Savaging, or piglet directed aggression, has been associated with neophobia, stress hormones and the inability to interact with piglets soon after birth.	

			See "Aversive response to sow" for activation of HPA and SAM system in relation to aggression	
Example references for housing condition	Baxter, Andersen & Edwards, 2018; Ahlström et al., 2002			
Slipping and gait	Sow slipping on surface and moving cautiously	Anxiety, discomfort, pain	*See "Difficult up/down" movement for anxiety related to difficulty moving and "Lameness" for discomfort and pain*	
Example references for housing condition	Devillers et al. 2019; Bonde et al. 2004;			
Skin lesions	Scratches/lesions /calluses from facility	Pain, discomfort, itchiness	Pigs with higher prevalence of generalised dermatitis perform significantly more scratching behaviour, indicating a feeling of discomfort and itchiness. *See "Pressure sores" for further evidence on pain and discomfort*	Hollanders et al. 1995
Example references for housing condition	Boyle et al., 2002; Kilbride et al. 2012			
Long farrowing duration	Length of total farrowing and average piglet birth interval	Weakness, exhaustion, fatigue, pain	A short duration of farrowing is important for piglet survival as a delay can increase the number of stillborn. In the past 3 decades, average farrowing time has increased from around 2 hours to more than 6 hours 40 minutes as litter size has increased. Behavioural indicators of pain (arched back, pawing, tail flick) are present during farrowing, but rare or absent pre-farrowing, supporting the idea that sows experience birthing pain and that a longer birth would cause more pain.	Ison et al. 2016
Example references for housing condition	Oliviero et al., 2010; Oliviero et al., 2008; Gu et al., 2011; Lawrence et al., 1997			

Poor sow hygiene	Specifically, in relation to dung, does not include dirt from wallowing. Low levels of cleanliness indicate that sow is unable to separate dunging/lying area	Skin irritation, pain, discomfort, frustration	Sows show a clear preference for leaving the nest and laying area to defecate. Inability to act on preferences to dung in separate area may result in frustration. Poor hygiene could lead to generalised or bacterial dermatitis conditions. Pigs with higher prevalence of generalised dermatitis perform significantly more scratching behaviour, indicating a feeling of discomfort and itchiness.	Andersen et al. 2011; Hollanders et al. 1995
Example references for housing condition	Andersen et al., 2011			
Sunburn	Irritated, inflammation, reddening of the skin, peeling of skin, blisters or sores	Pain, skin irritation	Sunburn can be a welfare issue for outdoor pigs, with white skinned animals being particularly susceptible. Pigs with sunburn exhibit acute pain response including squealing, muscle twitching, or dipping the back when walking. Ultraviolet radiation (sunburn) is used as a model for sensitization and inflammation in pain research, and animal models show the precise changes as they are observed in human skin; indicating that sunburn is a painful experience, and is as painful for pigs as it is in humans.	Amalraj et al. 2018; Lopez & McMahon 2016; Iowa State University 2020; Pietrosemoli & Tang 2020;
Example references for housing condition	Barnett et al. 2001			
Long term chilling	Shivering, increased feed intake, change in activity levels	Thermal discomfort, chilling	Lactating sows can in general tolerate cold temperatures, however, if prolonged or severe there will be an increase in energy requirements.	Hicks et al. 2011; Wathes et al. 2002

			Pigs exposed to acute cold will increase standing time, activity levels, and feed intake to maintain homeostasis. Pigs forced to choose between thermal comfort and fresh air (heating + ammonia *vs* chilling + fresh air), would most often choose heating, indicating a strong motivation to maintain thermal comfort. Long term stress will reduce ability to maintain homeostasis and may lead to further physiological conditions.	
Example references for housing condition	Barnett et al. 2001			
Aversive response to sow	Threats, avoidance behaviour and aggressions	Fear, anxiety, frustration, rage/anger	Aggressive behaviour in pigs has been demonstrated to activate the HPA axis and SAM system of both the aggressor and receiver, indicating it is a stressor for both and likely to cause unpleasant experiences, although these will differ depending on pig social rank.	Muráni et al. 2010; Fernandez et al. 1994; Otten et al. 1999; D'Eath et al. 2010
Example references for housing condition				
Short term heating	*See "Long term heating"*	Thermal discomfort, malaise, lethargy		
Short term chilling	*See "Long term chilling"*	Thermal discomfort, chilling		
Aversive response to human	Attacking or rapidly moving away, withdrawal/avoidance behaviour	Fear, anxiety, panic	Fear of humans can result in reduced welfare, productivity and maternal abilities	Hemsworth 2003; Rushen et al., 1999
Example references for housing condition	Hemsworth et al. 1981; Janczak et al. 2003; Hemsworth et al. 1994			

Lameness	Uneven gait, detection of sore foot/leg, locomotor score, heel-sole cracks, claw lesions	Pain, discomfort	Lameness is a painful condition that can be caused by both sow and environmental risk factors such as reduced movement, pen design, flooring/bedding type and quality and for outdoor sows, soil type and muddy conditions. Moderately to severely lame sows are less willing and/or able to walk for a feed reward, limiting access to potentially positive experiences. Lame sows given non-steroidal anti-inflammatory drugs spend less time lying, and in passive (non-engaged) behaviours than lame sows not given analgesia, providing behavioural and physical evidence of the unpleasant experience of pain associated with lameness.	Ala-Kurikka et al. 2017; Bos et al. 2015
Example references for housing condition	Calderón Díaz et al., 2014; Barnett et al 2001			
Mastitis-Metritis-Agalactia (MMA)	Incidence of MMA and teat pulling (by piglet), reduced appetite, fever, hard udder hungry piglets, reduced daily liveweight gain of piglets	Pain, malaise, sickness	MMA is a complex syndrome seen in sows shortly after farrowing and is caused by a bacterial infection of udder and/or the urogenital tract. Both farmers and veterinarians rated pain associated with infectious mastitis as 7.5 and 7.3 out of 10, recognising that the sows experience pain with this condition. Dairy cows with clinical mastitis have a lower nociceptive thermal threshold and perform more pain related behaviours (e.g. kicking, restlessness, decreased lying) compared to healthy cows.	Ison & Rutherford; Peters et al. 2015; Fogsgaard et al 2015
Example references for housing condition				

Birthing difficulty	Problems associated with farrowing requiring intervention, ease of farrowing score (EFS)	Pain, frustration, discomfort, malaise	Difficulties during farrowing can negatively impact of neonatal pig survival. Duration of farrowing, sow position, and presence of stillborn piglets and mummified foetuses have been reported to be important ease of farrowing indicators. Behavioural indicators of pain (arched back, pawing, tail flick) are present during farrowing, but rare or absent pre-farrowing, supporting the idea that sows experience birthing pain and that a difficult birth would cause more pain.	Ison et al. 2016
Example references for housing condition	Mainau et al 2010			
Eye/nose irritations and coughs	Nasal and eye discharges (e.g. Due to dust or ammonia, viral or bacterial infection) sneezing, coughing	Pain, discomfort, breathlessness, itchiness	Dust and gases, such as ammonia, arising from manure and poor ventilation can cause irritations of the upper respiratory tract, eyes and nose leading to coughing, nasal and ocular discharges. Bacterial and viral infections can cause mild-severe pneumonia if not managed and treated. Pigs with respiratory infections spend less time feeding and more time lying ventrally, indicating a behavioural response to sickness and the potential to feel pain and discomfort. Advanced respiratory disease in humans causes chronic breathlessness, fatigue, and fear in patients	Escobar et al. 2007; Booth et al. 2019
Example references for housing condition	McOrist 2014; Stärk 2000; Stärk et al. 1998			

Deviation in BCS	Rapid reduction in body condition score	Malaise, hunger, weakness	Inadequate control of sow body weight and condition can lead to farrowing difficulties, poor reproductive performance, and high culling rates.
Example references for housing condition	López-Vergé et al 2018; Barnett et al 2001		
Long term heating	Increased RR and body temperature, panting, shade seeking, wallowing, reduced feed intake, reduction in body condition score, morbidity, mortality	Thermal discomfort, malaise, lethargy	Pigs are comparatively less heat tolerant than other production animals, which puts them at risk of heat stress in hot conditions and has negative impacts on welfare and productivity *See "Clinical hyperthermia"*
Example references for housing condition	Ross et al. 2015; Huynh and Aarnink 2005; Mayorga et al. 2019		

Table 12. The inferred affective states for piglet-based IMPACT indicators and the rationale of their occurrence considered. References are provided for both affective state rationale (References) and for differences between housing conditions (Example references for housing condition). Indicators marked as *(Low confidence)* are those that the panel considered the evidence for inferred affective state to be minimal.

Indicator	Physical State Description	Inferred Affective State	Rationale	References
Abnormal repetitive/redirected behaviour *(low confidence)*	Belly nosing and sucking (pen mates)	Frustration, boredom, helplessness, depression	The presence of abnormal redirected behaviour is considered evidence of a poor physical and social environment and/or inadequate nutrition. The performance of abnormal redirected behaviours, such as belly nosing and sucking of pen mates can occur pre-weaning, but most studies relate to early weaning (risk factor for increased ARB) and post-weaning housing.	Mason 1991; Mason & Latham 2004
Example references for housing condition	De Jonge et al., 1996; Hötzel et al. 2004; Lidfors et al. 2020; Mason 2006; Rzezniczek et al., 2015; Torrey and Widowksi 2006; Tucker et al. 2010; Worobec et al. 1999			
Non-fatal crushing	Swellings, lameness, tissue damage, non-fatal trauma	Pain, fear, panic, breathlessness	Injuries are likely to result in acute and chronic experience of pain in piglets. Piglets that are injured as a result of partial trapping elicit distress calls that are a reliable indicator of fear, panic and stress (see *"Dead by trampling"*). Piglets that are trapped by overlay are likely to experience breathlessness as a result of suffocation (see *"Dead by overlay")*	Bolhuis et al. 2018; Rangstrup-Chritensen et al. (2018); Verdon et al. (2020); Weary et al. 1996
Example references for housing condition	Anderson et al. 2005; Marchant et al. 2000); Mazzoni et al. 2017; Weary, Lawson and Thompson 1996			
Lameness/Foot/Leg issues	Lameness, claw/hoof lesions	Pain	A primary cause of lameness in piglets are abrasions that introduce bacterial	Zoric et al. 2016

			infections and can result in lesions or bacterial arthritis. Lameness is a behavioural indication of pain, whereby piglets are reducing the physical weight loading on the affected joint. Piglets treated with penicillin and NSAIDs significantly reduced clinical lameness scores compared to no treatment, indicating that reducing the infection provided some relief from pain.	
Example references for housing condition	Westin et al. 2014; Zoric et al. 2008; Zoric et al. 2009			
Long term chilling	Shivering, reduced daily weight gain	Thermal discomfort, feeling cold	Smaller piglets are at greatest risk of chilling. Prolonged chilling increases energy requirements, reduces growth, and puts piglets at greater risk of starvation and accidental crushing/trampling. Piglets exposed to thermal conditions considered to be below the thermal comfort zone will huddle together and emit different vocalisations compared to those in a thermal comfort zone. Indicating a feeling of discomfort. *See "Hypothermia" for more details*	Baxter & Edwards 2018; da Silva Cordeiro et al., 2013; Mellor & Stafford 2004; Villanueva-García et al., 2020
Example references for housing condition	Baxter et al. 2009; Baxter et al. 2015; Fraser 2009; Mellor & Stafford 2004			
Long term heating	Increased respiratory rate, panting, shade seeking, reduced feed intake	Thermal discomfort, malaise, overheating	Heat stressed piglets will have increased respiration rate and rectal temperatures, which are considered reliable indicators of thermal discomfort.	Osorio et al., 2008; Oliveria et al., 2018

			Long term thermal discomfort can lead to dehydration and other hyperthermia related conditions.	
Example references for housing condition	Fraser 2009; Ross et al 2015			
Sunburn	*See "Sunburn" in Table 11*			
Vocalisations due to lack of maternal attention	Frequency of vocalisations, type of vocalisation	Frustration, hunger, anxiety, insecurity	Piglets will vocalise to get the attention of sows, maternal attention from the sow reduces welfare risks and mortality in piglets by attending to their needs. When piglets are deprived of food, are manually squeezed, or exposed to lower than normal thermal comfort levels, they express distinguishable vocal signals that can indicate the emotional response to each potential stressor. Piglets that are not receiving maternal attention may experience frustrations due to the lack of their needs being met. *See "Near-miss crush injury" for more on "scream" vocalisations.*	da Silva Cordeiro et al., 2013; Grimberg-Henrici et al. 2016
Example references for housing condition	Cronin et al. 1995; Grimberg-Henrici et al. 2016; Iacobucci et al. 2015; Singh et al. 2017			
Aversive response to another piglet *(low confidence)*	Displacement, moving away quickly, avoidance	Fear, anxiety, insecurity	Displacement by/avoidance of other piglets can occur within the pen, particularly during nursing. Avoidance is a good indicator that piglets may experience fear/anxiety. *See "Aversive response to sow" in Table 11*	

Example references for housing condition	Chaloupková et al. 2006; Colson et al. 2012; De Jonge et al., 1996; Oostindjer et al. 2011; Singh et al. 2017; van Nieuwamerongen et al. 2013			
Short term heating	*See "Long term heating"*			
Dead by trampling	Death by trampling, or euthanasia as a result of trampling injury	Pain, panic	If able, piglets involved in trampling/crushing incidents will let out distress calls, or "screams" to alert the sow. Piglet scream vocalisations are associated with increased arousal and emotional response and considered an "honest" indicator of pain and stress. During trampling/crushing incidents piglets may sustain injuries that result in significant lameness or inability to walk, indicating severe pain. Piglets are more likely to sustain injuries that require euthanasia during trampling whereas overlay is more likely to cause piglet death due to recumbence limiting the sow's ability to move in response to the piglet's vocalisation.	Illman et al. 2013; Linhart et al. 2015; Mullins et al. 2017; Puppe et al. 2005; Weary et al. 1998;
Example references for housing condition	Andersen et al. 2005; Kilbride et al. 2012; Nicolaisen et al. 2019			
Savaged	Killed by sow through intentional biting/trampling behaviour	Pain, fear, panic	Savaging results in injuries and in some cases death of piglets. Significant traumatic injuries likely causing pain prior to death. *See "Aversive response to sow" in Table 11 for rationale of fear and panic associated with aggression.*	
Example references for housing condition	Baxter et al. 2018; Chen et al. 2008			

Starvation	Low body weight and body condition score	Hunger, fatigue, weakness, malaise	Piglets are at particular risk of starvation the first few days after parturition and when litter numbers are high. Piglets that are not gaining weight or are low body condition are more likely to engage in behaviour that increases risks of crushing and trampling such as being in close proximity to the sow and spending more time nuzzling the udder in between nursing sessions. This behaviour indicates the piglets are highly motivated by hunger to take increased risks to survival. Starvation can induce hypothermia, due to inhibited heat production, and sluggishness. Indicators that piglets are likely to experience feelings of malaise or sickness.	Mellor & Stafford 2004; Weary et al. 1996
Example references for housing condition	Chidgey et al. 2015; Kilbride et al. 2012; Kirkden et al. 2013			
Face lesions	Face lacerations from piglet-piglet competition at udder	Pain, hunger, malaise	*See "Skin lesions"*	
Example references for housing condition	Sutherland (2015)			
Scours	Diarrhoea	Malaise, weakness, sickness, discomfort	Diarrhoeal diseases are a major cause of morbidity and mortality in pre-weaning piglets. Piglets become dehydrated, lose body weight, and are lethargic, which represent physiological and behavioural indicators of malaise, weakness, sickness and discomfort. Piglets with *Clostridium perfingens* present with severe diarrhoea, acute abdominal	Radulović et al., 2014; Van Breda et al., 2017

			pain, dehydration, weakness and are reluctant to move.	
Example references for housing condition	Leeb et al., 2019			
Pneumonia	Lethargic, low body weight, respiratory distress	Pain, breathlessness	Weak or colostrum deprived piglets are at risk of developing clinical respiratory pneumonia from pathogenetic infection. Symptoms of pneumonia include coughing, laboured breathing and lung lesions which can lead to breathlessness and pain. *See "Eye/nose irritations and coughs" in Table 11 for further information on behavioural response in pigs to respiratory infection.*	Maes et al. 1996
Example references for housing condition	Pandolfi et al. 2017			
Aversive response to human	Fast moving away, avoiding, vocalisations	Fear, anxiety, panic	Piglets that receive early gentle handling vs rough handling show significantly reduced fear response to humans. Similarly, positive handling (gentle patting, stroking, scratching) vs routine handling reduced piglets vocalisations and intensity of escape behaviour during routine husbandry procedures. These behavioural responses indicate that piglets may experience fear, anxiety and panic from human interaction if resilience has not been built up.	Brajon et al. 2015; de Oliveira et al. 2015; Hayes et al. 2021
Example references for housing condition	Brajon et al. 2015; Hayes et al. 2021; Hemsworth & Barnett 1992			

Dead by overlay	Death by crushing, or euthanasia as a result of crushing injury	Pain, panic, breathlessness	Piglet's likelihood of death increases the longer they are trapped during an overlay incident, suggesting many piglets are dying from suffocation rather than traumatic injury. This suffocation is a good indication that piglets experience breathlessness, fear and panic prior to death. *See "Dead by trampling" for more on pain and stress*	Weary et al., 1996
Example references for housing condition	Condous et al. 2016; Cronin et al. 2000; Ison et al. 2015; Kilbride et al. 2012; King et al. 2019; Mellor & Stafford 2004			
Skin lesions	Scratches, lesions, tissue damage, reddening, swelling	Pain	Trauma of the skin tissue from bites/scratches/ abrasions results in areas of reddening, broken skin, hair loss, and swelling. Piglets that are given topical analgesic for husbandry practices that result in trauma of the skin tissue (Ear clipping/notching, castration) have significantly reduced pain response compared to those given none, or only NSAIDs. This indicates that piglets will experience acute pain in response to tissue trauma as well as inflammatory pain in response to tissue damage.	Ison et al., 2016; Leslie et al. 2010; Lomax et al. 2018; Sheil et al., 2021
Example references for housing condition	Westin et al. 2014			
Eye/nose irritations	*See "Eye/nose irritations and coughs" in Table 11*			
Poor piglet hygiene	Low levels of cleanliness indication that sow/piglets are unable to separate dunging/lying area	Skin irritation, pain, discomfort	Piglets develop a preference for eliminating away from the lying area at an early age (between 4-8 days) and will have disrupted sleeping patters in the laying area is soiled	Buchenauer et al. 1982; Nannoni et al.

			indicating discomfort with soiled conditions. *See "Poor sow hygiene" in Table 11 for further discussion.*	2020; Whatson 1985
Example references for housing condition	Buchenauer et al. 1982; Nannoni et al. 2020; Whatson 1985			
Hypothermia	Morbidity, collapse, death	Thermal discomfort, malaise, chilling	Piglets are at greatest risk of hypothermia immediately after birth when the ambient temperature is significantly lower than the intrauterine temperature. Hypothermia results in reduced awareness and piglets are at greater risk of injury or death due to crushing. Piglets that succumb to hypothermia but never gain full consciousness after birth are of least concern, those that develop full breathing after birth but descend quickly to hypothermia are of greater concern. Piglets regulate their body temperature through shivering thermogenesis and other thermoregulating behaviours (e.g. heat seeking). Hypothermic piglets use reserves of glycogen which can result in hypoglycaemia leading to feelings of malaise.	Baxter & Edwards 2018; Mellor & Stafford 2004; Villanueva-García et al., 2020
Example references for housing condition	Kammersgaard et al. 2011; Mellor & Stafford 2004			
Short term chilling	*See "Long term chilling"*			

Table 13. The inferred affective states for sow-based IMPACT indicators specific to mating systems and the rationale of their occurrence considered. References are provided for both affective state rationale (References) and for differences between housing conditions (Example references for housing condition). Indicators marked as *(Low confidence)* are those that the panel considered the evidence for inferred affective state to be minimal.

Indicator	Physical State Description	Inferred Affective State	Rationale	References
Injury associated with boar	Lameness, skin lesions, difficulty moving/recumbent	Pain	Excessive mating or sexual behaviour directed towards sows that are not standing can cause skin lesions, fractures, or spinal cord injuries. *See "Lameness" and "Skin lesions" in Table 11*	
Example references for housing condition	Levis et al. 2011; Pedersen (2007); Rault et al. 2014			
Sow/sow riding injuries	Lameness, skin lesions on the flank, swollen/red/torn vulva	Pain	Sows in group housing may receive or deliver sexual behaviour. Excessive mating or sexual behaviour directed towards sows that are not standing can cause skin lesions, fractures, or spinal cord injuries *See "Lameness" and :"Skin lesions" in Table 11*	
Example references for housing condition	Barnett et al. 1986; Hemsworth et al. 1986; Pedersen (2007); Rault et al. 2014			

Appendix B: Evidence supporting inferred affective states for ENHANCEMENT indicators

Table 14. The inferred affective states for sow-based ENHANCMENT indicators and the rationale of their occurrence considered. References are provided for both affective state rationale (References) and for differences between housing conditions (Example references for housing condition). All ENHANCEMENT indicators were considered as *Low confidence* by the panel due to limited evidence supporting the inferred affective state, or to the significance of the ENHANCEMENTS for the sows.

Indicator	Physical State Description	Inferred Affective State	Rationale	References
Eating a variety of foods	Food intake from a variety of food types	Satiety, pleasure, gastrointestinal pleasure, curiosity	Pigs naturally have a varied diet of both plant and animal matter. Pigs show eagerness to eat a variety of different food rewards in experimental conditions but have not been shown to favour unpredictable rewards over predictable rewards. However, individual pigs may vary in their preference for unpredictable rewards, which is also demonstrated in other species. Preference to eat multiple types of foods would provide good evidence that a positive experience would occur, more research needs to be done in this space for domestic pigs.	De Jonge et al., 2008
Example references for housing condition				
Foraging behaviour	Demonstrating a variety of foraging and exploration behaviours	Curiosity, pleasure, engaged by activity, interested, pleasantly occupied	Pigs spend a large proportion of their day engaged in foraging and exploration behaviour. Domestic pigs in a semi-natural environment spent around 30% of their daytime grazing and 20% rooting. Pigs in barren environments that are given access to suitable material, or those that have	Studnitz et al., 2007 *(review paper)*

			had their nose ring removed, immediately begin rooting and exploratory behaviour, suggesting that these behaviours are highly motivated. Additionally, pigs that are thwarted from performing foraging behaviour develop abnormal redirected behaviour.	
Example references for housing condition	Johnson et al. 2001; Stolba and Wood-Gush 1989			
Exploration behaviour	*See "Foraging behaviour"*			
Utilisation of surfaces/areas	Demonstrating a use of different surfaces for different activities	Physical and thermal comfort, calm, sense of being in control, confident	Pigs are naturally very clean animals. Piglets as young as 5 days old already defecate and urinate in places remote from their lying areas. If that is not possible and the pen is soiled their lying time will be reduced. If the pen design allows a functional division of the available area, adult pigs use specific dunging areas for elimination. Before lying down, pigs normally check the cleanliness of the bedding and never lie in soiled areas, if they can avoid them.	
Example references for housing condition	Spinka 2009			
Nest building behaviour	Duration and intensity of nest building behaviour, and use of materials	Pleasure, in control, engaged by activity	Sows are highly motivated to engage in nest building behaviour, the presence and quality of nesting materials, and available space influences the performance of nest building behaviour. Positive maternal behaviours such as nose contact with piglets, pre-lying vocalisation, behavioural response to piglet distress calls, and restlessness when piglets are removed are increased when the drive for nest building is satisfied.	Andersen et al., 2005, Jarvis et al., 2005, Yun et al. 2014, Swan et al 2021., Bolhuis et al., 2018, Westin 2014)

			The motivation to perform nest building and flow on effect of maternal behaviours are good evidence that sows will experience positive affective states.	
Example references for housing condition	Hansen et al., 2017; Martins et al., 2021; Rosvold et al., 2019; Yun et al., 2014			
Wallowing	Use of wallow	Pleasure, thermal comfort	Access to a wallow in hot weather can reduce heat load in pigs. It may also have benefits for reducing sunburn and ectoparasites, but little scientific evidence is available. Wallowing may contribute to positive welfare however, there is little scientific knowledge regarding the motivation for wallowing behaviour.	Bracke 2011; Bracke & Spoolder 2011
Example references for housing condition	Svendsen and Steen Svendsen 1997;			
Friendly sow-sow interactions	Sniffs, proximity to other sows	Affectionate sociability, group rewards, calm, confident	Some pigs have been shown to form preferential associations. Additionally, given the choice (in a Y-maze), pigs will consistently choose social contact over bedding, and most often choose social contact over food although there was variation in induvial response. Preference for social contact, and even preference for particular associates suggests that pigs will experience positive affective states. However, there is limited evidence to identify the specific positive affects to the pig despite evolutionary advantages.	Camerlink et al., 2014; Durrell et al., 2004; Hemsworth et al. 2011; Gouman et al. 2020

Example references for housing condition				
Nose to nose contact and other interactions (piglets)	Amount of nose to nose contact, sniffing, nudging, pre-lying/nursing vocalisations	Affectionate sociability, maternal rewards, calm, confident, feels in control	Positive maternal behaviours such as nose contact with piglets, pre-lying vocalisation, behavioural responses to piglet distress calls, and restlessness when piglets are removed are increased when nest-building is conducted. Positive maternal behaviour has been shown to be negatively correlated with the risk of piglet crushing.	
Example references for housing condition	Bolhuis et al. 2018; Andersen et al., 2005; Jarvis et al., 2005; Yun et al. 2014; Swan et al 2021; Ocepek and Andersen 2017 Thodberg et al. 2002, Cronin et al., 1996			
Approach human for friendly interaction	Short flight distance, seeks contact	Calm, confident, feels in control	Fear of humans in domestic pigs is common due to human interactions often being aversive while providing no choice or control to the pigs as to whether they participate or how they participate. Pigs can discriminate and even recognise individual humans and respond differently depending on the nature of past interactions. The nature of the relationship matters as it will modulate not only pig health and welfare but also productivity and product quality as well as stockpeople work quality and job satisfaction. The duration of being stroked by a familiar human is positively associated with salivary oxytocin levels, more research is needed to understand the importance of oxytocin for assessing affective states.	Lürzel et al., 2020

			Voluntary approach behaviour is strong evidence that a positive experience would occur.	
Example references for housing condition	Hemsworth 2018			

Table 15. The inferred affective states for piglet-based ENHANCEMENT indicators and the rationale of their occurrence considered. References are provided for both affective state rationale (References) and for differences between housing conditions (Example references for housing condition). Indicators marked as *(Low confidence)* are those that the panel considered the evidence for inferred affective state to be minimal.

Indicator	Physical State Description	Inferred Affective State	Rationale	References
Foraging behaviour	Demonstrating a variety of foraging behaviours, excluding suckling behaviour	Curiosity, pleasure, engaged by activity, interested, pleasantly occupied	Foraging behaviour is increased when piglets are provided with suitable material, while inactivity, fighting and manipulation of pen mates is reduced. *See "Foraging behaviour" in Table 14*	Vanheukelom et al., 2011
Example references for housing condition	Oostindjer et al., 2011			
Exploration behaviour	*See "Foraging behaviour"*			
Utilisation of surfaces/areas	*See "Utilisation of surfaces/areas" in Table 14*			
Nose to nose contact, other interactions, and sow/piglet vocalisation	*See "Nose to nose contact and other interactions (piglets)" in Table 14*			
Play behaviour	Duration and intensity of play behaviour (locomotor and object)	Playfulness, excitement, pleasures	Play behaviour is an important indicator for assessing the welfare of young pigs as animals play when their primary needs are met.	Donaldson et al., 2002; Boissy et al., 2007; Held & Špinka, 2011
Example references for housing condition	Johnson et al. 2001; Newberry et al. 1988; Yang et al. 2018.			

Approach human for friendly interaction	Short flight distance, approach human for scratch/sniff	Calm, confident, feels in control	*See "Human approach" in Table 14*

Table 16. The inferred affective states for sow-based ENHANCEMENT indicators specific to mating systems and the rationale of their occurrence considered. References are provided for both affective state rationale (References) and for differences between housing conditions (Example references for housing condition). Indicators marked as *(Low confidence)* are those that the panel considered the evidence for inferred affective state to be minimal.

Indicator	Physical State Description	Inferred Affective State	Rationale	References
Pre-mating courtship with boar	Pre-mating behaviour	Pleasure, affectionate sociability	Contact with boar prior to mating may affect mating behaviour	Hemsworth 1982; Soede & Shouten 1991
Example references for housing condition				

Appendix C: Reference list for Tables 11-16 in Appendix A and B

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