Animal welfare risk assessment: Off-pasture management systems in the New Zealand dairy industry

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Prepared for MAF Biosecurity Operational Research
By Gwyneth Verkerk, DairyNZ, Hamilton

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Requests for further copies should be directed to:

Strategic Science Team
Policy and Risk Directorate
MAF Biosecurity New Zealand
P O Box 2526
WELLINGTON

Telephone: 0800 00 83 33
Facsimile: 04-894 0300

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1. Executive Summary

An animal welfare risk assessment of off-pasture management systems used in the New Zealand dairy industry was carried out. This was a formal hazard analysis process in which the opinions were gathered from members of a panel of sixteen experts. Fifty putative hazards were described and their impacts on dairy cows estimated (magnitude estimates). The probabilities of exposure to each hazard within eleven farm system scenarios were also calculated (risk estimates).

Non-parametric analysis of the data classified the putative hazards into hierarchies according to magnitude and risk estimates. In this way the key animal welfare risks across the range of management systems were identified. Some inherent difficulties were encountered with the methodology for deriving magnitude and risk estimates, as it does not allow for the cumulative effects of repeated exposure to hazards, or for the interactive relationships between hazards. Nevertheless the resulting output has been useful for definition of the key issues which can affect animal well-being in off-pasture management systems.

Nearly half of the identified hazards were considered common to all systems, e.g. relating to animal feeding or general animal husbandry skills, while others were system-specific, e.g. relating to ventilation in barn structures, or underfoot conditions in the areas where cows are held off pasture. The extent to which the identified hazards are regulated by current welfare regulations is discussed. Given the diverse nature of existing off-pasture management systems and the emergence of hybrid systems that offer benefits for both environmental protection and animal management, ensuring the well-being of animals in these systems will require a multi-faceted approach. While industry standards and regulations will mitigate the issues to some extent, e.g. relating to engineering specifications for facility design, reliable information to advise farmers about the inherent risks of off-pasture management systems, thus enabling them to adapt the principles of good husbandry practice to their own farm situations, will be an essential part of the solution for protecting animal welfare.

2. Introduction

Off-pasture management systems for dairy cattle are becoming increasingly common in New Zealand. Cows may be confined for varying durations in a range of systems from open concrete yards to covered bark-chip pads and loose-house systems, as well as free-stall barns. Drivers for this change include the need to change winter management systems to protect pastures and improve feed utilisation, and improving environmental management to reduce nitrate leaching and capture cow effluent for use as fertiliser.

Off-pasture management systems are mainly used during winter months for non-lactating cows. Use patterns are mostly intermittent depending upon weather conditions. Use of concrete feed pads for standing cows off-pasture has increased in recent times as farmers invest in feed pad systems to ensure supplementary feed is utilised more efficiently. Dry cows may spend up to 18 hours each day standing-off during wet periods of weather, usually for 3 to 5 consecutive days. They will then be allowed to stay on pasture for several days during which time they recover from lost rest. Achievement of adequate resting times is an important consideration for the welfare of cows (Fisher *et al*., 2002). Systems that confine cows continuously for several months at a time are seen mainly in southern regions. While predominant use patterns are related to winter management, they also serve to provide shelter for lactating cows on farms with winter milk contracts.

Housing has long been known to compromise and/or enhance different aspects of an animal's welfare and there have been many assessments (refer to Appendix 6 for a review). Formal animal welfare risk assessments are a mechanism to provide scientific opinion on farming and husbandry systems and the extent to which they meet animals' needs. The Scientific Committee of the Animal Health and Welfare (AHAW) Panel of the European Food Safety Authority (EFSA) has used formal risk assessment principles based on hazard analysis to develop opinions of dairy housing systems (Anonymous, 2009b&f). Risk assessment is a systematic, scientifically-based process to estimate the likelihood and severity of impact of putative hazards. Hazard analysis is used extensively by Codex Alimentarius and the World Health Organisation to determine risks to food safety.

The framework of hazard analysis as applied by AHAW to animal welfare risk assessment provided a means to understand the issues that might lead to poor welfare. In this context, a hazard is defined as a system-design criterion with potential to cause a negative animal welfare effect as measured by one or more indicators (Anonymous, 2009f). System-design criteria can relate to the full range of animal-environment interactions resulting from factors, often in combination, of animal management policies, husbandry practices, farm infrastructure or facility design.

Expert opinion is the basis of the process developed by the AHAW Panel in which the issue is considered using a series of defined steps:

Step 1: Scenario definition – the specific farm system scenarios to be considered are developed and agreed.

Step 2: Hazard identification and characterisation – the potential welfare hazards are described and their general impact on dairy cows when exposed is estimated. The level of uncertainty of the accuracy of available knowledge is also evaluated.

Step 3: Exposure assessment – the degree of exposure of the animals to each potential hazard is evaluated for each farm system scenario being considered, and the level of uncertainty about available knowledge is again evaluated.

Step 4: Data analysis (risk characterisation) – this is a statistical calculation process which combines the expert opinions.

The semi-quantitative approach generates data that represent the impact of a range of specified hazards (magnitude estimates) and the likelihood of exposure for each hazard (risk estimates) within a range of farm system scenarios. Magnitude estimates allow the impact of exposure to a single instance of each hazard to be compared. Risk estimates allow comparison of exposures across systems.

The formal animal welfare risk assessments undertaken in Europe (Anonymous, 2009b&f) have shown that some forms of dairy housing can compromise cow welfare whilst others promote better welfare. The AHAW Panel did however note that results should be interpreted with care. All systems have impacts of varying nature and degree, and it is the extent to which these are recognised and managed to protect animal welfare that is important. Conclusions about the suitability or otherwise of particular systems based on the outcomes of the analysis must be guarded, and interpretation should be focussed more on its usefulness to identify which hazards within each system require particular attention to protect cow welfare.

As yet, no animal welfare assessments have been conducted on off-pasture management systems as they occur in New Zealand. The objective of the welfare risk assessment described here was to examine the impact of off-pasture management systems employed in New Zealand by comparing hazard exposures in a range of farm system scenarios based on expert opinion.

3. Materials and Methods

3.1 EXPERT PANEL ESTABLISHMENT AND OVERALL APPROACH

The Expert Panel was established in October 2010 comprising 16 members who had been identified as having knowledge and experience in matters of dairy animal welfare, with some having particular expertise in off-pasture management systems (Appendix 1).

Experts were selected on the basis of their experience and interest in the use of off-pasture management systems in the New Zealand dairy industry. Hybrid dairying systems seek to maximise pasture use while keeping cows in off-pasture facilities in order to protect soils, pastures and the environment. Such systems are still at an emergent stage of development, so few of the local animal and veterinary science community have practical knowledge of their application or the implications of their use.

Analysis of the welfare risks of off-pasture management systems requires an assessment at the "systems level". The issues are complex and multi-faceted, and many components interact, e.g. feeding a high component of fresh pasture will directly influence foot health because effluent has higher water content. Furthermore the ways in which the skills and knowledge of farmers and stock handlers, management policies and decision rules all interact will influence the success of each farm system including welfare risk.

Incomplete scientific information about the performance of these developing New Zealand dairying systems and the small base of expertise and experience available meant it was impossible to replicate the approach to the risk analysis EFSA have taken where the expert panel is comprised of experts from the international welfare science community. Accordingly the Expert Panel in this assessment included those with practical expertise in the management of New Zealand-style systems, consultants with practical overseas experience of housing systems, and New Zealand scientists with theoretical understanding.

Expert Panel members were initially conditioned for the project by reading a literature review previously prepared as background information (Appendix 6).
Terms of Reference for the project were distributed to the panel members in a document that provided briefing information and a description of the risk analysis process (Appendix 2).

The Delphi technique was used throughout the risk analysis process. The general process at all stages involved solicitation of individual responses from the experts by the facilitator. Experts provided their responses in writing to the facilitator (see example spreadsheets, Appendix 2) and these were collated (approximately weekly) for statistical analysis. Individual panel members were then provided with graphs which showed their assessment for each hazard in each system scenario alongside the current analysis of the group's overall opinion at that time. The panel members were offered an opportunity to reassess their opinion in the light of these results, and make changes if they wished. In this way over a period of several weeks, the facilitator endeavoured to converge opinion.

During the process (between Steps 1 and 2) the group met for a single meeting (face-to-face with video- and tele-conference links). This was attended by the majority of panel members and was also a means to condition the expert group before the risk analysis stage commenced. The background and aims of the project, the approach to risk assessment (of which the EFSA process provided the working model), and parameter definitions were discussed.

The group shared the outcomes of Step 1 (Hazard identification and farm system scenario definition). The list of potential hazards was considered complex and lengthy, and the panel members were of the view that the issues had been dissected in too much detail. Accordingly some hazards were aggregated as a means to simplify the process, and the farm system scenarios to be analysed were also simplified and finalised.

The approach to estimation of the parameters for each hazard within each farm system scenario ((likelihood of exposure and uncertainty estimates) to be used in Step 2 was also discussed in a general manner at this meeting.

In keeping with the principles of the Delphi process, individual responses were shared only with the facilitator and the information returned to participants was limited to a graphical depiction of that individual's most recent submission in the current analysis of overall opinion at that time. As the process continued for several weeks it became clear that, given the diverse opinions being expressed to the facilitator, full convergence of opinions on all points would not be achievable.

Several panel members expressed an inability to complete the risk analysis assignment due to work commitments. As time pressure to complete the risk assessment came to bear without convergence, the decision was made to call the iterative risk assessment procedure to a halt. In the final analysis, thirteen expert panel members completed the full risk assessment, all completing at least one iteration to confirm their final position.

There was strong polarity of opinion on some issues, largely a consequence of varying practical and theoretical experiences of the individual panel members, making consensus unlikely. Expert advice was sought on statistical analysis and the Delphic method to develop an alternative approach whereby results were calculated as a mean with confidence interval information included.

The new approach allowed the panel's opinion to be analysed despite the failure to achieve consensus on some points. Hazards were therefore able to be ranked relative to their overall scores but still clearly identifying the level of agreement on those scores i.e. the size of the variance. It is our view that the inclusion of variance information where opinions cannot be converged may have greater value than a process in which panel members are forced to a point of consensus. Issues with high levels of variance merit further investigation.

The process followed for the risk analysis process is summarised as follows.
1. Literature review prepared
2. Expert Panel invited to participate
3. Literature review distributed for information and comment
4. Terms of reference, hazard identification worksheets and instructions distributed
5. Step1: Identification of hazards and farm system scenarios: iterative discussion with panel members to establish and define the hazards for consideration and the farm system scenarios
6. Expert panel meeting: final agreement of the hazards and farm system scenarios to be assessed; hazard characterisation procedures in Step 2 discussed.
7. Step2: Hazard characterisation: iterative discussion between the panel members and facilitator in an effort to achieve convergent opinion (this continued for several weeks)
8. Final report: final statistical analysis completed, draft report written and submitted to MAF.

3.2 STEP 1: HAZARD IDENTIFICATION AND FARM SYSTEM SCENARIO DEFINITION

Panel members were provided with a preliminary list of potential hazards derived from the EFSA project (Anonymous, 2009f) and asked whether the list was complete. The Welfare Quality® framework of principles and criteria of animal welfare was used to systematise the identification, description and categorisation of hazards.

This step included the specification of circumstances under which each hazard could exert its effect and a description of its welfare impact. Hazards were also categorised according to whether they occurred as a consequence of failure of system infrastructure and design, from management and/or farm policy decisions, or elements of both.

Panel members developed a list of New Zealand dairy farm system scenarios that include elements of confinement, taking account of design and construction characteristics as well as use patterns. Seven basic systems, with variations in feeding, provision of a roof, and bedding are outlined in Table 1.

Table 1: Matrix of system types that include elements of confinement

Confinement System	Feeding	Roof	Bedding
Hard surface stand-off without feeding	N	N	N
Constructed stand-off without feeding	N	N	Y
Feed pad also used for standing-off	Y	N	N
Constructed stand-off with feeding	Y	N	Y
Roofed shelters with concrete floor and feeding	Y	Y	Y/N
Roofed loose-house system with feeding	Y	Y	Y
Roofed free-stall barn and related hybrid systems	Y	Y	Y

Given that farm system scenarios vary in their implementation from farm to farm, and between years, depending on many factors including climate, staffing and availability of resources, e.g. for feed and bedding, it was agreed that the farm system scenarios should be considered as implemented on an "average" farm. After discussion the panel also agreed that the farm system scenarios should include the traditional pasture system where animals are kept either at pasture or on crops fed *in situ*.

3.3 STEP 2: HAZARD CHARACTERISATION

The objective of Step 2 was to characterise the identified hazards in terms of their impact on cow welfare. A spreadsheet template was distributed to panel members to complete. The task was to assess each hazard as it would affect a 'generic' cow, without reference to any particular system.

9. *Severity grading* – this was a subjective assessment of a hazard's impact on normal physiology, behaviour or health in the event that an animal was affected. The EFSA grading system described in Table 2 was adopted (Anonymous, 2009f).

Table 2: Severity grading system (Anonymous, 2009f)

Evaluation	Score	Explanation
Negligible	0	No pain, malaise, fear or anxiety as evidenced by a range of behavioural, physiological and clinical measures
Mild	1	Minor changes from normal indicative of pain, malaise, fear or anxiety
Moderate	2	Moderate changes from normality indicative of pain, malaise, fear or anxiety. Clear change in adrenal or behavioural reactions such as motor responses and vocalisation
Severe	3	Substantial change from normality indicative of pain, malaise, fear or anxiety. Marked change in adrenal or behavioural reactions such as motor responses and vocalisation
Very severe	4	Extreme change from normality indicative of pain, malaise, fear or anxiety usually in severe measures, that could be life threatening if they persist

10. *Duration of exposure* – this was a quantitative estimate of the number of days in a year (range: 1-365 days) that an animal would experience adverse effects if affected by a single occurrence of the hazard, e.g. if a cow were exposed to the hazard of "Social stress from mixing groups" then it could be construed that the duration of effect of exposure could persist for several days, while exposure to the hazard of "Inadequate access to water because the system cannot deliver desired flow rates" might be less than one day, as the water system should eventually refill the water troughs so the animal can drink.
11. *Likelihood of adverse effect* - this was a quantitative estimate of the likelihood that an adverse effect would occur if an animal was exposed to the described hazard. This estimate recognises that not all animals within a herd will be equally exposed or susceptible to the effects of the hazard, e.g. young or subordinate animals are more likely to be affected by over-crowding than older or dominant cows. Panel members were asked to provide estimates of "most likely", "minimum" and "maximum" of the proportion of a herd that might be affected.
12. *Uncertainty estimates* - this was a qualitative assessment of the uncertainty about the estimates relative to each expert's scientific knowledge, understanding of good practice and available technology, and their personal experience of the hazard and its impacts on dairy cow welfare. Panel members were asked to score their level of uncertainty as low, medium or high for each hazard. By ascribing a low level of uncertainty, the panel member was indicating they were confident that their opinion was backed by extensive personal knowledge with strong evidence, including support by scientific studies, that the hazard would produce the specified effect.

Analyses were run several times as Step 2 spreadsheets were submitted. Panel members received feedback on their assessment relative to the group's combined information and were asked whether they wished to change any of their assessments. This iterative process enabled some convergence of opinion. A meeting of 11 panel members (combined face-to-face with teleconference/videoconference connection by four members) after the Step 2 worksheet had been distributed enabled the project's objectives and methodology to be discussed.

3.4 STEP 3: RISK ESTIMATES

The objective of Step 3 was to assess the likelihood of exposure to the hazards within the context of the farm system scenarios. Panel members were asked to complete a second spreadsheet template with the following estimates:

1. *Likelihood of exposure:* this was a quantitative estimate of the likelihood that the hazard would have an effect within each farm system scenario. Estimates were made of the "most likely", "minimum" and "maximum" proportions of cows that would be affected.

2. *Uncertainty estimate:* as for Step 2, this was a qualitative assessment of the reliability of the knowledge used in the assessment of exposure within the farm system scenarios.

At Step 3, panel members were also asked to propose factors and indicators that could be used to assess the intensity of each hazard. If opinion was that intensity was influenced by external conditions, panel members could specify a range of intensity for the hazard, e.g. for heat stress, the intensity could depend on the environmental temperature.

The spreadsheet for Step 3 was distributed to panel members once they had commenced Step 2. While the initial intention had been for Step 3 to also be an iterative process, time pressures precluded that happening, and Step 3 spreadsheets were only returned to panel members where there had been an omission or need for clarification that required correction before analysis

3.5 STATISTICAL ANALYSIS

Software was developed to extract data from the spreadsheets for analysis. The analytical methods used in the EFSA process were scrutinised and some issues with respect to the information and methods of analysis were raised during these discussions. The approach used by EFSA was based on achieving full consensus within the group, so risk estimates did not reflect variance of opinion. This was not an achievable endpoint in this project, both because of time constraints and the diverse nature of the expert panel, so a means of determining variance between opinions was developed within the statistical analysis.

All completed spreadsheets returned by early January 2011 were used for the final statistical analysis. The estimates were combined to calculate magnitude estimates for each hazard, as well as risk estimates for each within the 11 farm system scenarios. Risk estimate distributions were calculated using a beta-pert distribution and simulation (2000 iterations; Genstat v.13) as described by EFSA (Anonymous, 2009f).

Estimates were based on the following calculations, adopted from the EFSA process:

Magnitude estimate = (Severity score/4) * (Duration of the effect)

The measurement unit for magnitude estimate is "severity unit.day". Thus a magnitude estimate of 20 severity unit.day could result, for example, from a severe hazard (score 4) that will affect the cow for 20 days, or from a mild hazard (score 1) that will affect the cow for 80 days.

Risk estimates were comprised of both:

- Likelihood of impact of the hazard (data derived during Step 2 Hazard characterisation)
- Likelihood of exposure in each of the eleven farm system scenarios (Step 3).

Risk estimate = (Magnitude Estimate) * (Likelihood of adverse effect) * (Likelihood of exposure within the scenario)

The measurement unit for risk estimates is per cent (%). Risk estimates are conditional probabilities that reflect the overall probability of exposure to 1 severity unit.day arising from each specific hazard within each farm system scenario. Confidence intervals (95%) for risk estimates were calculated with reference to the minimum and maximum likelihood data provided, using the simulation model.

Uncertainty estimates were analysed by inspection of counts for each classification. Where more than 50% of panel members indicated a particular level of uncertainty about the hazard, that level is reported as the estimate. Where more diverse uncertainty was expressed by panel members, the most conservative level is reported.

4. Results

4.1 STEP 1: IDENTIFICATION OF HAZARDS AND FARM SYSTEM SCENARIOS

An initial list of 76 individual hazards identified as having potential to have adverse effects on cow welfare in off-pasture management systems was reduced by mutual agreement to 50 hazards for further consideration in Steps 2 and 3. Hazards were grouped into thirteen general categories and allocated a hazard number accordingly. Some hazards presented several levels of specification, e.g., Hazard 2.1 "Inadequate feeding facilities" was further specified as Hazard 2.1a "Too few spaces" and Hazard 2.1b "Poor position/design" which were considered to be two separate hazards.

To reduce the number of hazards to be assessed, similar hazards were combined, e.g. "Insufficient light – too dark for cows at night" and "Insufficient light – too dark for cows generally" were deemed similar, so the former was omitted. "Failure to act on clinical health monitoring" and "Failure to treat lameness when detected" were also considered similar and combined.

Initial discussion recognized eleven specific design features for free-stalls that could be considered as hazards. These were combined for Steps 2 and 3 as Hazard 6.1a "Free-stall design poor".

Hazards were categorised as to whether they arose as a consequence of infrastructure and design, management and farm policy, or elements of both. Detailed descriptions of the individual hazards and their potential effects are listed in Appendix 2.

The initial identification of farm system scenarios was based on common use patterns found in New Zealand off-pasture management systems. Systems were differentiated by whether use patterns were intermittent, e.g. cows only confined for a few days during periods of high rainfall, or continuous, e.g. cows continually confined for six to eight weeks for winter management. Systems were also differentiated on the basis of whether use was by dry or lactating cows. Approached in this way, 30 separate farm system scenarios were identified (Appendix 3; Table I). It was agreed that this classification was too complex and that the variations in duration of exposure arising from an analysis of use patterns should be considered separately. This reduced the number of farm systems scenarios for consideration to eleven (Appendix 3; Table II).

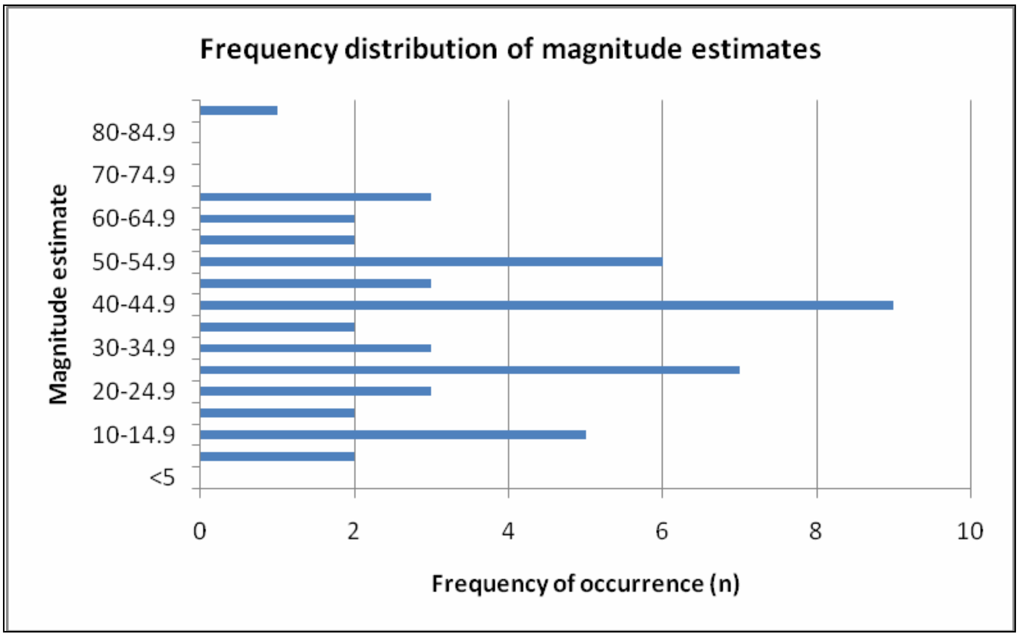
4.2 STEP 2: HAZARD CHARACTERISATION

Thirteen members of the Expert Panel completed the spreadsheets for Step 2 in full to provide the data for characterisation of the 50 putative hazards. Magnitude estimates for each hazard are presented in Table 3a-d. The range of magnitude estimates was 5.9 - 86.0 severity unit.day (mean: 37.9 severity unit.day). Figure 1 shows the frequency distribution of magnitude estimates.

Standard errors (sem) calculated for the magnitude estimates were large relative to their size (Tables 3a-d). On average they were 52% of their respective magnitude estimate. Large variance was due to divergent opinions about both severity and duration. The two points with greatest disagreement were Hazards 1.1a "Insufficient light – too dark for cows" and 9.1c

"Trough position inadequate". Severity estimates for both ranged from 1 to 4 units, while duration estimates ranged from 0.5 to 365 days and from 1 to 365 days, respectively. This resulted in sem being 81% of the magnitude estimate in both cases. Agreement was greatest for Hazard 12.2 "Inability to quarantine sick animals" for which the sem was 31% of the magnitude estimate. Hazard 4.1a "Too hot/humid" and Hazard 12.1c "Inadequate fly control" both had sem that were 34% of their respective magnitude estimates.

Figure 1: Frequency distribution of magnitude estimates



While the iterative process was intended to bring the panel members towards a consensus view, in fact they maintained their opinions firmly, with only a small reduction in the sem through successive iterations. The consequence of the variability was that estimates could not be differentiated using conventional statistical interpretation. Further analysis was non-parametric, with hazards ranked by magnitude estimate, then categorised into quartiles (Tables 3a-d). While the tables present the hazards in rank order, this should not be interpreted as absolute because of the overlapping confidence intervals.

Table 3a: Magnitude estimates, sem, uncertainty rating (low, medium, high) and category for hazards in the top quartile (greatest magnitude; range: 51.0 – 86.0 severity unit.day). Category refers to the basis of the hazard (M/P: management/farm policy-related; I/D: infrastructure/design-related; Both: elements of both M/P and I/D)

Hazard Description	Magnitude estimate (severity unit.day)	sem	Uncertainty rating	Category
13.1c Failure to act on monitoring	86.0	31.9	low	M/P
6.1a Free-stall design poor	69.6	31.6	medium	I/D
2.1b Inadequate feeding facilities - poor position or design	67.4	31.8	medium	I/D
2.4 Underfeeding	65.5	27.4	low	M/P
13.5 Lack of planning and operational procedures	61.4	27.3	high	M/P
7.1a Walking passages too narrow	60.1	29.0	medium	I/D
13.2 With-holding therapeutic maintenance, e.g. hoof trimming	58.8	28.8	medium	M/P
2.1a Inadequate feeding facilities - too few spaces	58.4	27.0	low	I/D
7.2 Walking passage surfaces poor	53.9	26.5	medium	I/D
3.1 Poor air quality (ammonia, dust, aerosols)	53.6	29.3	medium	I/D
7.1b Insufficient crossovers in walking passages	51.6	29.4	medium	I/D
12.3 Inadequate foot bathing/foot hygiene measures	51.3	25.1	medium	Both
5.1 Inadequate bedding	51.0	26.8	low	Both

Table 3b: Magnitude estimates, sem, uncertainty rating (low, medium, high) and category for hazards in the third quartile (range: 40.3 –50.5 severity unit.day). Category refers to the basis of the hazard (M/P: management/farm policy-related; I/D: infrastructure/design-related; Both: elements of both M/P and I/D).

Hazard Description	Magnitude estimate (severity unit.day)	sem	Uncertainty rating	Category
7.3 Walking passages too crowded	50.5	27.4	medium	I/D
7.4 Manure removal from walking passages poor	46.6	26.9	medium	Both
13.1b Inability to recognise the abnormal	45.9	23.2	low	M/P
2.2a Poor feed quality - nutritive value/palatability	45.1	21.2	low	Both
8.1 Facility entrance surface poorly maintained	43.7	22.1	medium	I/D
13.3 Poor management of down cows	42.0	27.3	low	M/P
1.2 Photoperiod inappropriate	41.6	28.1	medium	I/D
6.1b Free-stall maintenance poor	41.6	27.2	medium	I/D
9.1a Not enough access to water from overcrowding	40.8	21.7	medium	I/D
11.4 Lack of opportunity for self-grooming	40.7	23.7	medium	Both
13.4 Inadequate identification and recording systems	40.6	18.1	medium	M/P
13.1a Stock monitoring too infrequent	40.3	17.8	low	M/P

Table 3c: Magnitude estimates, sem, uncertainty rating (low, medium, high) and category for hazards in the second quartile (range: 25.2 – 40.0 severity unit.day). Category refers to the basis of the hazard (M/P: management/farm policy-related; I/D: infrastructure/design-related; Both: elements of both M/P and I/D).

Hazard Description	Magnitude estimate (severity unit.day)	sem	Uncertainty rating	Category
11.3 Lack of opportunity for allogrooming/positive cow-cow	40.0	23.8	medium	Both
1.1b Insufficient light - too dark for stock handlers	36.5	27.5	medium	I/D
9.1b Water system cannot deliver flow rates required	35.4	21.3	medium	I/D
9.1c Trough position inadequate	34.3	27.7	medium	I/D
1.1a Insufficient light - too dark for cows generally	34.2	27.8	medium	I/D
2.3 Improper ration composition	30.1	13.2	low	M/P
6.2 Fewer free-stalls than cows	29.6	13.7	low	I/D
2.2b Poor feed quality - increased feed sorting by cows	27.6	14.4	medium	M/P
5.2 Lying areas overcrowded	27.5	13.9	medium	I/D
11.2 Negative human-animal interactions	27.3	14.7	medium	M/P
12.1b Rodent/pest contamination of feed	26.6	14.2	medium	M/P
2.6 Inadequate feeding schedule	25.5	13.9	medium	M/P
2.5 Overfeeding	25.2	10.4	low	M/P

Table 3d: Magnitude estimates, sem, uncertainty rating (low, medium, high) and category for hazards in the first quartile (least magnitude; range: 5.9 – 24.8 severity unit.day). Category refers to the basis of the hazard (M/P: management/farm policy-related; I/D: infrastructure/design-related; Both: elements of both M/P and I/D).

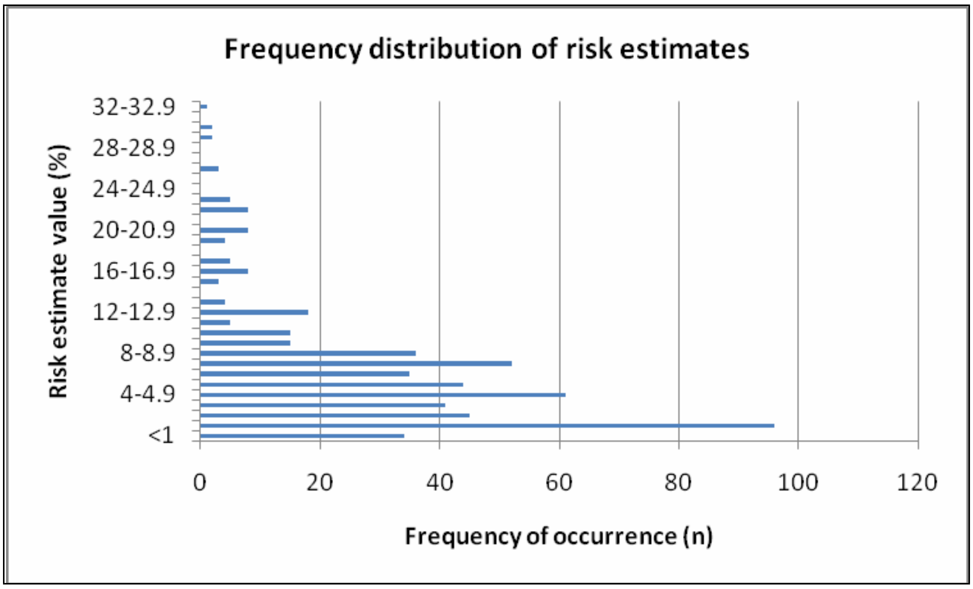
Hazard Description	Magnitude estimate (severity unit.day)	sem	Uncertainty rating	Category
9.2 Inadequate water quality	24.8	13.7	medium	I/D
8.2 Facility not readily accessible	24.7	13.7	medium	I/D
12.1c Inadequate fly control	23.1	7.8	medium	M/P
12.2 Inability to quarantine sick animals	18.1	5.6	medium	I/D
4.1b Too cold/wet	16.4	8.8	low	Both
10.2b Unsuitable surface for calving cows	13.6	5.4	medium	I/D
8.3 Disturbance from other farm activity	13.5	7.6	medium	M/P
4.1a Too hot/humid	13.1	4.4	low	Both
10.1 Inability to separate cows needing attention	12.0	6.8	medium	I/D
12.1a Inadequate visitor biosecurity	10.6	5.7	medium	M/P
10.2a Inability to separate calving cows	8.8	4.3	medium	I/D
11.1 Social stress from mixing groups	5.9	2.5	medium	M/P

4.3 STEP 3: RISK ESTIMATES FOR FARM SYSTEMS SCENARIOS

The 50 potential hazards were considered within each of the eleven farm system scenarios resulting in a total of 550 risk estimates being determined. Risk estimates ranged from 0% to 32.1%. The highest risk estimate was for Hazard 5.1 "Inadequate bedding" for Farm System Scenario 2 "Hard surface stand-off; no feeding".

The frequency of risk estimates (Figure 2) was skewed towards the lower end of the range. Risk estimates of 0% were obtained for 34/550 assessments. Overall 57 risk estimates were less than 1%, and 96 were in the range 1 - 2%. This was anticipated because some hazards could only occur in specific systems, e.g. the hazards relating to free-stall design only apply to Farm System Scenario 11 "Steel-roof free-stall barn and hybrids". Risk estimates of 0% were also derived more often for Farm System Scenario 1 “No off-pasture/off-crop system” as was also expected, since some hazards, e.g. air quality or walking passages, do not apply.

Figure 2: Frequency distribution of risk estimates for all potential hazards in the eleven farm system scenarios considered.



The range of the top quartile (highest risk; 138/550 data points) was 8.1 - 32.1%, with the ranges of third and second quartiles being 5.0 - 8.0% and 2.2 - 4.9%, respectively.

Individual hazards could be differentiated into two groups when their risk estimates across the eleven farm system scenarios were compared:

- Generic hazards (n=23; Table 4) where the risk estimates were similar for all farm system scenarios whether off-pasture management was used or not, and irrespective of the confinement method employed.
- System-specific hazards (n=27; Appendix 5, Tables I-III) where risk estimates for individual hazards varied between the farm system scenarios.

Table 4 lists the generic hazards in rank order of the mean risk estimate calculated across all the farm system scenarios. Seven generic hazards had risk estimates of 8.1% or greater, so were in the top (highest risk) quartile. Four of these had magnitude estimates in the top (greatest magnitude) quartile, while the remaining three were in the third quartile (Table 4). All were categorised as management/farm policy issues, while one had elements also of infrastructure and design.

Table 4: Mean risk estimate (%), 95% confidence interval (CI), category, magnitude estimate (MagEst) ranking (Q1-Q4) and uncertainty rating (low, medium, high) for generic hazards (n=23). Mean risk estimate is the average across all farm system scenarios; 95% CI is the 95% confidence interval across all farm systems scenarios; category refers to the basis of the hazard (M/P: management/farm policy-related; I/D: infrastructure/design-associated; Both: elements of both M/P and I/D. Mean risk estimates (%) for the seven hazards listed in bold type were in the top quartile of risk estimates (≥8.1%).

Hazard Description	Mean risk estimate (%)	95% CI	Category; MagEst ranking; uncertainty rating
2.4 Underfeeding	23.9	18.9-28.9	M/P; Q4; high
13.1c Failure to act on monitoring	20.5	13.5-28.4	M/P; Q4; medium
2.2a Poor feed quality – nutritive value/palatability	15.4	12.0-18.8	Both; Q3; high
13.5 Lack of planning and operational procedures	12.5	8.0-17.6	M/P; Q4; medium
13.1b Inability to recognise the abnormal	10.9	6.8-15.5	M/P; Q3; medium
13.2 With-holding therapeutic maintenance, e.g. hoof trimming	9.1	6.3-12.2	M/P; Q4; medium
13.4 Inadequate ID and recording systems	8.2	5.8-11.1	M/P; Q3; medium
13.1a Stock monitoring too infrequent	7.9	4.1-11.8	M/P; Q3; high
2.3 Improper ration composition	7.1	5.3-9.2	M/P; Q2; high
12.3 Inadequate foot bathing/foot hygiene measures	7.1	4.0-10.8	Both; Q4; high
9.2 Inadequate water quality	6.1	4.6-7.9	I/D; Q1; high
9.1b Water system cannot deliver required flow rates	5.7	3.3-8.8	I/D; Q2; high
9.1a Inadequate access to water due to overcrowding	5.3	3.0-8.3	I/D; Q3; high
9.1c Trough position inadequate	4.8	2.8-7.4	I/D; Q2; high
13.3 Poor management of down cows	4.6	2.3-6.5	M/P; Q3; high
12.1c Inadequate fly control	3.9	1.9-6.0	M/P; Q1; high
11.2 Negative human-animal interactions	3.9	2.1-5.9	M/P Q2; medium
10.2b Unsuitable surface for calving cows	2.0	1.2-3.0	I/D; Q1; high
12.2 Inability to quarantine sick animals	1.8	0.8-3.1	I/D; Q1; high
10.1 Inability to separate cows needing attention	1.7	1.2-2.3	I/D; Q1; high
12.1a Inadequate visitor biosecurity	1.4	0.7-2.5	M/P; Q1; medium
10.2a Inability to separate calving cows	1.1	0.7-1.6	I/D; Q1; high
11.1 Social stress from mixing groups	0.6	0.4-0.9	M/P; Q1; medium

Risk estimate data for the 27 system-specific hazards are presented in Appendix 5 (Table Ia&b: hazards associated with infrastructure and design (n=15), Table II: hazards associated with management and farm policy (n=6); Table III: hazards associated with elements of both infrastructure/design and management/policy (n=6)).

4.4 UNCERTAINTY ESTIMATES

The general pattern of uncertainty estimates suggests that the experts were more certain of the level of knowledge and understanding about those hazards which occurred more generally across all farm system scenarios, e.g. relating to feeding and husbandry practices.

Thirteen hazards (26%) had magnitude estimates with low uncertainty (Hazards 2.1a, 2.2b, 2.3-2.5, 4.1a&b, 5.1, 6.2, 13.1a-c and 13.3; Appendix 2) while only one (2%) had high uncertainty (Hazard 13.5). Uncertainty estimates for each magnitude estimate are listed in Table 3a-d.

There was greater uncertainty expressed, especially in the less common farm system scenarios (Table 5). While 20% (112/550 estimates) had a low level of uncertainty, 35% (191/550 estimates) had a high level of uncertainty. Uncertainty estimates for risk estimates of specific hazards within farm system scenarios are provided in Table 5 and Appendix 5 (Tables I-III).

Table 5: Number of risk estimates for which uncertainty estimates were low, medium or high within each farm system scenario considered

Farm system scenario	Low uncertainty estimates (n)	Medium uncertainty estimates (n)	High uncertainty estimates (n)
No off-pasture/crop management system used	18	20	12
Hard surface stand-off/no feeding	14	21	15
Constructed stand-off/no feeding	12	23	15
Feed pad also used for standing-off	12	19	19
Constructed stand-off with feeding	11	20	19
Steel-roofed shelter with feeding/concrete floor (slatted or solid)	8	23	19
Plastic-roofed shelter with feeding/solid concrete floor	9	23	18
Plastic-roofed shelter with feeding/slatted floor	9	23	18
Steel-roofed loose-house system with feeding	8	24	18
Plastic-roofed loose-house system with feeding	9	23	18
Steel-roofed free-stall barn and related hybrid systems with free-stalls and feeding	2	28	21

Some hazards had risk estimates with similar uncertainty estimates for all farm system scenarios. Hazards that were consistently considered to have low uncertainty estimates, irrespective of the system, were Hazards 7.1a&b and 7.4 (Appendix 2). Hazards with medium uncertainty estimates, irrespective of the system, were Hazards 2.5, 2.6, 4.1a&b, 5.2, 8.1, 8.2, 9.1b, 11.1, 12.1a, 13.1b&c, 13.2, 13.4 and 13.5 (Appendix 2). Hazards with risk estimates with high uncertainty estimates, irrespective of the system, were Hazards 2.4, 9.1c, 9.2, 10.2b, 12.2b & c and 12.2 (Appendix 2).

5. Discussion

An animal welfare risk assessment for dairy cows managed under a range of off-pasture systems in New Zealand was conducted by gathering and analysing expert opinion. Using a formal risk assessment framework, participants identified and characterised 50 hazards that might affect cows in ten off-pasture management systems as well as the traditional system in which cows are kept on pasture or crop paddocks.

Hazard characterisation involved grading the severity and duration of a single exposure to each hazard considered, and combining these to determine a magnitude estimate. The extent to which cows may be exposed in each farm system scenario was then estimated, and values combined to determine a risk estimate for each hazard in each scenario. The values of both magnitude estimates and risk estimates were then ranked and the resulting hierarchical arrangement of issues was inferred to indicate which hazards present the most risk to animal welfare.

Animal welfare risk assessment provides information that allows the risk manager to evaluate specific situations regarding the fulfilment of animal needs so that welfare standards can be optimised within each farm system by either improving aspects of infrastructure and design, or by implementation of specific management policies and procedures.

5.1 DIVERGENT OPINIONS, VARIABILITY AND UNCERTAINTY

The EFSA welfare assessment process achieved a consensus view through a series of discussions by a panel of welfare scientists. Once consensus had been reached, there was no variance in opinion to report. While the process used in the analysis described here did attempt to converge opinion through an iterative process at Step 2, this was not effective. Instead variance estimates were calculated and reflect differences of opinion. This alternative approach was taken for several reasons.

Firstly, there are few people in New Zealand with specialist knowledge of management systems that include off-pasture management. Accordingly the panel was derived from a base with a wider industry perspective and included veterinary practitioners, farm advisors and facility designers, as well as welfare scientists. The opportunity to bring this more disparate grouping to consensus was limited within the time-frame available, and given the polarisation of views amongst the individuals involved, might never have been achievable.

Secondly, the New Zealand situation proved to be complex because there is considerable variability, depending on circumstances such as farm size and location, in the off-pasture management systems being adopted by farmers. By contrast, farm systems in Europe incorporate higher levels of confinement and are generally more standardised in their application. The EFSA panel considered cows kept in four farm system scenarios (free-stall barns, tie-stalls, straw yards and pasture) while eleven farm system scenarios were considered here, with a total of 30 variations identified when use patterns were also considered which greatly increased the complexity of the panel’s deliberations.

Results also need to be interpreted in light of the uncertainty levels expressed by panel members. While low levels of uncertainty were expressed about both magnitude and risk estimates for some hazards, panel members were less certain about others, especially those that are occurring in emergent farm systems with which some panel members were less familiar. Interpretation of the welfare risk assessment must be done in light of this expression of uncertainty.

Due to these issues, the decision was made in collaboration with the statistician that the best approach to understanding the output of the welfare risk assessment would be by non-parametric analysis, i.e. using the rank order of the magnitude and risk estimates to establish hierarchies. With the caveat that the variance measures could not differentiate statistically between many of the hazards, the hierarchies identify which hazards were considered to be of most importance to manage in order to protect animal welfare.

5.2 AN APPROACH TO FINDING SOLUTIONS

Farm system design is currently in a state of change as hybrid systems evolve that combine pasture-based management with varying levels of confinement to manage specific seasonal issues. New Zealand dairy farmers, as free agents with a high level of personal inventiveness, are always exploring ways to improve pasture and feed management. The integration of grazed pasture or crops into the feed supply remains a core component of resource-efficient and cost-effective milk production, and the principle that the cow should harvest the greater proportion of her feed herself, influences the nature of management systems being developed. Within this context, management systems that incorporate some degree of confinement are emerging strategies to achieve sustainable farming outcomes.

Hazards naturally fall into groupings according to their origin, i.e. issues of farm infrastructure and facility design and issues of farm management practices and policy. These are inextricably linked to the delivery of conditions for animals within each farm system. Improving farm infrastructure and having good design will relieve many of the hazards identified, while poor design will have long term consequences, even with excellent management. Good design may reduce the need for operational procedures and good forward planning, but good operators that are well aware of their cows' needs and who implement strict management policies to ensure these are met, can achieve good results even where infrastructure or design is less satisfactory.

5.2.1. Generic hazards

A number of generic hazards were identified for which risk estimates indicated a similar probability of occurrence irrespective of the farm system scenario considered (Table 4).

Table 6: Minimum standards from the Animal Welfare (Dairy Cattle) Code of Welfare 2010 (Anonymous, 2010a) as they apply to the hazards which were considered generic, i.e. having similar risk estimates, irrespective of the farm system scenario.

Hazard Description	Relevant Minimum Standard
2.4 Underfeeding	MS 2 - Food
13.1c Failure to act on monitoring	MS 19 - Health
2.2a Poor feed quality – nutritive value/palatability	MS 2 - Food
13.5 Lack of planning and operational procedures	MS 1 - Stockmanship
13.1b Inability to recognise the abnormal	MS 19 - Health
13.2 With-holding therapeutic maintenance, e.g. hoof trimming	MS 19 - Health
13.4 Inadequate ID and recording systems	MS 1 - Stockmanship
13.1a Stock monitoring too infrequent	MS 1 - Stockmanship
2.3 Improper ration composition	MS 2 - Food
12.3 Inadequate foot bathing/foot hygiene measures	MS 19 - Health
9.2 Inadequate water quality	MS 5 - Water
9.1b Water system cannot deliver required flow rates	MS 5 - Water
9.1a Inadequate access to water due to overcrowding	MS 5 - Water
9.1c Trough position inadequate	MS 5 - Water
13.3 Poor management of down cows	MS 16 – Caring for recumbent cows
12.1c Inadequate fly control	MS 19 - Health
11.2 Negative human-animal interactions	MS 10 – Stock handling
10.2b Unsuitable surface for calving cows	Not covered
12.2 Inability to quarantine sick animals	Not covered
10.1 Inability to separate cows needing attention	Not covered
12.1a Inadequate visitor biosecurity	Not covered
10.2a Inability to separate calving cows	Not covered
11.1 Social stress from mixing groups	Not covered

Thirteen hazards were categorised as farm management/policy issues, eight as infrastructure/design issues, and two contained elements of both. The hazard with the highest magnitude estimate (Hazard 13c "Failure to act on monitoring") was a generic hazard. Eight of the generic hazards had magnitude estimates that ranked them into the third or fourth quartiles.

Given that these hazards apply across all farm system scenarios, including Farm System Scenario 1 "No off-pasture/off-crop", solutions should be sought at a more general level. Their appearance likely reflects the experts' views that these are key issues to address as part of improving general husbandry practice across the full range of New Zealand farming systems.

Many of the generic issues identified are already subject to regulation within the Animal Welfare (Dairy Cattle) Code of Welfare 2010 (Anonymous, 2010a) which specifies minimum standards for the care of dairy cattle. Relevant minimum standards apply to the seventeen highest ranking generic hazards (Table 6) leaving a balance of six which are not specifically covered. Stockmanship, provision of feed and water, and herd health are all subjects of considerable effort in industry extension and education/training programmes. It is debatable whether further regulation would improve their management.

5.2.2. System-specific hazards

The animal welfare risk assessment further identified a number of hazards for which risk estimates showed significant system-specific variation (Appendix 5; Tables I-III). These lists comprise the key issues to be addressed within each system considered. It is important that these potential animal welfare hazards are identified and appropriate mechanisms are put in place to ensure that cow welfare is protected.

As with the generic hazards, many of these issues are already covered by Minimum Standards in the Animal Welfare (Dairy Cattle) Code of Welfare 2010 (Anonymous, 2010) as follows:

- Minimum Standard 6 - Shelter
- Minimum Standard 7 - Farm Facilities
- Minimum Standard 8 - Stand-off Areas and Feed pads
- Minimum Standard 9 – Housing Cows and Calves

The focus and intent of Minimum Standards in New Zealand Codes of Welfare are based on a key principle of animal welfare science that wherever possible the measures of welfare delivery should be based on the outcomes for the animals concerned. This principle recognises firstly that the outcome of any system for an animal is best measured in terms of its impact on the animal itself. Simple provision of specific resources, e.g. through sound infrastructure and farm design, does not necessarily produce the desired outcomes for animals. Secondly it recognises that good welfare can be delivered in a number of ways within any system, and good management and appropriate farm policy can resolve issues where resources may be limited.

The rapid evolution of housing systems and their associated management practices were recognised when the Dairy Cattle Code of Welfare (Anonymous, 2010a) was released. In its report accompanying the code (Anonymous, 2010b), the National Animal Welfare Advisory Committee (NAWAC) recognised that although information about management of cows in housing systems overseas should be considered cautionary, it may have limited relevancy as the nature of housing and its patterns of use in New Zealand are unique. Rather NAWAC endeavoured to set standards that were flexible and based on animals' requirements to achieve satisfactory lying times as adequate rest makes a significant contribution to the comfort and well-being of dairy cows in systems where there are periods of confinement.

Floor characteristics, provision of bedding and spacing allowances were all recognised as important components in providing a comfortable area for cows to lie down; hence NAWAC provided a Minimum Standard that should meet the welfare needs of animals in a range of housing and management systems (Anonymous, 2010b). Minimum Standard 8 (Stand-off Areas and Feed pads) states that "Dairy cattle must be able to lie down and rest comfortably for sufficient periods to meet their behavioural needs." Minimum Standard 9 (Housing Cows and Calves) repeats this requirement, and further specifies that construction and maintenance of facilities must ensure no hazards are likely to cause injury, and that ventilation must be sufficient to prevent harmful gas build-up.

The Minimum Standards outlined above provide a foundation for the management of cows in systems with varying degrees of confinement. Most (15/27) hazards with risk estimates in the top (highest risk) quartile related to infrastructure and facility design issues (Appendix 5, Tables Ia-b). Two of these (Hazard 3.1: Poor air quality; Hazard 5.2: Lying areas crowded) are both addressed by existing Minimum Standards. Design of feeding facilities is one area that is not specifically addressed, but could be construed as covered by Minimum Standard 9 (construction and maintenance must ensure no hazards are likely to cause injury).

Hazard 6.1a (Free-stall design poor) and hazards associated with walking passages in free-stall barns likewise are not specifically addressed in Minimum Standards of the Welfare Code. The problem here however, is that it is difficult to make specific recommendations. The wide ranging aspects of free-stall design identified at Step 1 by the Expert Panel are laid out in Table 7.

These hazards are all well recognised in overseas systems and considerable research has been invested in finding ways to manage the issues arising. While modern free-stall designs mitigate many of the issues, some are not easily resolved. In the end it is the vigilance of the stock handlers and their ability to recognise when a cow encounters difficulty with the system that is important. Furthermore, while guidelines for matters such as free-stall size can be determined, they may not be suitable, or may even be detrimental, if imposed through a regulatory mechanism. For example, New Zealand dairy cows can vary greatly in size. Specifying stall sizes to meet the needs of the largest cows (600 kg) will not meet the needs of smaller cows (400 kg) who may rather utilise the extra space provided to stand back-to-front in the stall leading to contamination of the bedding area and further issues consequent to that.

Table 7: Specific hazards identified for free-stall design

Hazard description	Adverse effect
Lying space too short	Cow hangs over end of kerb when sitting or sits half-in; too little rest, too much standing; udder injury; mastitis, poor milking hygiene; behaviour disruption, pain, fear
Lying space too narrow	Unwilling to lie down; too little rest, too much standing; injuries from contact with sidebars
Inadequate lunge space	Unwilling to lie down; too little rest; difficulty standing
Dividers too high at the shoulder	Cows may sit in wrong alignment in free-stall; increased soiling of stall; unwilling to lie down; too little rest; difficulty standing; injuries; mastitis
Dividers too low at the level of the hind limbs	Difficulty standing; cows may be trapped under divider; unwilling to lie down; too little rest; injuries
Projections and supports in the wrong place	Difficulty standing; injuries
Brisket locators too high	Difficulty standing; unwilling to lie down; too little rest
Brisket locators too hard	Cows reluctant to sit forward in free-stall; unwilling to lie down; too little rest; difficulty standing; brisket injuries
Brisket locators have space underneath	Cows may get a foot trapped under brisket locator; difficulty standing; injuries
Forward locator absent or wrongly placed	Cow sits forward in stall - stall becomes contaminated; difficulty standing; unwilling to lie down; too little rest; injuries; mastitis, poor milking hygiene
Neck/wither rail wrongly placed	Difficulty positioning for lying and standing; unwilling to lie down; too little rest; injuries

5.2.3. Developing management protocols and guidelines for infrastructure and design

Tables 8a-f present, on a system-by-system basis, those hazards that the Expert Panel considered to represent the greatest risk to cows. These lists collate both generic and system-specific hazards and their ranking based on risk estimates provides a hierarchy of importance for their resolution. They should underpin the development of future recommendations and standards, as well as being the basis for the development of dairy industry extension programmes.

As discussed above, many of the generic issues are already covered in a regulatory sense. Addressing of issues relating to infrastructure and design may be better served by developing specifications for the design and engineering of off-pasture confinement areas. In this regard, one of the major problems facing the industry as it adopts off-pasture systems is that many farmers and most farm workers have little experience and skill in their management. This may be the single most important issue to be resolved if these systems are to provide long term solutions to improve environmental management while protecting cow welfare.

Table 8a: Risk estimates (%),95% confidence intervals (95% CI), category, magnitude estimate (MagEst) ranking (Q1-Q4), risk type (generic or system-specific) and uncertainty rating (low, medium, high) for hazards in the top quartile for Farm System Scenarios 1 (No off-pasture/off-crop; n=8) and 2 (Hard surface stand-off; no feeding; n=12). Category refers to whether the issue is management and farm policy-related (M/P), infrastructure and design-associated (I/D); or elements of both (Both).

Hazard	Risk estimate (%; 95% CI)	Category; MagEst ranking; Risk type; Uncertainty rating
1 No off-pasture/off-crop		
2.4 Underfeeding	23.9 (18.9-28.9)	M/P; Q4; generic; high
13.1c Failure to act on monitoring	20.5 (13.5-28.4)	M/P; Q4; generic; medium
2.2a Poor feed quality – nutritive value/palatability	15.4 (12.0-18.8)	Both; Q3; generic; low
13.5 Lack of planning and operational procedures	12.5 (8.0-17.6)	M/P; Q4; generic; medium
13.1b Inability to recognise the abnormal	10.9 (6.8-15.5)	M/P; Q3; generic; medium
5.1 Inadequate bedding	9.2 (6.3-12.2)	Both; Q4; system specific; medium
13.2 With-holding therapeutic maintenance, e.g. hoof trimming	9.1 (6.3-12.2)	M/P; Q4; generic; medium
8.2 Inadequate ID and recording systems	8.2 (5.8-11.1)	M/P; Q3; generic; medium
2 Hard surface stand-off; no feeding		
5.1 Inadequate bedding	32.1 (27.5-37.1)	Both; Q4; system specific; low
2.4 Underfeeding	23.9 (18.9-28.9)	M/P; Q4; generic; high
13.1c Failure to act on monitoring	20.5 (13.5-28.4)	M/P; Q4; generic; medium
2.2a Poor feed quality – nutritive value/palatability	15.4 (12.0-18.8)	Both; Q3; generic; medium
13.5 Lack of planning and operational procedures	12.5 (8.0-17.6)	M/P; Q4; generic; medium
7.2 Walking passages surface poor	12.2 (8.6-16.6)	I/D; Q4; system specific; low
5.2 Lying areas crowded	11.1 (8.9-13.6)	I/D; Q2; system specific; medium
13.1b Inability to recognise the abnormal	10.9 (6.8-15.5)	M/P; Q3; generic; medium
7.4 Manure removal from walking passages poor	10.2 (6.8-14.5)	Both; Q3; system specific; low
13.2 With-holding therapeutic maintenance, e.g. hoof trimming	9.1 (6.3-12.2)	M/P; Q4; generic; medium
8.1 Facility entrance poorly maintained	8.7 (5.7-12.6)	I/D; Q3; system specific; medium
8.2 Inadequate ID and recording systems	8.2 (5.8-11.1)	M/P; Q3; generic; medium

Table 8b: Risk estimates (%),95% confidence intervals (95% CI), category, magnitude estimate (MagEst) ranking (Q1-Q4), risk type (generic or system-specific) and uncertainty rating (low, medium, high) for hazards in the top quartile for Farm System Scenarios 3 (constructed stand-off; no feeding; n=10) and 4 (Feedpad used for stand-off; n=13). Category refers to whether the issue is management and farm policy-related (M/P), infrastructure and design-associated (I/D); or elements of both (Both).

Hazard	Risk estimate	Category; MagEst rating; Risk type; Uncertainty rating
3 Constructed stand-off; no feeding		
2.4 Underfeeding	23.9 (18.9-28.9)	M/P; Q4; generic; high
5.1 Inadequate bedding	23.7 (18.5-28.7)	Both; Q4; system specific; medium
13.1c Failure to act on monitoring	20.5 (13.5-28.4)	M/P; Q4; generic; medium
2.2a Poor feed quality – nutritive value/palatability	15.4 (12.0-18.8)	Both; Q3; generic; medium
13.5 Lack of planning and operational procedures	12.5 (8.0-17.6)	M/P; Q4; generic; medium
13.1b Inability to recognise the abnormal	10.9 (6.8-15.5)	M/P; Q3; generic; medium
13.2 With-holding therapeutic maintenance, e.g. hoof trimming	9.1 (6.3-12.2)	M/P; Q4; generic; medium
7.4 Manure removal from walking passages poor	9.0 (6.0-13.0)	Both; Q3; system specific; low
5.2 Lying areas crowded	8.7 (6.9-10.7)	I/D; Q2; system specific; medium
8.2 Inadequate ID and recording systems	8.2 (5.8-11.1)	M/P; Q3; generic; medium
4 Feed pad used for stand-off		
5.1 Inadequate bedding	30.6 (26.5-35.3)	Both; Q4; system specific; low
2.4 Underfeeding	23.9 (18.9-28.9)	M/P; Q4; generic; high
13.1c Failure to act on monitoring	20.5 (13.5-28.4)	M/P; Q4; generic; medium
2.2a Poor feed quality – nutritive value/palatability	15.4 (12.0-18.8)	Both; Q3; generic; high
2.1b Inadequate feeding facilities – poor position/design	15.1 (10.5-19.9)	I/D; Q4; system specific; high
13.5 Lack of planning and operational procedures	12.5 (8.0-17.6)	M/P; Q4; generic; medium
7.2 Walking passages surface poor	12.2 (8.6-16.7)	I/D; Q4; system specific; low
13.1b Inability to recognise the abnormal	10.9 (6.8-15.5)	M/P; Q3; generic; medium
5.2 Lying areas crowded	9.6 (7.5-12.1)	I/D; Q2; systems vary; medium
7.4 Manure removal from walking passages poor	9.5 (6.3-13.8)	Both; Q3; system specific; low
13.2 With-holding therapeutic maintenance, e.g. hoof trimming	9.1 (6.3-12.2)	M/P; Q4; generic; medium
8.1 Facility entrance poorly maintained	8.5 (5.5-12.2)	I/D; Q3; system specific; medium
8.2 Inadequate ID and recording systems	8.2 (5.8-11.1)	M/P; Q3; generic; medium

Table 8c: Risk estimates (%),95% confidence intervals (95% CI), category, magnitude estimate (MagEst) ranking (Q1-Q4), risk type (generic or system-specific) and uncertainty rating (low, medium, high) for hazards in the top quartile for Farm System Scenarios 5 (constructed stand-off with feeding; n=12) and 6 (Steel roof shelter; concrete floor (slatted or solid); n=14). Category refers to whether the issue is management and farm policy-related (M/P), infrastructure and design-associated (I/D); or elements of both (Both).

Hazard	Risk estimate	Category; MagEst ranking; Risk type; Uncertainty rating
5 Constructed stand-off with feeding		
2.4 Underfeeding	23.9 (18.9-28.9)	M/P; Q4; generic; high
5.1 Inadequate bedding	22.8 (18.2-27.9)	Both; Q4; system specific; medium
13.1c Failure to act on monitoring	20.5 (13.5-28.4)	M/P; Q4; generic; medium
2.1b Inadequate feeding facilities – poor position/design	15.5 (10.6-20.6)	I/D; Q4; system specific; medium
2.2a Poor feed quality – nutritive value/palatability	15.4 (12.0-18.8)	Both; Q3; generic; high
13.5 Lack of planning and operational procedures	12.5 (8.0-17.6)	M/P; Q4; generic; medium
13.1b Inability to recognise the abnormal	10.9 (6.8-15.5)	M/P; Q3; generic; medium
13.2 With-holding therapeutic maintenance	9.1 (6.3-12.2)	M/P; Q4; generic; medium
7.4 Manure removal from walking passages poor	8.6 (5.4-12.6)	Both; Q3; system specific; low
5.2 Lying areas crowded	8.7 (6.9-10.7)	I/D; Q2; system specific; medium
2.1a Inadequate feed facility – too few spaces	8.2 (5.0-11.7)	I/D; Q4; system specific; high
8.2 Inadequate ID and recording systems	8.2 (5.8-11.1)	M/P; Q3; generic; medium
6 Steel roofed shelter/concrete floor (solid/slatted)		
5.1 Inadequate bedding	30.4 (25.4-35.9)	Both; Q4; system specific; medium
2.4 Underfeeding	23.9 (18.9-28.9)	M/P; Q4; generic; high
13.1c Failure to act on monitoring	20.5 (13.5-28.4)	M/P; Q4; generic; medium
2.1b Inadequate feeding facilities – poor position/design	17.4 (12.6-22.4)	I/D; Q4; system specific; medium
2.2a Poor feed quality – nutritive value/palatability	15.4 (12.0-18.8)	Both; Q3; generic; high
13.5 Lack of planning and operational procs	12.5 (8.0-17.6)	M/P; Q4; generic; medium
7.2 Walking passages surface poor	12.1 (8.7-16.2)	I/D; Q4; system specific; low
13.1b Inability to recognise the abnormal	10.9 (6.8-15.5)	M/P; Q3; generic; medium
3.1 Poor air quality (ammonia, dust, aerosols)	9.7 (4.6-15.5)	I/D; Q4; system specific; medium
1.1b Insufficient light – too dark for handlers	9.6 (5.0-14.3)	I/D; Q2; system specific; medium
13.2 With-holding therapeutic maintenance	9.1 (6.3-12.2)	M/P; Q4; generic; medium
7.4 Manure removal from walking passages poor	8.6 (5.4-12.6)	Both; Q3; system specific; low
2.1a Inadequate feed facility – too few spaces	8.2 (5.2-11.6)	I/D; Q4; system specific; high
8.2 Inadequate ID and recording systems	8.2 (5.8-11.1)	M/P; Q3; generic; medium

Table 8d: Risk estimates (%),95% confidence intervals (95% CI), category, magnitude estimate (MagEst) ranking (Q1-Q4), risk type (generic or system-specific) and uncertainty rating (low, medium, high) for hazards in the top quartile for Farm System Scenarios 7 (plastic roofed shelter; solid concrete floor; n=12) and 8 (Plastic roof shelter; slatted floor); n=11). Category refers to whether the issue is management and farm policy-related (M/P), infrastructure and design-associated (I/D); or elements of both (Both).

Hazard	Risk estimate	Category; MagEst ranking; Risk type; Uncertainty rating
7 Plastic roofed shelter; solid concrete floor		
5.1 Inadequate bedding	29.4 (24.1-35.3)	Both; Q4; system specific; low
2.4 Underfeeding	23.9 (18.9-28.9)	M/P; Q4; generic; high
13.1c Failure to act on monitoring	20.5 (13.5-28.4)	M/P; Q4; generic; medium
2.1b Inadequate feeding facilities – poor position/design	17.3 (12.5-22.4)	I/D; Q4; system specific; medium
2.2a Poor feed quality – nutritive value/palatability	15.4 (12.0-18.8)	Both; Q3; generic; high
13.5 Lack of planning and operational procedures	12.5 (8.0-17.6)	M/P; Q4; generic; medium
7.2 Walking passages surface poor	12.1 (8.7-16.2)	I/D; Q4; system specific; low
13.1b Inability to recognise the abnormal	10.9 (6.8-15.5)	M/P; Q3; generic; medium
3.1 Poor air quality (ammonia, dust, aerosols)	10.4 (5.6-16.1)	I/D; Q4; system specific; medium
13.2 With-holding therapeutic maintenance, e.g. hoof trimming	9.1 (6.3-12.2)	M/P; Q4; generic; medium
7.4 Manure removal from walking passages poor	8.6 (5.4-12.6)	Both; Q3; system specific; low
8.2 Inadequate ID and recording systems	8.2 (5.8-11.1)	M/P; Q3; generic; medium
8 Plastic roof shelter; slatted floor		
5.1 Inadequate bedding	29.5 (24.2-35.3)	Both; Q4; system specific; low
2.4 Underfeeding	23.9 (18.9-28.9)	M/P; Q4; generic; high
13.1c Failure to act on monitoring	20.5 (13.5-28.4)	M/P; Q4; generic; medium
2.1b Inadequate feeding facilities – poor position/design	16.8 (12.3-21.6)	I/D; Q4; system specific; medium
2.2a Poor feed quality – nutritive value/palatability	15.4 (12.0-18.8)	Both; Q3; generic; high
13.5 Lack of planning and operational procedures	12.5 (8.0-17.6)	M/P; Q4; generic; medium
7.2 Walking passages surface poor	11.0 (8.1-14.5)	I/D; Q4; system specific; low
13.1b Inability to recognise the abnormal	10.9 (6.8-15.5)	M/P; Q3; generic; medium
3.1 Poor air quality (ammonia, dust, aerosols)	9.9 (5.3-15.5)	I/D; Q4; system specific; medium
13.2 With-holding therapeutic maintenance, e.g. hoof trimming	9.1 (6.3-12.2)	M/P; Q4; generic; medium
8.2 Inadequate ID and recording systems	8.2 (5.8-11.1)	M/P; Q3; generic; medium

Table 8e: Risk estimates (%),95% confidence intervals (95% CI), category, magnitude estimate (MagEst) ranking (Q1-Q4), risk type (generic or system-specific) and uncertainty rating (low, medium, high) for hazards in the top quartile for Farm System Scenarios 9 (Steel roof loose-house; n=13) and 10 (Plastic roof loose-house; n=13). Category refers to whether the issue is management and farm policy-related (M/P), infrastructure and design-associated (I/D); or elements of both (Both).

Hazard	Risk estimate	Category; MagEst ranking; Risk type; Uncertainty rating
9 Steel roof loose-house		
2.4 Underfeeding	23.9 (18.9-28.9)	M/P; Q4; generic; high
5.1 Inadequate bedding	23.4 (19.5-27.6)	Both; Q4; system specific; medium
13.1c Failure to act on monitoring	20.5 (13.5-28.4)	M/P; Q4; generic; medium
2.1b Inadequate feeding facilities – poor position/design	17.1 (12.6-21.9)	I/D; Q4; system specific; high
2.2a Poor feed quality – nutritive value/palatability	15.4 (12.0-18.8)	Both; Q3; generic; medium
13.5 Lack of planning and operational procs	12.5 (8.0-17.6)	M/P; Q4; generic; medium
3.1 Poor air quality (ammonia, dust, aerosols)	12.4 (6.5-19.1)	I/D; Q4; system specific; medium
7.2 Walking passages surface poor	12.1 (8.7-16.2)	I/D; Q4; system specific; low
13.1b Inability to recognise the abnormal	10.9 (6.8-15.5)	M/P; Q3; generic; medium
13.2 With-holding therapeutic maintenance	9.1 (6.3-12.2)	M/P; Q4; generic; medium
7.4 Manure removal from walking passages poor	8.7 (5.4-12.6)	Both; Q3; system specific; low
7.1a Walking passages too narrow	8.3 (5.2-12.2)	I/D; Q4; system specific; low
8.2 Inadequate ID and recording systems	8.2 (5.8-11.1)	M/P; Q3; generic; medium
10 Plastic roof loose-house		
2.4 Underfeeding	23.9 (18.9-28.9)	M/P; Q4; generic; high
5.1 Inadequate bedding	22.5 (18.2-27.0)	Both; Q4; system specific; low
13.1c Failure to act on monitoring	20.5 (13.5-28.4)	M/P; Q4; generic; medium
2.1b Inadequate feeding facilities – poor position/design	17.5 (12.9-22.2)	I/D; Q4; system specific; medium
2.2a Poor feed quality – nutritive value/palatability	15.4 (12.0-18.8)	Both; Q3; generic; high
3.1 Poor air quality (ammonia, dust, aerosols)	13.9 (7.8-20.6)	I/D; Q4; system specific; medium
7.2 Walking passages surface poor	12.8 (9.2-17.0)	I/D; Q4; system specific; low
13.5 Lack of planning and operational procs	12.5 (8.0-17.6)	M/P; Q4; generic; medium
13.1b Inability to recognise the abnormal	10.9 (6.8-15.5)	M/P; Q3; generic; medium
7.4 Manure removal from walking passages poor	9.4 (6.0-13.5)	Both; Q3; system specific; low
13.2 With-holding therapeutic maintenance	9.1 (6.3-12.2)	M/P; Q4; generic; medium
7.1a Walking passages too narrow	8.3 (5.2-12.2)	I/D; Q4; system specific; low
8.2 Inadequate ID and recording systems	8.2 (5.8-11.1)	M/P; Q3; generic; medium

Table 8f: Risk estimates (%),95% confidence intervals (95% CI), category, magnitude estimate (MagEst) ranking (Q1-Q4), risk type (generic or system-specific) and uncertainty rating (low, medium, high) for hazards in the top quartile for Farm System Scenarios 11 (Barn systems with free-stalls; n=19). Category refers to whether the issue is management and farm policy-related (M/P), infrastructure and design-associated (I/D); or elements of both (Both).

Hazard	Risk estimate	Category; MagEst ranking; Risk type; Uncertainty rating
11 Barn systems with free-stalls		
6.1a Free-stall design poor	23.9 (17.9-30.4)	I/D; Q4; system specific; low
2.4 Underfeeding	23.9 (18.9-28.9)	M/P; Q4; generic; high
13.1c Failure to act on monitoring	20.5 (13.5-28.4)	M/P; Q4; generic; medium
5.1 Inadequate bedding	19.8 (15.5-24.5)	Both; Q4; system specific; low
2.1b Inadequate feeding facilities – poor position/design	17.8 (12.8-23.1)	I/D; Q4; system specific; medium
2.2a Poor feed quality – nutritive value/palatability	15.4 (12.0-18.8)	Both; Q3; generic; high
13.5 Lack of planning and operational procs	12.5 (8.0-17.6)	M/P; Q4; generic; medium
3.1 Poor air quality (ammonia, dust, aerosols)	12.5 (6.4-18.9)	I/D; Q4; system specific; medium
7.1a Walking passages too narrow	11.5 (7.4-16.8)	I/D; Q4; system specific; medium
7.2 Walking passages surface poor	11.5 (7.7-16.1)	I/D; Q4; system specific; medium
13.1b Inability to recognise the abnormal	10.9 (6.8-15.5)	M/P; Q3; generic; medium
1.1b Insufficient light – too dark for handlers	10.3 (6.1-14.7)	I/D; Q2; system specific; medium
7.4 Manure removal from walking passages poor	9.9 (6.6-14.1)	Both; Q3; system specific; medium
7.3 Walking passages too crowded	9.4 (5.9-13.6)	I/D; Q3; system specific; medium
13.2 With-holding therapeutic maintenance, e.g. hoof trimming	9.1 (6.3-12.2)	M/P; Q4; generic; medium
7.1b Insufficient cross-overs in walking passages	9.1 (5.6-13.3)	I/D; Q4; system specific; medium
6.1b Free-stall maintenance poor	8.7 (5.6-12.1)	I/D; Q3; system specific; high
8.2 Inadequate ID and recording systems	8.2 (5.8-11.1)	M/P; Q3; generic; medium
2.1a Inadequate feeding facilities – too few spaces	8.1 (5.0-11.5)	I/D; Q4; system specific; medium

5.3 REPEATED EXPOSURE AND CUMULATIVE IMPACTS

The methodology enabled a list of defined hazards to be ranked according to their relative importance to the cow as perceived by the Expert Panel, but the approach was based on the use of a common unit of currency (severity unit.day) to represent the cost of each hazard's impact. This approach is very simplistic and its validity is arguable. In many instances animals are exposed to more than one hazard simultaneously, and hazards are often inter-connected, especially those relating to infrastructure and design. Furthermore the use patterns for confinement systems are such that exposure is often repeated over consecutive days (Appendix 2, Table I).

Severity ratings should therefore include a consideration of the cumulative impact of multiple hazards. For example, a subordinate cow within a herd is more likely to be exposed to social stresses which may interact at the feed table to reduce feed intake, reduce that animal's willingness to access water, and also reduce her lying times; but these cumulative effects are not recognised in the methodology as implemented. While a common unit has been generated to derive the magnitude estimates, this should not be taken to imply that hazards might be additive or even multipliable.

Severity ratings should also take account of the varying lengths of exposure in different systems if the total impact of each system is to be compared. Some hazards will have cumulative effects, e.g. hazards that lead to reduced lying time may be tolerable for 1 or 2 days, but if animals are exposed continuously for 60 days, then the cumulative nature of the insult may produce a more severe effect.

5.4 OTHER POINTS AND ISSUES

The assessments for hazards that affect only a small number of individual animals do not rank in the higher quartiles either for magnitude estimate and risk estimate, yet for the individual cow they may in fact be extreme, e.g. the hazards relating to provision for calving and down cows. This is an artefact of the way that assessments were made, but their importance for the individual animal means that they also must be regarded as hazards for which solutions are required.

One concern expressed by several panel members in relation to infrastructure was that there is a tendency for New Zealand farmers to develop their systems by altering pre-existing facilities on the farm, e.g. converting old hay barns or sheep-farming facilities into cow barns. The experience is that many of these result in unsatisfactory systems for cows, often associated with poor ventilation and/or lack of light. Poor ventilation especially becomes an issue as it can also influence the moisture content of bedding leading to a range of health and welfare issues, especially for lactating cows for whom clean dry bedding is required for mastitis management.

6. Acknowledgements

The author would like to acknowledge the experts identified in Appendix 1 that provided the data for the welfare risk analysis. Their knowledge of off-pasture systems has been fundamental to the results, and they have provided valuable commentary about the issues being considered.

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7. Appendices

7.1 APPENDIX 1: EXPERT PANEL COMPOSITION

The following participants are acknowledged for their contribution to the welfare risk analysis:

1. Dr Richard Laven, Massey University, Palmerston North – veterinarian; special interest in lameness

2. Dr Sue Macky, Dairy Production Systems, Hamilton – veterinarian; adviser in dairy cattle nutrition, dairying systems and animal husbandry

3. Dr Mark Bryan, VetSouth, Winton – veterinarian; special interest in dairy cattle wintering systems

4. Prof Kevin Stafford, Massey University, Palmerston North – animal welfare specialist

5. Dr Lindsay Matthews, AgResearch, Hamilton – animal ethologist and welfare scientist

6. Dr Jim Webster, AgResearch, Hamilton – animal ethologist and welfare scientist

7. Dr Mark Fisher, Kotare Bioethics, Hastings – agricultural ethics and welfare specialist

8. Mr Chris Glassey, DairyNZ, Hamilton - dairy farm systems scientist

9. Mr Jakob Kleinmans, Genetic Technologies, Auckland – adviser in dairy cattle nutrition; international experience with dairy housing systems

10. Ms Charlotte Rutherford, Fonterra, Hamilton – Programme manager (Sustainability)

11. Ms Katrina Lee, DeLaval Pty Ltd, Solution Manager Farm Supply and Barn Equipment, Sales company SANZA, Melbourne – extensive practical experience in farming systems world-wide

12. Mr Tom Pow, Herd Homes Ltd, Whangarei – farmer and Principal of Herd Homes® Ltd; extensive practical experience in managing animals in Herd Home® shelters

13. Mr Harmen Heesen, Cow House Ltd (subsidiary of Technipharm), Putaruru – supplier of farm equipment and housing systems in New Zealand

14. Dr Virginia Williams, NZVA, Canterbury – veterinary welfare specialist

15. Dr Kate Littin, AW Directorate, Biosecurity New Zealand, Wellington – welfare specialist

16. Dr Eric Hillerton, Chief Scientist, DairyNZ, Hamilton – dairy production systems scientist with extensive overseas experience in mastitis management

7.2 TERMS OF REFERENCE AND WORKSHEET DOCUMENTS

Distributed to Expert Panel members in preparation for the risk assessment procedure:

Risk assessment: Terms of Reference

Background:
MAF has commissioned an animal welfare risk assessment of the use of off-pasture management systems for dairy cows. The process will be conducted using a similar approach to that adopted by the European Food Safety Authority (EFSA) in developing their opinion in 2009 in which an Animal Welfare Risk Framework was developed based on formal risk assessment principles. This involves hazard and risk characterisation, and an assessment of the level of exposure to these risks within a range of farm system scenarios.

Developing the Animal Welfare Risk Framework:
Objective: To understand the hazards[1] that lead to disease or other causes of poor welfare in dairy cows managed under current and near-future off-pasture management systems.
Risk assessment is a systematic, scientifically-based process to estimate the likelihood and severity of impact of a supposed hazard. The process is used extensively by Codex Alimentarius (WHO) to determine risks to food safety. The EFSA Animal Health and Welfare Panel developed this process and used it to analyse risks to animal welfare in a series of defined steps:

Step 1: Scenario definition – the specific farm systems scenarios to be included at Step 3 are developed and agreed by the Expert Panel.
Step 2: Hazard identification and characterisation – the potential welfare hazards are described and the general impact of exposure of dairy cows are estimated. The level of uncertainty of the accuracy of available knowledge is also evaluated.
Step 3: Exposure assessment – the degree of exposure of the animals to each potential hazard is evaluated for each farm system scenario.
Step 4: Data analysis (risk characterisation) – this is a statistical calculation process which combines the expert opinions and will be completed after panel members have undertaken Steps 1-3.

[1] A **hazard** to animal welfare is defined as a system-design criterion with potential to cause a negative animal welfare effect as measured by one or more indicators. In this context, system-design criteria relate to the full range of animal-environment interactions resulting from factors of animal management/husbandry or facility design.

Step 1: Definition of Farm System Scenarios

Objective: to identify the farm system scenarios to be considered in Step 3.

Off-pasture facilities can be broadly categorised by their design/construction and use patterns. New Zealand off-pasture confinement systems can be placed into seven broad categories according to their general design and construction[2], and the degree to which they provide resources for the animals, i.e. feeding facilities, shelter from a roof, and bedding. Table 1 describes the seven categories and their provision of resources.

Confinement System	***Feeding***	***Roof***	***Bedding***
1 "Hard" surface stand-off without feeding	*N*	*N*	*N*
2 Constructed stand-off without feeding	*N*	*N*	*Y*
3 Feed pad also used for standing-off	*Y*	*N*	*N*
4 Constructed stand-off with feeding	*Y*	*N*	*Y*
5 Roofed shelter with slatted floor and feeding	*Y*	*Y*	*Y/N*
6 Roofed loose-house system with feeding	*Y*	*Y*	*Y*
7 Roofed free-stall barn and related hybrid systems	*Y*	*Y*	*Y*

Table 1: Summary of provision of feeding facilities, overhead shelter and bedding materials in the seven confinement system categories

[2] Specific details of design and construction are variable but seven distinct facilities can be recognised:

1. "Hard surface" stand-off areas without roof, feeding area or provision of bedding material, e.g. concrete dairy yards and areas constructed from gravel or limestone
2. Constructed stand-off pads without roof or feeding area, but bedding material provided, e.g. bark chip, sand or sawdust
3. Feed-pads used as stand-off areas without roof or provision of bedding material, i.e. concrete surfaces with facilities to feed cows
4. Constructed stand-off pads without a roof that provide bedding material and also access to an area to feed cows (usually concrete)
5. Roofed shelters that include facilities to feed cows with slatted concrete floors upon which bedding may be provided depending on circumstance
6. Roofed loose-housed barns with bedding material and facilities to feed cows
7. Roofed free-stall barn and related hybrid systems that provide individual bedding areas and facilities to feed cows

The farm system scenarios can also be defined by use patterns. These vary with geography, climate and whether the cows are dry or lactating, but five distinct use patterns can be recognised:

1. Intermittent use for dry cows - confinement for up to 18 h/day with cows grazing pasture for the balance of each day, for intermittent periods of 3-5 days in response to an adverse weather event (usually high rainfall) – Systems 1-5
2. Intermittent use for lactating cows throughout the year to feed supplement to lactating cows that also graze pasture, with periods of confinement up to 18 h/day for intermittent periods of 3-5 days in response to an adverse weather event (usually high rainfall) – Systems 1-5
3. Continuous use for wintering dry cows - animals fully confined for 6 to 12 weeks during winter and early spring – Systems 4-7
4. Continuous use for wintering lactating cows - confinement for 12 to 20 weeks in late autumn, winter and early spring, with intermittent access to graze pasture or crop depending on weather conditions – Systems 6-7
5. Continuous use for lactating cows – animals confined continuously for more than 20 weeks each year – applies to Systems 6-7 above

When system types and use patterns are combined there are 18 farming system scenarios described for off-pasture practices on New Zealand dairy farms (Table 2).

Confinement system	Intermittent use by dry cows	Intermittent use by lactating cows	Periods of continuous use for wintering dry cows	Periods of continuous use for wintering lactating cows	Continuous use for lactating cows
1 "Hard" surface stand-off - no feeding	X (1)	X (2)			
2 Constructed stand-off - no feeding	X (3)	X (4)			
3 Feed pad also used for standing-off	X (5)	X (6)			
4 Constructed stand-off with feeding	X (7)	X (8)	X (9)		
5 Roofed shelter with slatted floor and feeding	X (10)	X (11)	X (12)		
6 Roofed loose-house system with feeding			X (13)	X (14)	X (15)
7 Roofed free-stall barn and related hybrid systems			X (16)	X (17)	X (18)

Table 2: System type by use pattern matrix representing 18 farm system scenarios using off-pasture confinement systems (numbers in brackets will become reference numbers for the scenarios)

Farm system scenarios will vary in their implementation from farm to farm, and between years, depending on many factors including climate, staffing and availability of resources e.g., for feed and bedding. It is impossible to consider the full range so for scoring in Step 3, it is proposed that the farm scenarios will be considered as they would be implemented on an "average" farm.

POINTS TO CONSIDER:

- **Do you think that the 18 farm system scenarios described above adequately cover the range of systems used in New Zealand?**
- **Are 18 scenarios too many? What would you leave out?**
- **Is there anything important that is missing within these scenarios?**
- **Should the assessment include one or more farm system scenarios without confinement i.e. wintering on pasture or crop?**

Step 2: Hazard Identification and characterisation

Objective: to identify the full range of animal welfare hazards that may be associated with off-pasture confinement systems and characterise each one in terms of its consequences for cow welfare.

> **IMPORTANT NOTES:**
> Remember: hazards may relate to both management and facility design factors.
> In Step 2, each hazard is considered for its impact on a "generic cow" i.e., independent of the farm system scenario.

Each possible hazard is described in a standard manner. There are five parts to this:

1) Hazard description – this step includes specifications of circumstances under the hazard exerts its effect and a description of the welfare impact for the animals. Some hazards may have several levels of specification, e.g. if the hazard is "inadequate access to drinking water", then the further specifications could be "water reticulation system break down" and "not enough drinkers/troughs for the size of the group" which effectively equates to two separate hazards.

2) Severity grading – this is a subjective assessment from each panel member of the overall impact of the hazard on an animal's normal physiology, behaviour or health. The grading system uses a 5 point scale and is described in Table 3.

Evaluation	Score	Explanation
Negligible	0	No pain, malaise, fear or anxiety as evidenced by a range of behavioural, physiological and clinical measures
Mild	1	Minor changes from normal indicative of pain, malaise, fear or anxiety
Moderate	2	Moderate changes from normality indicative of pain, malaise, fear or anxiety. Clear change in adrenal or behavioural reactions such as motor responses and vocalisation
Severe	3	Substantial change from normality indicative of pain, malaise, fear or anxiety. Marked change in adrenal or behavioural reactions such as motor responses and vocalisation
Very severe	4	Extreme change from normality indicative of pain, malaise, fear or anxiety usually in severe measures, that could be life threatening if they persist

Table 3: Severity scoring description (as described in the EFSA evaluation process)

3) Duration of exposure – this is a quantitative estimate (by each panel member) of the number of days in a year that an animal would experience the adverse effects if exposed to the hazard (range: 1-365 days)

4) Likelihood of adverse effect - this is a quantitative estimate (by each panel member) of the likelihood that an adverse effect would occur with exposure to the described hazard. Estimates for "most likely", "minimum" and "maximum" will be required.

5) **Uncertainty estimate -** this is a qualitative assessment (by each panel member) of the reliability of the information used in their assessment of severity (Table 4). For a hazard to be

accepted in the analysis, there needs to be evidence that exposure to it can affect welfare. Many practices adopted on farms in New Zealand have been evaluated scientifically. It is expected that the panel will bring their own practical knowledge and experience when making their assessments, but that this will be reflected in the Uncertainty score that is allocated to each point. New Zealand's Animal Welfare Act allows some precedent for this – when developing codes of welfare, recommendations are based on the combination of scientific knowledge, good practice and available technology.

Level of uncertainty	Explanation
Low	Strong evidence that the hazard will produce the assessed effect, i.e. well supported by scientific studies
Medium	Some information available for supporting the assessment but incomplete or relies on extrapolation from other species or systems
High	Scarce or no scientific data available with evidence based on observation and anecdote

Table 4: Qualitative uncertainty scores for assessment of likelihood

Example of a panel member's assessment at Step 2:

1. Hazard description: insufficient access to water
    - Hazard specification: reticulation system broken
    - Adverse effect: thirst, social stress, frustration
2. Severity grading: 2 – moderate
3. Duration of exposure – 0.5 days
4. Likelihood of adverse effect – most likely 90%; min 80%; max 100%
5. Uncertainty estimate for impact - medium

Reasoning:

- Severity grading - proposed as moderate on the basis that insufficient access to water due to reticulation system breakdown is likely to result in moderate levels of thirst for an exposed animal.
- Duration of exposure - limited to half a day on the basis that the problem will be identified quickly and the system repaired.
- Likelihood of adverse effect – estimate for "most likely" is that 90% of a group of cows would be affected by thirst to some degree if exposed to this hazard; minimum and maximum proportions affected are estimated as 80% and 100%, respectively
- Uncertainty estimate of impact of exposure – the specific impact of this hazard (short-term water deprivation) has not been fully described in the scientific literature, but practical knowledge suggests that water deprivation due to

POINTS TO CONSIDER:

- **Does the list of hazards in Appendix 1 cover the full range?**
- **What does not apply in the New Zealand situation?**
- **What additional hazards need to be included?**

Step 3: Exposure assessment

Objective: to assess the effects of the hazards characterised at Step 2 within the context of the farm systems scenarios agreed in Step 1.

Panel members will be asked to grade the impact of each hazard within each farm system scenario in a three part process:

1) Duration of exposure: this is a quantitative estimation of the number of days in a year that an animal will be exposed to the hazard within a specific farm system scenario (range: 1-365 days)

2) Intensity of exposure: this is an estimation of the level of exposure of the animal to the hazard within the farm system scenario. In most cases this will be either “full exposure” or “no exposure”. Where the intensity of a hazard is influenced by external conditions, panel member may specify a range of intensity for that hazard, e.g. for heat stress, the intensity will depend on the environmental temperature.

3) Likelihood of exposure: this is a quantitative estimation of the likelihood that the hazard will come into play within each farm system scenario. Panel members will be asked to estimate the proportion of cows affected according to “most likely”, “minimum” and “maximum”.

4) Uncertainty estimate for exposure assessment: this is a qualitative assessment of the reliability of the information/knowledge used in the assessment of the level of exposure to each hazard within each farm system scenario.

Continuing the previous example for an assessment at Step 3 and considering the case for Farm system Scenarios 5 and 9:

- Hazard description: insufficient access to water
  - Hazard specification: reticulation system broken
  - Adverse effect: thirst, social stress, frustration:

	Scenario 5: Intermittent use of feed pad for standing off by dry cows	Scenario 9: Continuous use of constructed stand-off pad for wintering dry cows
Duration of exposure	0.5	1
Intensity of exposure	Full exposure	Full exposure
Likelihood of exposure	Most likely: 5%; min 0%; max 10%	Most likely: 10%; min 0%; max 20%
Uncertainty estimate (exposure)	High	Medium

Reasoning:

- Duration of exposure - limited to half a day for Scenario 5 on the basis that dry cows on a feed pad for standing off will have access to pasture at some stage during the day which will reduce the time that they are exposed to the hazard. Duration of exposure is longer for Scenario 9 where there is no other access to drinking water until the reticulation systems is repaired.
- Intensity of exposure – "full exposure" – if the hazard occurs then each cows would be fully exposed to it, not just part of the herd
- Likelihood of exposure – based on an estimate that water reticulation failure is less likely to occur in Scenario 5 than in Scenario 9 in which water demand is likely to be higher and animals have limited alternative options to obtain water.
- Uncertainty estimate – the estimates made have been based on practical knowledge rather than on scientific data about the rate of water reticulation failure. There is more uncertainty for Scenario 5 than for Scenario 9 because facilities where feed pads are used for intermittent standing off are likely to be more variable.

Step 4: Data analysis (risk characterisation)

Once all the work sheets have been returned by the panel members, this step uses a statistical process to combine the opinions of the expert panel. The estimates from Steps 2 and 3 will be combined to calculate risk magnitude scores for each hazard in each farm system scenario. Risk estimate distributions will be calculated using a stochastic simulation model.
The aim of the risk characterisation is to give information to the risk manager to evaluate the specific situation regarding the fulfilling of animal needs and maximising good welfare within each system scenario. The results must be interpreted with caution and their limitations recognised. This is principally a means to rank the importance of the range of hazards within each system and to compare the risk between systems for each hazard. The calculations for each hazard should be considered as discrete. It would be incorrect to use the outputs of this assessment to assess the effect of exposure to several hazards as the different exposures are not mutually exclusive, i.e. they cannot be summated. Interpretation of results should also consider the level of uncertainty.

The qualitative assessment of uncertainty will be derived using the classification matrix in Table 5.

		Exposure uncertainty		
		High	**Medium**	**Low**
Adverse effect uncertainty	**High**	High	High	High
	Medium	High	Medium	Medium
	Low	High	Medium	Low

Table 5: Uncertainty classification matrix

Continuing the hypothetical example for water reticulation system breakdown for Farm system scenarios 5 and 9:
Panel opinions were analysed and the Risk Characterisation was:

	Scenario 5: Intermittent use of feed pad for standing off by dry cows	**Scenario 9: Continuous use of constructed stand-off pad for wintering dry cows**
Magnitude of adverse effect	0.25	0.25
Risk estimate (±SD)	0.01 ± 0.01	0.02 ± 0.01
Qualitative uncertainty	HIgh	Medium

Interpretation: this hazard is of low magnitude - the theoretical range for magnitude is 0-365. The calculated magnitude in this example is <1 because the duration if impact is short, and its effect on the animals is moderate.

The theoretical range for risk estimate is also 0-365. For the worked example the risk estimate is also small because although a majority of cows would be affected by an occurrence of the hazard (most likely estimate of adverse effect: 90%), the likelihood of exposure to the hazard in each farm scenario is low (5% and 10% for Scenarios 5 and 9, respectively).

WORKSHEETS FOR EXPERT PANEL

a) Example of hazard characterisation worksheet for Step 2

Experts were asked to complete a series of tables for each identified hazard. Below is an example of the worksheet for characterisation of hazards relating to light.

Hazard number	Hazard description	Hazard specification	Adverse effect	Severity of adverse effect	Duration of adverse effect	Likelihood of adverse event			Uncertainty (L/M/H)
						min	middle	max	
1 LIGHT									
1.1a	Insufficient light level	Too dark for cows generally	Light intensity 50 lux or less during the day; inability to carry out normal behaviour; risk of panic if sudden event occurs and cows cannot see						
1.1b		Too dark for cows during the night	Light intensity 50 lux or less at night; inability to carry out normal behaviour; risk of panic if sudden event occurs and cows cannot see						
1.1c		Too dark for stock handlers	Light intensity less than 50 lux; reduced ability to observe animals and detect problems						
1.2a	Insufficient day duration (photoperiod)	Day too short	Inability to carry out normal behaviour; reduced feed intake						
1.2b		Day too long	Extends beyond 16h light:8h dark - Insufficient rest						

B) Example of scenario assessment worksheet for hazards at Step 3

Experts were asked to complete a likelihood assessment for each hazard characterised in Step 1 within in each of the 11 scenarios. Below is an example of the sheet for completion for Hazard 1.1a Insufficient light level: too dark for cows.

Hazard: 1 LIGHT **1.1a: Insufficient light level: too dark for cows**

Scenario		Likelihood of exposure to the hazard (%)			Uncertainty (L/M/H)	Factors influencing intensity
		min	most likely	max		
1	No off-pasture/crop management system used					
2	Hard surface stand-off/no feeding					
3	Constructed stand-off/no feeding					
4	Feedpad also used for standing-off					
5	Constructed stand-off with feeding					
6	Steel-roofed shelter with feeding/concrete floor (slatted or solid)					
7	Plastic-roofed shelter with feeding/solid concrete floor					
8	Plastic-roofed shelter with feeding/slatted floor					
9	Steel-roofed loose house system with feeding					
10	Plastic-roofed loose house system with feeding					
11	Steel-roofed free-stall barn and related hybrid systems with free-stalls and feeding					

7.3 APPENDIX 3: HAZARDS CHARACTERISED AT STEP 2

Hazard no.	Hazard description	Hazard specification	Adverse effect
1 LIGHT			
1.1a	Insufficient light level	Too dark for cows generally - light intensity 50 lux or less during the day; no night light provided	Inability to carry out normal behaviour; risk of panic if sudden event occurs and cows cannot see possibly leading to injury
1.1b		Too dark for stock handlers	Light intensity less than 50 lux; reduced ability to observe animals and detect problems
1.2	Inappropriate day length/photoperiod	Day too long/short	Inability to carry out normal behaviour; reduced feed intake; insufficient rest
2 FEEDING			
2.1a	Inadequate feeding facilities	Too few feeding spaces	Reduced feed access, hunger, behavioural frustration, increased negative social interactions possibly leading to injury
2.1b		Incorrect positioning or design	Cows cannot reach feed without leaning or kneeling against hard objects; leg and brisket injuries, claw disorders, pain
2.2a	Poor feed quality – nutritive value/palatability	Poor nutritive value, improper sensory quality (unpalatable), fungal contamination	Hunger, digestive upset, under-nutrition and physiological stress, mycotic disease (abortion, pneumonia, other), floors stay wet leading to hoof disorders
2.2b		Increased level of feed sorting by cows	Subordinate cows receive an inadequate ration
2.3	Improper ration composition	Unbalanced ration and/or fibre quality/chop length	Reduced rumination, sub-acute ruminal acidosis, laminitis, claw disorders, pain
2.4	Underfeeding	Inadequate supply in relation to genotype, physiological state and production level	Hunger, under-nutrition and physiological stress, inability to buffer short term adverse events, e.g. cold weather, social stress
2.5	Overfeeding	Including over supply in relation to genotype, physiological state and production level	Over-fat, metabolic upset, social disruption
2.6	Inadequate feeding schedule	Feed provided infrequently or not pushed up often enough	Social stress, under-nutrition and physiological stress (especially subordinate cows), inability to buffer short term adverse events, e.g. cold weather
3 AIR			
3.1	Poor air quality, poor ventilation and air flow	High levels of ammonia or bio-aerosols, dust; high humidity	Respiratory discomfort, eye discharge, mucous membrane irritation, surfaces remain wet (condensation drips from roof); reduced lying times, mastitis, poor milking hygiene, claw disease

Hazard no.	Hazard description	Hazard specification	Adverse effect
4 THERMAL COMFORT			
4.1a	Inappropriate temperature/humidity	Too hot/humid	Thermal discomfort (heat stress)
4.1b		Too cold/wet/windy	Thermal discomfort (cold stress)
5 PROVISION OF BEDDING			
5.1	Inadequate bedding in lying areas	Insufficient or no bedding provided; bedding poorly maintained; bedding/lying area hard, slippery, dirty, wet	Too little rest, behaviour disruption, lameness; cows become dirty, udder contamination; mastitis, poor milking hygiene
5.2	Inadequate space allowance in lying areas	Too crowded in lying areas	Social behaviour disruption, increased aggressive encounters, possibly leading to injury
6 FREE-STALL DESIGN			
6.1a	Poor free-stall design	Lying space too short, narrow; neck/wither rail incorrectly placed; inadequate lunge space; dividers at shoulder and rear incorrect; brisket locators absent, too high, too hard or space underneath	Cow cannot sit correctly; too little rest, unwillingness to lie down; too much standing; udder injury; mastitis, poor milking hygiene; behaviour disruption, pain, fear
6.1b	Poor free-stall maintenance	Structures broken and/or corroded	Injuries
6.2	Fewer free-stalls than cows	Cows cannot all lie down at the same time	Too little rest, too much standing, behaviour disruption, frustration, pain, fear
7 WALKING PASSAGES			
7.1a	Poor walking passage design	Areas where animals walk, congregate and turn is too narrow	Fear of slipping/falling, injury, fear of dominant animals
7.1b		Insufficient cross overs (not enough or too narrow)	Failure to utilise some areas of the facility leading to disrupted social interactions, fear of dominant animals
7.2	Inadequate floor in walking areas	Too slippery, too rough, too hard, uneven, poorly maintained, poor hygiene	Locomotion problems, leg and claw injuries, poor hygiene, pain, fear of slipping/falling, fear of dominant animals, cows in oestrous do not display mounting behaviour
7.3	Inadequate space in walking areas	Too crowded	Fear of dominant animals, disrupted social interactions, inadequate exercise, risk of injury
7.4	Inadequate manure removal systems	Passages/alleys covered in manure	Hoof issues, poor hygiene, lameness, fear of slipping/falling, injuries
8 FACILITY IN RELATION TO OTHER FARM INFRASTRUCTURE			
8.1	Entrance areas to facilities poorly maintained	Stones carried onto hard surface areas; cows enter facility with dirty feet	Hoof injuries and lameness, pain
8.2	Facility not sited in an accessible area for cows	Increased walking distance	Lameness, inadequate rest
8.3	Animals disturbed by other activity in the vicinity of the facility	Exposure to sudden, unusual or unexpected events or noise	Fear/panic, slipping and injuries

Hazard no.	Hazard description	Hazard specification	Adverse effect
9 WATER			
9.1a	Insufficient access to water	Not enough space around drinking troughs, overcrowded	Thirst, frustration, physiological stress, fear of dominant animals
9.1b		System cannot deliver appropriate flow rates	Thirst, physiological stress, frustration especially for subordinate animals
9.1c		Wrong trough positioning, e.g. too high/deep	Thirst, physiological stress, frustration, manure contamination
9.2	Inadequate water quality	Manure contamination of drinking water from poor positioning of troughs	Reduced water intakes, thirst, physiological stress, frustration, spread of infectious enteric diseases
10 ANIMAL HANDLING FACILITIES			
10.1	Inadequate or lack of handling facilities	Inadequate ability to separate and attend to individual cows	Behaviour disruption, pain, fear
10.2a	Inadequate provision for calving	Inability to provide separation/space away from other animals	Social stress, frustration
10.2b		Unsuitable surface area for calving	Slipping and injuries (cow and calf); skin and udder contamination (cow); delayed access to colostrum (calf); navel contamination (calf)
11 SOCIAL STRUCTURE AND IMPORTANT BEHAVIOURS			
11.1	Mixing animals from different groups	Increased aggressive interactions in group receiving new animals	Social disruption, injury and pain, fear
11.2	Insufficient or inappropriate contact with humans	Human-animal interactions negative	Fear
11.3	Insufficient opportunity for allogrooming and positive social interaction between animals	Negative social interactions	Social disruption, fear
11.4	Insufficient opportunity to self-groom and maintain skin/coat health	Lack of opportunities to scratch or self-groom	Coat contamination; skin disease
12 BIOSECURITY			
12.1a	Inadequate biosecurity	Inadequate hygiene measures for visitors to the farm, e.g. boot washes; including contractors' machinery	Disease introduction; food safety concerns
12.1b		Control of feed contamination by rodents and other pests	Disease spread, e.g. Leptospirosis; food safety concerns
12.1c		Fly control	Behaviour disruption; skin irritation
12.2	Inadequate or lack of quarantine areas for sick animals	Inability to quarantine sick animals (lack of hospital pens)	Poor recovery, pain, disease transmission
12.3	Inadequate foot hygiene, e.g. foot bathing	Inadequate foot hygiene	Stone bruises, hoof disorders, lameness

Hazard no.	Hazard description	Hazard specification	Adverse effect
13 HUSBANDRY PRACTICES			
13.1a	Insufficient or inappropriate care of animals by stock handlers	"Walking through" for general monitoring too infrequent (or not at all)	Inadequate monitoring, emerging problems are undetected
13.1b		Inability to recognise "normal" and "abnormal" (lack of relevant knowledge)	Inadequate monitoring, emerging problems undetected;
13.1c		Failure to act on clinical health monitoring	Disease conditions, e.g. mastitis and lameness are untreated, infectious diseases spread, pain, fear
13.2	Withholding hoof health care routines	e.g. claw trimming	Locomotion problems, pain
13.3	Improper management of 'downer cows'	Lack of good bedding, proper facilities and lifting devices, lack of physiotherapy	Pain, behavioural disturbance, fear
13.4	Inadequate animal identification and recording systems	Failure to monitor herd health, lack of individual cow information	Sick animals not treated and monitored appropriately
13.5	Lack of an overall management plan and procedures for caring for confined animals	Failure to monitor animals in a coordinated manner; failure to make necessary management adjustments	Poor maintenance; poor management; inability to review situation and make management adjustment

7.4 APPENDIX 4: FARM SYSTEM SCENARIOS

Table I: Thirty farm systems scenarios using off-pasture management identified at Step 1 with estimates of duration (day/year) that cows spend in these systems

	Farm System Scenario Descriptions	Duration (d/y)
1	No off-pasture/crop management system used	0
2	Hard surface stand-off/no feeding/intermittent use by dry cows	15
3	Hard surface stand-off/no feeding/intermittent use by lactating cows	5
4	Constructed stand-off/no feeding/intermittent use by dry cows	25
5	Constructed stand-off/no feeding/intermittent use by lactating cows	10
6	Feed pad also used for standing-off/intermittent use by dry cows	25
7	Feed pad also used for standing-off/intermittent use by lactating cows	24
8	Constructed stand-off with feeding/intermittent use by dry cows	25
9	Constructed stand-off with feeding/intermittent use by lactating cows	10
10	Steel-roofed shelter with feeding/slatted or solid concrete floor/intermittent use by dry cows	35
11	Steel-roofed shelter with feeding/slatted or concrete floor/intermittent use by lactating cows	20
12	Steel-roofed shelter with feeding/slatted or concrete floor/periods of continuous use wintering dry cows	80
13	Plastic-roofed shelter with feeding/solid concrete floor/intermittent use by dry cows	35
14	Plastic-roofed shelter with feeding/solid concrete floor/intermittent use by lactating cows	30
15	Plastic-roofed shelter with feeding/solid concrete floor/periods of continuous use wintering dry cows	80
16	Plastic-roofed shelter with feeding/slatted floor/intermittent use by dry cows	80
17	Plastic-roofed shelter with feeding/slatted floor/intermittent use by lactating cows	30
18	Plastic-roofed shelter with feeding/slatted floor/continuous use wintering dry cows	80
22	Steel-roofed loose-house system with feeding/continuous use wintering dry cows	80
23	Steel-roofed loose-house system with feeding/continuous use wintering lactating cows	80
24	Steel-roofed loose-house system with feeding/continuous use lactating cows (20+ weeks/yr)	200
25	Plastic-roofed loose-house system with feeding/continuous use wintering dry cows	80
26	Plastic-roofed loose-house system with feeding/continuous use wintering lactating cows	80
27	Plastic-roofed loose-house system with feeding/continuous use lactating cows (20+ weeks/yr)	200
28	Steel-roofed barn systems with free-stalls and feeding/continuous use wintering dry cows	80
29	Steel-roofed barn systems with free-stalls and feeding/continuous use wintering lactating cows	120
30	Steel-roofed barn systems with free-stalls and feeding/continuous use lactating cows (20+ weeks/yr)	200+

Table II: Eleven farm system scenarios considered in the welfare risk assessment at Step 3

System no.	Farm System Scenario
1	No off-pasture/crop management system used
2	Hard surface stand-off/no feeding
3	Constructed stand-off/no feeding
4	Feed pad also used for standing-off
5	Constructed stand-off with feeding
6	Steel-roofed shelter with feeding/concrete floor (slatted or solid)
7	Plastic-roofed shelter with feeding/solid concrete floor
8	Plastic-roofed shelter with feeding/slatted floor
9	Steel-roofed loose-house system with feeding
10	Plastic-roofed loose-house system with feeding
11	Barn systems with free-stalls and feeding

7.5 APPENDIX 5: INDIVIDUAL RISK ESTIMATES FOR HAZARDS WITH SYSTEM-SPECIFIC VARIATION

Table Ia: Risk estimates (%; 95% confidence interval; uncertainty rating (L: low; M: medium; H: high) for hazards (n=15) associated with infrastructure and facility design for the eleven farm system scenarios considered. Hazards with risk estimates were in the top quartile (8.1% and above) are in bold type.

	1 No off-pasture /off-crop	2 Hard surface stand-off; no feeding	3 Constructed stand-off; no feeding	4 Feed pad used for stand-off	5 Constructed stand-off with feeding	6 Steel roofed shelter; concrete floor	7 Plastic roofed shelter; solid concrete floor	8 Plastic roof shelter; slatted floor	9 Steel roofed loose-house	10 Plastic roofed loose-house	11 Barn systems with free-stalls
6.1a Free-stall design poor	0; L	0; L	0;L	0; L	0; L	0; L	0; L	0; L	0; L	0; L	**23.9 (17.9 – 30.4); L**
2.1b Inadequate feeding facilities – poor position/design	0.5 (0.3-0.6); L	7.1 (5.7-8.7); L	7.1 (5.7-8.6); L	**15.1 (10.5-19.9)**	**15.5 (10.6-20.6); M**	**17.4 (12.6-22.4); M**	**17.3 (12.5-22.4); M**	**16.8 (12.3-21.6); M**	**17.1 (12.6-21.9); M**	**17.5 (12.9-22.2); M**	**17.8 (12.8-23.1); M**
7.1a Walking passages too narrow	0; L	3.3 (1.8-5.4); L	3.3 (1.8-5.4) ; L	6.6 (4.4-9.3); L	6.6 (4.4-9.4); L	7.4 (4.7-10.7); L	7.4 (4.7-10.7); L	7.4 (4.8-10.7); L	**8.3 (5.2-12.2); L**	**8.3 (5.2-12.2); L**	**11.5 (7.4-16.8); M**
2.1a Inadequate feeding facilities – too few spaces	1.4 (1.0-2.0) ; L	2.8 (1.9-3.9); L	2.8 (1.9-3.9); L	7.9 (5.0-11.2); H	**8.2 (5.0-11.7); H**	**8.2 (5.2-11.6); H**	8.0 (5.0-11.4); M	7.7 (4.9-10.7); M	7.6 (4.9-10.8); M	7.9 (5.1-11.0); M	**8.1 (5.0-11.5); M**
7.2 Walking passages surface poor	0; L	**12.2 (8.6-16.6); L**	6.4 (3.0-10.6); M	**12.2 (8.6-16.7); L**	6.2 (3.1-9.9); L	**12.1 (8.7-16.2); L**	**12.1 (8.7-16.2); L**	**11.0 (8.1-14.5); L**	**12.1 (8.7-16.2); L**	**12.8 (9.2-17.0); L**	**11.5 (7.7-16.1); M**
3.1 Poor air quality (ammonia, dust, aerosols)	0; L	0.2 (0.1-0.3); L	0.4 (0.3-0.6); L	1.8 (0.7-2.9); M	3.0 (1.5-4.8); M	**9.7 (4.6-15.5); M**	**10.4 (5.6-16.1); M**	**9.9 (5.3-15.5); M**	**12.4 (6.5-19.1 ; M**	**13.9 (7.8-20.6); M**	**12.5 (6.4-18.9); M**
7.1b Insufficient cross-overs in walking passages	0; L	2.6 (1.4-4.2); L	2.6 (1.4-4.2); L	5.1 (3.4-7.3); L	5.0 (3.4-7.3); L	5.7 (3.6-8.3); L	5.7 (3.7-8.3); L	5.7 (3.7-8.3); L	6.4 (4.0-9.5); L	6.4 (4.0-9.5); L	**9.1 (5.6-13.3); M**
7.3 Walking passages too crowded	0.2 (0.1-0.4) ; L	7.7 (4.6-11.4); M	7.7 (4.7-11.3); M	7.7 (4.6-11.3); L	7.7 (4.7-11.3); L	7.7 (4.6-11.); L	7.7 (4.6-11.3); L	6.7 (4.1-9.9); L	7.7 (4.6-11.3); L	7.4 (4.5-10.8); L	**9.4 (5.9-13.6); M**

Table Ib: Risk estimates (%; 95% confidence interval; uncertainty rating (L: low; M: medium; H: high) for hazards (n=15) associated with infrastructure and facility design for the eleven farm system scenarios considered. Hazards with risk estimates were in the top quartile (8.0% and above) are in bold type.

	1 No off-pasture /off-crop	2 Hard surface stand-off; no feeding	3 Constructed stand-off; no feeding	4 Feed pad used for stand-off	5 Constructed stand-off with feeding	6 Steel roofed shelter; concrete floor	7 Plastic roofed shelter; solid concrete floor	8 Plastic roof shelter; slatted floor	9 Steel roofed loose-house	10 Plastic roofed loose-house	11 Barn systems with free-stalls
8.1 Facility entrance poorly maintained	1.1 (0.6-1.9); L	**8.7 (5.7-12.6); M**	6.9 (4.4-10.0); M	**8.5 (5.5-12.2); L**	6.4 (4.1-9.3); L	7.9 (4.7-11.7); L	7.8 (4.7-11.7); L	7.3 (4.5-10.9); L	7.1 (4.3-10.5); L	7.1 (4.3-10.5); L	7.5 (4.6-11.2); M
1.2 Photoperiod inappropriate	1.5 (1.2-2.0); L	1.5 (1.2-2.0); L	1.5 (1.2-2.0); L	1.5 (1.2-2.0); L	1.5 (1.2-2.0); L	7.6 (3.8-12.0); M	4.8 (2.6-7.3); M	4.7 (2.6-7.3); M	4.7 (2.1-7.9); M	3.2 (1.4-5.3); M	6.1 (2.6-10.2); M
1.1b Insufficient light – too dark for stock handlers	2.2 (1.5-3.0); L	2.2 (1.5-3.0); L	2.2 (1.5-3.0); L	2.2 (1.5-3.0); L	2.2 (1.5-3.0); L	9.6 (5.0-14.3); M	5.3 (3.1-7.8); M	5.6 (3.4-8.0); M	6.7 (3.0-10.6); M	4.5 (2.3-7.0); M	**10.3 (6.1-14.7); M**
1.1a Insufficient light – too dark for cows	1.6 (1.3-2.0); L	1.6 (1.3-2.0); L	1.6 (1.3-2.0); L	1.6 (1.3-2.0); L	1.6 (1.3-2.0); L	7.6 (4.0-11.7); M	3.5 (2.1-5.4); M	3.6 (2.1-5.4); M	4.6 (2.2-7.4); M	2.6 (1.1-4.5); M	7.9 (5.0-11.2); M
6.2 Fewer free-stalls than cows	0; L	0; L	0; L	0; L	0; L	0; L	0; L	0; L	0; L	0; L	4.8 (3.0-7.1); H
5.2 Lying areas crowded	1.5 (0.7-2.4); M	**11.1 (8.9-13.6); M**	**8.7 (6.9-10.7); M**	**9.6 (7.5-12.1); M**	**8.7 (6.9-10.7); M**	8.0 (5.7-10.5; M	8.0 (5.8-10.5); M	8.0 (5.7-10.5); M	6.7 (4.7-8.9); M	6.7 (4.7-8.9); M	6.7 (4.7-8.8); M
8.2 Facility not readily accessible	0.4 (0.2-0.7); M	3.5 (2.0-5.5); M	3.5 (2.0-5.6); M	3.5 (2.0-5.5); M	3.3 (1.8-5.1); M	2.7 (1.5-4.5); M	2.8 (1.5-4.5); M	2.6 (1.4-4.3); M	2.5 (1.3-4.1); M	2.5 (1.4-4.1); M	2.4 (1.3-3.9); M

Table II: Risk estimates (%; 95% confidence interval; uncertainty rating (L: low; M: medium; H: high) for hazards (n=6) for management and farm policy for the eleven farm system scenarios considered. Hazards with risk estimates were in the top quartile (8.0% and above) are in bold type.

	1	2	3	4	5	6	7	8	9	10	11
	No off-pasture /off-crop	**Hard surface stand-off; no feeding**	**Constructed stand-off; no feeding**	**Feed pad used for stand-off**	**Constructed stand-off with feeding**	**Steel roofed shelter; concrete floor**	**Plastic roofed shelter; solid concrete floor**	**Plastic roof shelter; slatted floor**	**Steel roofed loose-house**	**Plastic roofed loose-house**	**Barn systems with free-stalls**
6.1b Free-stall maintenance poor	0; L	0; L	0; L	0; L	0; L	0; L	0; L	0; L	0; L	0; L	**8.7 (5.6-12.1); H**
2.2b Poor feed quality – increased sorting by cows	2.1 (1.4-2.9); M	2.1 (1.4-2.9) ; M	2.1 (1.4-2.9) ; M	3.6 (2.6-4.8); H	4.4 (2.9-6.2) ; H	4.4 (2.9-6.2) ; H	4.4 (2.9-6.2) ; H	4.4 (2.9-6.2) ; H	4.4 (2.9-6.2) ; H	4.4 (2.9-6.2) ; H	4.4 (2.9-6.2) ; H
12.1b Rodent/pest contamination of feed	2.1 (1.2-3.5) ; H	3.5 (1.9-5.8) ; H	3.5 (1.9-5.8) ; H	3.8 (2.0-6.1) ; H	3.9 (2.1-6.6) ; H	4.0 (2.1-6.7) ; H	4.0 (2.1-6.7) ; H	4.0 (2.1-6.7) ; H	4.0 (2.1-6.7) ; H	4.0 (2.1-6.7) ; H	4.1 (2.2-6.8) ; H
2.6 Inadequate feeding schedule	3.7 (3.1-4.4); L	3.8 (3.2-4.5); M	3.8 (3.2-4.5) ; M	5.0 (3.9-6.1) ; M	5.9 (4.3-7.5) ; M	5.8 (4.2-7.5) ; M	5.9 (4.2-7.5) ; M	5.8 (4.2-7.5) ; M	5.9 (4.3-7.5) ; M	5.9 (4.2-7.5) ; M	5.9 (4.2-7.5) ; M
2.5 Overfeeding	1.9 (1.3-2.5); L	1.9 (1.3-2.4) ; M	1.9 (1.3-2.4) ; M	2.6 (1.8-3.4) ; M	2.6 (1.9-3.5); M	2.7 (1.9-3.6) ; M	2.7 (1.9-3.6) ; M	2.7 (1.9-3.6) ; M	2.9 (2.0-3.9) ; M	2.9 (2.0-3.9) ; M	2.9 (2.0-3.9) ; M
8.3 Disturbance from other farm activity	0.4 (0.2-0.7) ; M	1.4 (0.8-2.2) ; M	1.3 (0.7-2.1) ; M	1.2 (0.7-2.1) ; M	1.2 (0.7-2.1) ; M	1.2 (0.7-2.0) ; M	1.2 (0.7-2.1) ; M	1.2 (0.7-2.1) ; M	1.2 (0.7-2.0) ; M	1.2 (0.7-2.0) ; M	1.0 (0.5-1.7) ; M

Table III: Risk estimates (%; 95% confidence interval; uncertainty rating (L: low; M: medium; H: high) for hazards (n=6) associated with elements of both infrastructure/design and management/farm policy for the eleven farm system scenarios considered. Hazards with risk estimates were in the top quartile (8.0% and above) are in bold type.

	1 No off-pasture /off-crop	2 Hard surface stand-off; no feeding	3 Constructed stand-off; no feeding	4 Feed pad used for stand-off	5 Constructed stand-off with feeding	6 Steel roofed shelter; concrete floor	7 Plastic roofed shelter; solid concrete floor	8 Plastic roof shelter; slatted floor	9 Steel roofed loose-house	10 Plastic roofed loose-house	11 Barn systems with free-stalls
5.1 Inadequate bedding	9.2 (6.3-12.2); M	**32.1 (27.5-37.1); L**	**23.7 (18.5-28.7); M**	**30.6 (26.5-35.3); L**	**22.8 (18.2-27.9); M**	**30.4 (25.4-35.9); M**	**29.4 (24.1-35.3); L**	**29.5 (24.2-35.3); L**	**23.4 (19.5-27.6); M**	**22.5 (18.2-27.0); L**	**19.8 (15.5-24.5); L**
7.4 Manure removal from walking passages poor	0.2 (0.1-0.3); L	**10.2 (6.8-14.5); L**	**9.0 (6.0-13.0); L**	**9.5 (6.3-13.8); L**	**8.6 (5.4-12.5); L**	**8.6 (5.4-12.6); L**	**8.6 (5.2-12.6); L**	8.0 (5.0-11.5); L	**8.7 (5.4-12.6); L**	**9.4 (6.0-13.5); L**	**9.9 (6.6-14.1); M**
11.4 Lack of opportunity for self-grooming	1.6 (0.7-2.5); M	5.1 (3.0-7.7); H	4.4 (2.4-6.7) ; H	4.4 (2.4-6.8) ; H	4.4 (2.4-6.8) ; H	4.4 (2.4-6.7) ; H	4.4 (2.4-6.7) ; H	4.4 (2.4-6.8) ; H	4.4 (2.4-6.8) ; H	4.4 (2.4-6.7) ; H	5.2 (3.1-7.7) ; H
11.3 Lack of allogrooming & positive cow-cow	1.4 (0.7-2.3); M	5.0 (3.1-7.4) ; H	4.4 (2.5-6.5); H	4.4 (2.6-6.5) ; H	4.4 (2.5-6.5) ; H	4.4 (2.6-6.5) ; H	4.4 (2.6-6.5) ; H	4.4 (2.5-6.4) ; H	4.4 (2.6-6.5) ; H	4.4 (2.6-6.5) ; H	5.1 (3.1-7.4) ; H
4.1b Too cold/wet	5.5 (4.1-7.2): M	5.4 (4.0-7.3) : M	5.4 (4.0-7.3) : M	5.5 (4.1-7.4) : M	5.5 (4.1-7.4) : M	2.7 (1.5-4.3) : M	2.1 (1.2-3.4) : M	1.8 (1.1-2.8) : M	1.9 (1.1-3.1) : M	2.2 (1.3-3.5) : M	2.1 (1.2-3.4) : M
4.1a Too hot/humid	4.5 (3.5-5.6) : M	3.5 (2.5-4.6) : M	3.5 (2.5-4.6) : M	3.5 (2.5-4.6) : M	3.6 (2.6-4.8) : M	2.8 (1.6-4.4) : M	2.8 (1.7-4.2) : M	2.6 (1.6-3.8) : M	2.8 (1.6-4.3) : M	3.0 (1.8-4.5) : M	2.9 (1.7-4.4) : M

7.6 APPENDIX 6: LITERATURE REVIEW

Off-pasture dairy management systems

a) Lachlan Pearson[1], Jim Webster[2], Sharon Woodward[1], Gwyneth Verkerk[1]

[1] DairyNZ, Private Bag 3221, Hamilton
[2] Animal Behaviour and Welfare Group, AgResearch, Private Bag 3123, Hamilton

Background to this review

This literature review was prepared in support of a regulatory review of off-pasture management systems for dairy cows in New Zealand. Its purpose is to:

- Summarise the use of off-pasture management systems on New Zealand farms.
- Document international research and opinion about good management practices when using off-pasture systems.
- Provide technical information to support a welfare risk assessment by a panel of experts of off-pasture management systems used by the New Zealand dairy industry.

Executive Summary

The evolution of New Zealand dairying systems over the past 20 years has seen increasing use of off-pasture confinement systems. Confinement systems commonly adopted in New Zealand are described along with a summary of available information about use patterns. The drivers for this trend towards increasing use of off-pasture systems are discussed. The predominant drivers are pasture protection and improved utilisation of supplementary feed, with effluent capture and opportunities to reduce nitrate leaching emerging as important for the future. The consequence is that increasing numbers of animals are spending more time on hard surfaces which has implications for their welfare. This inherently creates welfare risks due to the greater complexity of emerging systems and husbandry skills to deal with this need to be developed.

The predominantly international literature describing the critical success factors for delivery of good welfare in off-pasture systems is reviewed. The impact of design features such as space allowances, bed design and feeding areas, and management factors that influence environmental and social conditions for animals kept in confinement systems are discussed. Potential issues arising for animal health, especially mastitis and lameness, are addressed along with specific aspects of behavioural freedom. Previous (overseas) assessments of the welfare of cows in confinement systems are also considered, and a brief summary of good husbandry principles and design features that are recommended to protect animal welfare are provided.

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V Welfare risk assessments of dairy housing systems

  - i University of Bristol
  - ii European Food Safety Authority

VI Good practice recommendations (good husbandry indicators)

VII Appendices

  - i Key international reference sites for good housing practice
  - ii References and sources

I The evolution of New Zealand dairying systems

The New Zealand dairy industry is internationally acclaimed for its extensive use of grazed pasture, and the common perception is that New Zealand cows spend their lives at pasture. This is true for much of the year and in most parts of the country, given the temperate New Zealand climate which is well suited to the thermal comfort requirements of dairy cows; but many dairying areas are subject to intermittent periods of high rainfall so off-pasture systems have been developed to protect pastures from treading damage and pugging. Over the past 20 years it has become common practice for cows to be held in a range of constructions such as concrete feed pads, mulched stand-off pads, concrete dairy yards and sacrifice paddocks for varying amounts of time each day, dependent on soil moisture conditions, especially during the higher rainfall months of late winter and spring.

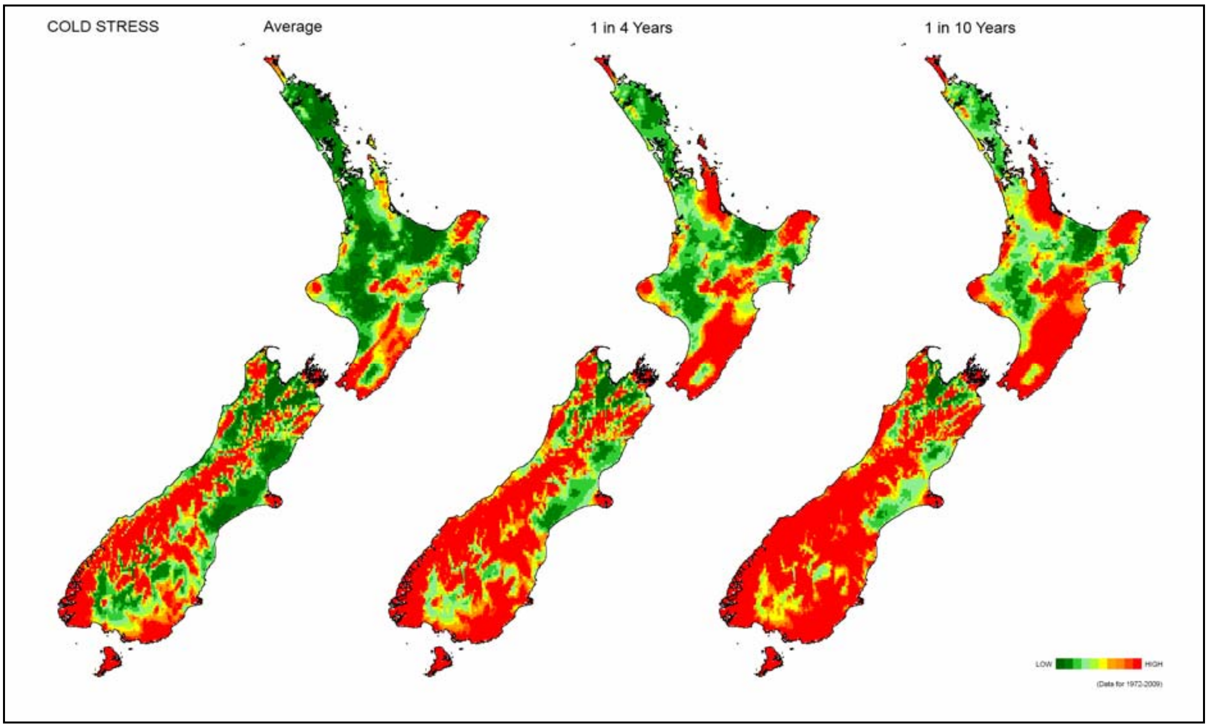
A further practice that is increasingly common is the use of supplementary feeds, especially for lactating cows. Feeding systems have evolved to meet the greater feed demand of today's dairy cow that produces 25% more milksolids than her counterpart of 20 years ago (Anonymous, 2009). Supplementary feeding systems provide management flexibility when pasture growth is slow in early spring and during summer dry periods. They are also an important risk management strategy that ensures that cows' nutritional needs can be met during periods when environmental conditions are adverse. Supplements are expensive relative to grazed pasture, and wastage can be high if fed by spreading on pasture. A key factor to successful incorporation of supplementary feeding into pasture systems has been the development of efficient feeding facilities. Feed pad strategies, such as bins or barriers through which cows eat, have increased economic returns from supplementary feeding because they minimise wastage. It has been a natural progression to use these areas to hold animals off-pasture during wet soil conditions.

Over the past 20 years the New Zealand dairy cow population has increased by 87%, with much of this development into areas where winter conditions are more severe. Bryant *et al*. (2010) investigated the risk of cold stress events throughout New Zealand using weather data for 40 years from 1970 to 2009. The model utilises a cold stress index based on the energetic requirements to maintain core body temperature for a 450 kg non-lactating dairy cow with a body condition score of 4.5 on a 10 point scale (Roche and Macdonald, 2004). Figure 1 shows model estimates of average risk as well as the severity of 1-in-4 and 1-in-10 year weather events.

In colder southern areas, pasture will not grow during the two to three months of winter and wintering costs comprise around 20% of farm working expenses (Dalley, 2010). The majority of farmers winter their cows outdoors on crops such as brassicas and fodder beet on support blocks or with graziers. Farmers express ongoing dissatisfaction with current crop feeding systems, especially because feed wastage can be high (up to 40% wastage has been reported) and the energetic costs to cows of maintaining thermal neutrality contribute further to inefficient use of feed resources. Furthermore there is increasing concern about the environmental impact, especially nitrate leaching loss, of crop paddocks during winter when rainfall is high and plant growth is too static to capture nitrate from soil water (Monaghan *et al*., 2007).

Stand-off pads and wintering barns are a subject of interest to farmers in colder climates who are looking for management systems that increase feed utilisation. Wintering barns are also seen as a means to extend the length of lactation, with further incentive provided by premiums paid for winter milk in southern areas. As winter approaches, and again during spring, farmers use wintering barns to extend lactation length. Lactating cows require higher standards of hygiene and comfort than dry cows because the risk of mastitis is greater (Hogan, 2010). Accordingly where winter confinement systems are used for milk production, the infrastructure and animal management needs to be more sophisticated to ensure that these particular needs are met.

Figure 1: Risk maps of cold stress events for the winter months of June, July and August based on the model of Bryant et al. (2010). Evaluation is based upon an assessment of the risk that weather conditions would require a 450 kg cow with a body condition score of 4.5 and managed outdoors to utilise 5 MJ/day, or more, to maintain thermo-neutrality. Colour gradients indicate the number of days that thresholds are exceeded during the total 3 month period (red = more than 20 days; dark green = 0 days). The map on the left represents average risk across all years, the centre and right maps represent conditions during 1-in-4 and 1-in-10 year events, respectively.



All these factors are contributing to an emergence of systems where cows may be fully confined for periods of 6-12 weeks. While much of the current drive for off-pasture systems in the south comes from a desire to improve winter management, systems are also emerging in which cows are confined for longer periods and with variable access to pasture for grazing. Development of robotic milk-harvesting systems may signal the next step in the evolution of housing systems in New Zealand.

One challenge to feed-pad construction has been storm-water management. Large areas of concrete collect large volumes of water during storm events. Yards where cows defaecate and urinate must drain into the farm's effluent system and in high rainfall areas the requirement for increased effluent storage capacity can make it more cost-effective to roof the area and divert storm-water. This approach also provides a considerable opportunity to protect animals from inclement weather.

New Zealand has a tradition of feeding cows on pasture all year round. Farming on pasture has several obvious advantages for dairy cow welfare. Cows can be more easily examined individually as farmers move them from paddocks at milking or to new pasture. Unusual behaviour such as difficulty in standing, slow walking and standing away from the herd are readily apparent. Another advantage is that cows often have plenty of room to avoid being continually bullied especially when feeding. Pasture provides an environment which is generally comfortable for cows to lie down. Well-managed rotational grazing systems provide an environment with less faecal contamination while the effects of wind and sun reduce bacterial counts (Hogan, 2010). Disadvantages can involve less control of exposure of cows to wind and rain, possibly less control of feed intakes and exposure to parasites, less control of damage to the environment. What is certain is keeping cows off-pasture requires an unique set of farming skills. These include being proactive in monitoring and controlling the environment, as well as monitoring cow behaviour.

The main risks to welfare in off-pasture systems include a reduction in cow comfort arising from increased contact with hard surfaces with resultant lameness. Within housing systems, open bedded systems seem to have the least potential for problems and provide the most option for natural behaviours. Cows are not averse to using housing, and free access systems may provide the greatest potential for positive welfare while still meeting demands for intensification.

The evolution of dairy systems over the past 20 years has resulted in a large variety of systems to keep cows off pasture especially during the wet and winter conditions. System design and management can both have important impacts on cow welfare, and there are implications for the way in which the dairy industry markets its products internationally.

It is a much promoted perception that problems with animal welfare are more likely to arise in housed cows and environmental conditions can become more challenging on a regular basis to their normal behaviour. New Zealand is likely to evolve off-pasture management systems that are quite unique compared to systems used in other countries. An important first step is pre-empting what is required to farm dairy cows in New Zealand in a humane and acceptable manner when off-pasture with consideration also of its impact on product quality and public perception.

II New Zealand systems for off-pasture cow management

II.i Descriptions of off-pasture systems

II.i.i Fenced areas

The lowest cost system for keeping cows off-pasture is to confine cows in areas such as cow races and milking parlour yards (Figure 2). Cows may become very dirty, exposed and are often crowded as yard facilities generally provide a space allowance of only 1-2 m2/per cow. Few cows will lie down in milking parlour yards (Blackwell, 1993). These areas may have limited access to water and lack facilities for providing feed. While milking parlour yards allow for effluent capture, cow races do not, so there is potential for contamination of waterways in the area. Damage to farm races from standing off for long periods in the rain may predispose cows to lameness unless repaired (which can be costly).

Figure 2: Cows standing off on concrete dairy yard (photo: Mairi Stewart, AgResearch)

II.i.ii Unproductive areas (sacrifice paddocks and temporary feedlots)

Cows may be held during high rainfall periods on areas of the farm that are unproductive such as old riverbeds, stream or gully sidings, or in areas of crop aftermath or paddocks scheduled for pasture renewal. These may be simple stand-off areas with cows receiving their intakes from daily pasture grazing, while others will provide some supplementary feed so that they function as a temporary feedlot. While often cheap and easy to organise, there is a risk of longer term soil damage and contamination of waterways from sediment and effluent run-off' Cows become contaminated with mud and faeces and may also be exposed to additional thermal stress from standing in mud if the area is not well drained.

II.i.iii Stand-off pad (calving pad)

Stand-off pads are open fenced areas. They may have a constructed base that allows for effluent capture and drainage, and they may have wind-break cloth or some other form of shelter along one or more sides. They are also known as calving pads which are used on some farms to confine cows close to calving for easier supervision. Stand-off pads may also be designed alongside concrete strips where cows can be fed, or alongside silage stacks so cows can be given access to self-feed from the stack face (see Figures 3&4). Ground surfaces, space allowances, provision of shelter from wind and rain, and the nature and amount of bedding material are highly variable (Stewart *et al*., 2002).

Many pads of older design have rock or limestone bases, without constructed drainage areas, especially in areas where their use is determined by rainfall and so is intermittent. These facilities are increasingly under regional council scrutiny because they fail to manage effluent in an appropriate manner. A survey of 100 stand-off pads indicated that where pads were used for more than 50 consecutive days they were more likely to be concrete-free and provide bedding material (Stewart *et al*., 2002).

The most common bedding materials used on stand-off pads in New Zealand are derived from the forestry industry i.e. bark chips, post-peelings and sawdust (Stewart *et al*., 2002), but changing practices in that industry as they pursue renewable energy sources means that sawmills now use these products for their own purposes and they are increasingly difficult to source.

Figure 3: Bark chip stand-off pads in Southland (photos: Gwyneth Verkerk (left); Mairi Stewart, AgResearch (right))

Figure 4: Cows on a bark stand-off pad with adjacent concrete area and self-fed silage (photo: Bob Duckworth, AgResearch)

II.i.iv Feed pad used for stand-off

The boundary between stand-off and feed pads is a blurry one, especially where a desire for facilities to provide supplementary feeding is an important driver. When feed pad utilisation for standing cows off-pasture is taken into account, concrete is the common surface, especially where use patterns are intermittent and for short periods (Figure 5). These areas generally have a simple design where feed is presented either in bins or along a barrier through which cows put their heads. Their pattern of use is generally intermittent and largely determined by soil conditions, with cows spending some time on most days at pasture. Where a feed pad with feed bins is used as a stand-off area, feed bin should not be deep as cows can be up-ended and become trapped in the bins. In colder areas there are examples of dual purpose feed /stand-off pads where cows may be fully confined during winter months, i.e. for periods of 6-12 weeks. In this context, several examples exist of uncovered concrete stand-off areas that also provide cubicle space with mats to encourage cows to lie down.

Figure 5: Concrete feed pad used for standing cows off pasture, with bins for feeding in Waikato (photos: Sarah Adams, DairyNZ)

II.i.v Shelter systems with slatted floors

Group housing systems with concrete slatted floors are a common design for cattle in many overseas countries. Animals are free to move around within the building, and can feed and lie down largely at will. Bedding (usually straw) may be provided in lying areas. Manure, urine, bedding and other waste falls through the slats into the space below and can be stored until required for use as fertiliser.

Figure 6: Left – dry cows housed in a Herd Home® with straw provided for bedding over the slats; right - cow scratching an ear with her hind leg, a behaviour which she would not express if she had concerns that the surface was slippery or unstable for her to balance her weight (photos: Tom Pow, Herd Homes® Ltd)

In New Zealand the predominant system with this type of flooring is marketed under the trade name of Herd Home® Ltd (Figures 6-9). These shelter systems use horticultural-type plastic film over wooden framing for roof construction, with options for shade cloth ceilings and air venting systems in the roof especially where cows use them to obtain shade in hot weather. Feeding tables are constructed along the outside lengths of the shelter. Floors have a strip of solid concrete along the sides where cows have access to the feed table, and the balance of the floor is slatted. The company offers a range of slat sizes dependent upon the predominant breed of cow (i.e. for Jersey herds the slat width is smaller). The slat flooring is constructed in sections so they can be lifted out to empty the effluent bunkers. The Herd Home® company recommends that, in facilities where cows are held off-pasture for extended periods or where calving occurs, cows should be provided with straw or other bedding. An option that provides a central row of free-stalls where cows can lie down is also available.

Figure 7: Left – slatted floor configuration used in Herd Home® shelters; right – cow foot size relative to slat size in Herd Home™ (photos: Tom Pow, Herd Homes™ Ltd)

Figure 8: Left – external feed table with post-and-rail barrier design and tractor lane alongside a Herd Home® shelter; right – Herd Home® with shade cloth ceiling in place for summer heat protection (photos: Tom Pow, Herd Homes® Ltd)

Figure 9: Left – cows in a Herd Home® in which the section of floor closest to the camera has been coated with a rubberised product; right – segregated calving pen in a Herd Home® shelter with extra space allowance and bedding (photos: Tom Pow, Herd Homes® Ltd)

Slatted floor systems are common in Europe where cows may be confined on them for long periods. In some European countries they are not considered suitable for long term housing of lactating cows. Various methods to attach rubber surfaces to the floor slats have been developed in Europe, and rubber coating has also been trialled in New Zealand (Figure 9). The rubber surface is moulded to fit on top of the floor slats so that effluent can still fall into the collection tanks unimpeded. Benz (2002) demonstrated that the self-cleaning function of slatted floors was not impeded by the coating, and in fact in some cases this was enhanced because cows were more active.

II.i.vi Composting (pack-bedding) barns

Composting or pack-bedding barns are used in wintering systems in southern parts of New Zealand (Figure 10). These may have steel or horticulture-plastic roofing with a base is constructed to allow liquid effluent to drain through the bedding pack into a collection system. To assist with ventilation and drying, it is preferably to have no walls, or they are limited to one or two sides usually in relation to the prevailing direction of cold weather. Feed is usually provided on a feed table along the edges of the building where cows stand on a raised platform. Bedding, usually straw, is added regularly into the large central area where the cows can lie or stand.

Figure 10: Cows in composting barns: clockwise from top left – cows bedded on straw and eating at the feed table which is on three sides, straw chopper/blower for laying out bedding at back left of picture (photo: Mark Bryan, VetSouth); barn early in the season showing steps up for cows to access feed table (photo: Gwyneth Verkerk); composting barn with plastic roof design (photo: MAF-VA); composting barn with fresh straw added while cows feed at the perimeter (photo: Gwyneth Verkerk)

II.i.vii Free-stall (cubicle) barns

The free-stall barn is a modern housing system designed for lactating dairy cows, and is widely used in North America and Europe. Free-stall barns were designed to give cows freedom to move around (as opposed to tie-stalls[3] which were the previous predominant

[3] Tie-stall barns, where cows are restrained by a neck tether within an individual space which allows them to stand and lie with access to individually-provided food and water (Rushen, 2008) are not used in New Zealand. They are most commonly found in parts of Europe and North America, i.e., where herds are small and climatic conditions include periods of extreme cold weather. These systems require intensive management and have a heavy reliance on mechanical assistance (Powell, 2006). Because they are unlikely to ever be considered acceptable in New Zealand they will not be discussed further.

housing design) while providing individual spaces where cows could stand or lie down in safety but defaecate and urinate in the alley outside (Figure 11).

Free-stall barns in New Zealand are generally constructed from steel including roofs, although internationally there is a move towards the use of horticulture-plastic for roofing to increase the level of light. There is preference for few walls to assist ventilation and drying. New Zealand designs often have only one solid wall on the side of prevailing winter weather leaving the other sides open or with a curtain of horticultural cloth as a wind break. Feed is provided via a central lane that is accessible to machinery and cows have free access lie in individual stalls (cubicles) which are constructed in rows in the middle or along the length of the outside walls of the building.

The floor is made of concrete but can vary in its design. Where cows stand to eat at the feed table is usually solid concrete. The alleys where cows walk to get water and access to stalls may be slatted so that excreta drops through into an effluent capture system, or solid concrete with an automatic scraper system programmed to travel the length of the cow alleys every hour or so, and scrape effluent out of the housing area into a holding tank.

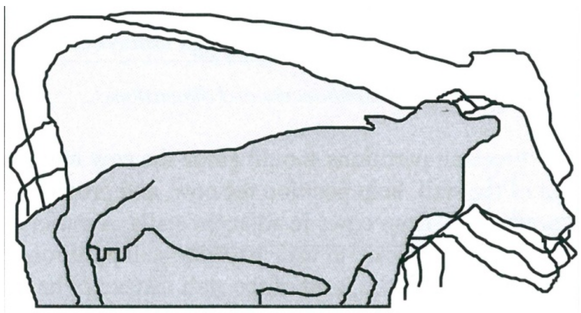
Figure 11: left: free-stall barn for 500 cows, configuration with central feed alley, solid concrete floor with effluent scraper, three rows of stalls on one side and two on the other; right – cows feeding and resting in a free-stall barn (photos: Gwyneth Verkerk).

Stalls are built in rows, on platforms above the level of the cow alleys. A common design is for either two or three rows of stalls down the length of the barn, but some overseas systems will have four or six rows of stalls. As barn designs evolved through the 1980s and 1990s, stall design became a compromise between keeping the lying surface clean and encouraging cows to use the stall for resting. The platform kerb delineates the end of the stall, and should be at least 0.15 m high to discourage cows from lying partially outside the stall (Powell, 2006) and no more than 0.25 m high, including the mat or mattress.

Stalls vary in length and width depending on the positioning of the steel framework. In most designs, there is a neck rail and a brisket locator (usually a solid board or moulded rubber fitting) placed at the front of the stall to act as a positioning guide for cows. Brisket locators discourage cows from sitting forward in the stall so that they are less likely to soil the stall when they void urine and faeces upon standing up. The aim is that, when cows sit down, their rear-most extremity is just in front of the kerb. Useable stall length is determined by the placement of both the neck rail and the brisket board. Restrictive stall designs may reduce daily cleaning requirements but the more restrictive they are, the less attractive they become for the cow to enter and lie down.

Stall dimensions need to consider the breed and size of cows on the individual farm and ensure they can accommodate the cow's natural rising behaviour which includes the need to lunge forward. As a cow rises, she needs clear space of up to 1.5 m in front of her to move her head and shoulders forward as she brings her weight onto her knees. As she stands, she next must bring one of her front legs forward by one pace (about 0.5 m) and she uses that to lift her body upwards. This extra clear space of 0.7 to 1 m required in front of the cow is referred to as lunge space (Anderson, 2010; Figure 12).

Figure 12: Diagrammatic representation of the lunge space which is the free space that should be provided in front of the cow which allows her to extend her head and one front leg when rising. The distance from the nose when seated to the furthermost point during rising should be 0.7-1 m, depending on the breed/size of the cows being housed (Figure: Nigel Cook, University of Wisconsin)



If the head space is blocked by either a solid wall or the neck rail, and/or if she must lift her supporting leg over the brisket locator to get traction to lift her weight, then she will experience difficulty standing. When this happens the result usually is that she must rock backwards and forwards to re-position herself which causes her to knock her backbone against the side rails and abrade her hocks against the lying surface. Brisket locators and neck rails need to be placed so that they do not obstruct cows as they stand up. Solid brisket boards may be restrictive and pose difficulties for cows to step over as they rise.

General guidelines for stall dimensions include that the height of the brisket board should not exceed 0.1 m, the neck-rail should be 1.2 to 1.25 m high and the length of the stall from brisket board to kerb should be 1.6m to 1.8m (Powell, 2006). Allowances for the total length of the bed, including the area in front of the brisket board, range from 2.05 m for 500 kg cows to 2.4 kg for 800 kg cows, and where the cubicle faces a solid wall so there is no open space for the cow to lunge forward, an additional 0.3 m should be added.

Figure 13: left - cows at feed alley with post-and-rail barrier design; right – cows in free-stall barn at Wageningen UR – Livestock Research Farm, Waiboerhoeve, Netherlands – cow alleys are slatted floor design and sawdust has been laid onto the stall mats to promote lying (photo: Gwyneth Verkerk).

Where rows of free-stalls are designed so that cows face each other when in the stall, cows may not fully utilise stalls. Subordinate cows will avoid having to move to sit in front of dominant cows because of social tension. Where cubicles face each other, a deterrent bar may be placed across the front of the stall to prevent cows walking straight through, but this should be in such a position that it does not interfere with the lunge space (Anderson, 2010).

Cows prefer to lie facing uphill. A fall of 2-3% from the front to the back of the stall is satisfactory to assist liquid excreta to drain (Powell, 2006). A similar fall is recommended for passages to prevent the build-up of slurry. Slopes in excess of 10% have been associated with an increased incidence of leg problems (Hristov, 2008).

Total kerb height (including the mat or mattress) should be between 120 and 250 mm. Alleys between rows of free-stalls should be at least 3M and alleys between free-stalls and the feeding table should be at least 5M wide (Powell, 2006). The number of passages available for cows to move between the rows of stalls and the feed alley is important to ensure good cow flow and access between areas of the barn. United Kingdom recommendations are for rows of stalls to be interrupted by a cross passage spaced at least every 20 stalls to allow access to the feed area (Powell, 2006).

Lying surfaces in free-stalls are also variable. Concrete is the primary surface and rubber mats or cow mattresses are usually provided. There is a great deal of research effort ongoing to improve the nature of mats and mattresses with a wide range of engineering solutions and products being tested worldwide. Daily cleaning and sprinkling with lime to reduce bacterial counts are recommended and management practises may also include spreading straw or sawdust bedding across the mats for additional cow comfort and sanitation (Figure 13).

Recent developments in stall design have produced the deep-pack stall which is increasingly being utilised in the Northern Hemisphere (Figure 14). These stalls still have a concrete base but the centre is open with concrete kerbs so that bedding material, such as sand or straw, is provided in the area where the cows lie down. Over a period of time, if straw is used this develops into a firm pack base. Deep-pack stalls require frequent replenishment of bedding material and full cleaning if contents become wet or severely soiled. Sand should be at least 100 mm deep and it should be deeper at the front of the stall (Bell 2007).

Figure 14: Novel system for deep pack bedding in free-stalls – the rubberised grid provides a framework within the stall base that can be packed with sand to increase comfort (photo: Gwyneth Verkerk)

II.ii Prevalence and patterns of use on New Zealand dairy farms

Several studies in the past 10 years provide information about the frequency and type of systems used to keep cows off-pasture in New Zealand. The majority of farms have systems that allow them to bring cows off-pasture as conditions require but the duration and extent of this practice is highly variable between farmers and between regions.

Stewart *et al*. (2002) surveyed winter stand-off practices for dry cows on 100 dairy farms in Waikato, Northland and Southland (75% with fewer than 400 cows). They reported that 87% of farms used some system to stand cows off-pasture during winter months, with 12% providing a roof. Use patterns varied widely with North Island farms showing more intermittent use patterns (47% used stand-off pads for fewer than seven consecutive days at a time) and provision of feed and water was highly variable. Decisions to stand cows off-pasture in the Waikato were weather dependent with cows stood-off on average for 18 h/day, with the balance of 6 hours spent grazing pasture. In contrast, on Southland farms stand-off pads were used for 24 hrs a day and up to 5 months during winter (Stewart *et al*., 2002).

A survey of 132 members of the New Zealand Large Herds Association in 2005 (average 910 cows /farm) found that 51% used stand-off facilities. Of these, 60% described their stand-off facility as purpose built i.e. 31% of farms (Tucker *et al*., 2005a).

Glassey and McLeod (2008) studied stand-off use patterns on nine farms in the Hauraki Plains for three months from June to August 2008. Uncovered facilities varied from the dairy yard covered with rubber mats on one farm to a purpose-built woodchip stand-off area while two farms had Herd Home® shelters, and five farms fed supplements while cows were standing off. The predominant (85%) reason for standing cows off was to protect pastures and facility use (days stood-off/month) was correlated to the number of rain days per month (R^2 = 0.77). Across all farms, cows spent 5.7, 7.7 and 5.5 h/d standing-off in June, July and August, respectively. During the study the average rate of facility use was 46% since farmers rotated multiple herds through during the course of each day (30%, 46% and 61% for June, July and August, respectively). Higher total use rates in August were due to provision of supplementary feed more often in early lactation than during the dry period (58% of days in

August as calving commenced compared with 29% of days in June when cows were not lactating).

Kira *et al*. (2008) interviewed farmers by telephone to determine their effluent, nutrient, waterway and winter management practices. Farmers were selected to represent the geographical distribution of dairy farming. Table 1 gives the data for off-pasture management systems. The majority of farmers sent cows off farm for wintering, but there is considerable regional variation reflecting the need for farmers to manage varying soil types and weather conditions throughout the dairying areas of New Zealand with off-pasture systems more predominant in Northland, West Coast, Otago and Southland.

Arnold *et al*. (2009) investigated the potential impacts of New Zealand housing systems in two surveys - veterinarians with clients that used housing systems and dairy farmers with a range of roofed confinement systems. Veterinarians (n=14) identified mastitis, dirtiness, hoof health and injury as being potential welfare issues in these systems. The dairy farmers (n=24) most often identified pasture protection and animal health/welfare goals as their primary reasons for using housing, with environmental management and production goals as a secondary consideration. Approximately half of the barns were used in summer months to feed supplement or provide shade, and 34% were used for calving cows.

The number of farms developing off-pasture systems appears to be increasing, but the use of buildings is mainly concentrated into the South Island. Environment Southland reports a steady demand for resource consents for building structures (Rachel Miller, Environment Southland, *pers comm.*) and one engineering company that constructs housing systems in the south reports ongoing enquiries from farmers, and currently has orders for eight buildings to be constructed before winter 2011.

Table 1: Off-pasture systems and their prevalence on farms throughout New Zealand. Data collated from Kira et al. (2008).

Region	Total	Winter off	Feed pad	Calving pad	Housing system	Stand-off pad	Wintering pad
Northland	78	40 (51%)	26 (33%)	6 (8%)	1 (1%)	12 (15%)	8 (10%)
Auckland	40	20 (50%)	9 (23%)	1 (3%)	0	1 (3%)	0
Waikato	358	103 (29%)	69 (19%)	16 (5%)	5 (1%)	77 (22%)	26 (7%)
Bay of Plenty	63	36 (57%)	11 (17%)	1 (2%)	0	2 (3%)	3 (5%)
Taranaki	156	58 (37%)	17 (11%)	0	0	8 (5%)	6 (4%)
Manawatu and Wanganui	71	53 (75%)	24 (34%)	3 (4%)	0	10 (14%)	2 (3%)
Canterbury	67	49 (73%)	5 (2%)	0	0	4 (6%)	1 (1%)
West Coast	33	23 (70%)	4 (12%)	4 (12%)	0	14 (42%)	3 (9%)
Otago	33	23 (70%)	6 (18%)	7 (21%)	2 (6%)	7 (21%)	16 (48%)
Southland	62	48 (77%)	9 (15%)	10 (16%)	2 (3%)	14 (23%)	6 (10%)

Based on these studies, a conservative estimate would be that one third to one half of dairy farms have purpose-built facilities where cows can be held off-pasture, with around 250 farms (4% of all farms) using roofed housing systems. The predominant period of use for all these facilities is the winter and early spring when pasture conditions are very wet. Feed pads continue to be used frequently, especially during the early and late parts of the milking season when supplementary feeding is required during periods of poor pasture growth. There is also some use of housing during the hotter months to provide shade for cattle.

III Drivers for off-pasture systems

The use of off-pasture systems is driven by a range of potential benefits that may accrue to improve productivity, improve nutrient management with consequential environmental benefits, facilitate management to make it easier for farm workers, and provide shelter and shade which can improve animal health and welfare. Commentators on future trends in the dairy industry have proposed that intensification of dairy production associated with efforts to increase productivity creates forces that will lead to reduced access to pasture and more use of cow housing systems (Stafford and Gregory, 2008). These authors concluded that housing systems provided protection from negative environmental conditions reduced the amount of walking required and reduced the probability that cows would be underfed.

Care and Hedley (2008) explored drivers for the use of roofed shelters for wintering and surveyed the opinion of 13 farmers from 4 regions that used facilities which included covered feed pads, Herd Homes® and wintering barns. They found that pasture and soil protection was the predominant reason for their use, with peace of mind, feed utilisation, effluent management and animal welfare also amongst the five reasons identified most commonly.

III.i Production drivers

- Reduced feed demand: protecting animals from winter weather reduces their overall feed requirement. Depending on weather conditions this may mean that cows can be over wintered on 8-10 kg DM/day compared to 12-15 kg DM/day which may be required during cold weather conditions.

- Improved pasture growth: avoiding overgrazing, soil compaction and pugging damage to pastures increases overall pasture growth. Maintaining pasture growth in late winter and early spring is particularly important. Failure to have sufficient pasture cover in early spring means lower peak production and lower total production for that season and may reduce farm income by up to $200/ha (Lambourne and Betteridge, 2004). Horne (2002) examined the interaction of weather and soil water capacity on pasture damage across three years on a 540 cow farm on heavy pallic soils. Depending on annual rainfall, pugging damage was predicted to occur between 28 and 118 days, which in the latter case would reduce annual pasture availability by 5% due to both pugging damage and poor utilisation.

- Improved feed utilisation: supplementary feed provided in troughs or feed tables so that it is protected from trampling will reduce wastage.

- Reduced need for imported fertiliser inputs: the additional effluent captured and stored when cows are off-pastured becomes an important resource which reduces the need to import fertiliser. Model predictions based on cows being held off-pasture for 12 hours each day suggest fertiliser imports can be reduced by around 25% (Care and Hedley, 2008). While there are costs associated with emptying bunkers and spreading effluent and waste substrate from stand-off areas, these may be outweighed by the reduced need for fertiliser imports.

- Extended milking season: feeding systems that maximise pasture availability and provide supplements efficiently ensure that body condition is maintained in the latter parts of the lactation so that cows can achieve a lactation of 305 days rather than having to be dried off early to allow time to restore condition.

III.ii Environmental drivers

- Improved nutrient management: nutrient capture in effluent management systems reduces nutrient loss from pastures in unfavourable conditions. Systems that store effluent so that it can be applied evenly when soil moisture and temperatures are favourable for pasture growth will reduce nitrate leaching into ground water. Model predictions suggest that holding cows off-pasture for 12 hours each day would reduce nitrate losses from leaching into ground water by around 20%, although the rate of gaseous nitrogen loss by volatilisation from effluent storage (N_2O and ammonia) would increase (Care and Hedley, 2008).

- Reduced N_2O emissions from pasture: Luo *et al*. (2008) reported that off-pasture systems could reduce direct N_2O emissions in wet conditions. When pasture emissions were compared between cows with full access to pasture and cows restricted to 6h grazing each day in late autumn and winter, total N_2O emission rates from pasture were less than half those of the restricted regime.

III.iii Social drivers

- Peace of mind: farmers using off-pasture systems identify a sense of greater management control because they have better options for feeding cows and protecting pastures during wet weather and during periods of poor pasture growth, e.g. during drought. They also express a reduction in their concerns about the risks of causing environmental damage. Farm workers believe that working conditions are better; there is less stress in daily tasks and improvements in labour efficiency.

- Flexibility and ease of operation: once developed, off-pasture systems allow greater flexibility to implement a range of management approaches.

- Pride in animal husbandry performance: stock managers who work on farms where there is a higher level of confinement report that managing these systems increases knowledge and understanding of individual animals leading to overall improvements in husbandry care and greater job satisfaction.

- Reduced requirement for staff: off-pasture feeding systems combined with a range of emerging technologies to monitor cow behaviour (rumination collars, pedometers, milking system sensors to measure temperature and milk quality) and milk them, i.e. a robotic milking system, reduces labour demands, although it must be noted that the skills of that labour force will be different from the skills required on conventional farms (A. van Leeuwen, farmer, *pers comm*.)

- Individual personal preferences: individual experience of overseas farming methods where housing is used, as well as the influence of farm advisors and other farmers, may all provide drivers towards increased use of off-pasture systems.

III.iv Animal husbandry drivers

- Opportunity to provide shade and shelter: reduction in heat and cold stress for cows. Temperatures inside Herd Home® shelters with shade cloth ceilings and venting systems have been reported as around 5°C lower than those recorded outside the shelters (John Poels, farmer, *pers comm*). Many farmers in northern areas report that they use their roofed facilities to provide shade for cows during summer.

- Improved animal health: while opinion on this is mixed, and it is acknowledged that some health issues need specific management, farmers believe that their improved ability to feed supplements efficiently, along with the benefits of extra shelter, leads to an overall reduction in disease and lower animal health costs.

- Self containment (wintering-on) on farm: transporting animals to runoffs or agistment, and placing cows in the care of graziers who often lack experience in dairy husbandry is expensive and risky.

III.v Negative drivers

- Capital investment: these include costs of building developments and investment in specialised machinery, e.g. straw choppers/floor scrapers. The cost is dependent upon the level of sophistication of the facility being built and whether additional capacity to handle effluent is required over and above what the dairy system is currently designed to capture. Industry estimates of cost vary from around $400 per cow for constructed stand-off pads to $2000 per cow for free-stall facilities.

- Increased maintenance costs: facilities will have ongoing maintenance costs which will vary according to the nature of the facility. Ongoing maintenance costs may be as low as $25/cow/year for stand-off pads where maintenance is mainly removal and replacement of bedding material, with costs increasing proportionately with the sophistication of the facility. Machinery maintenance costs also need to be factored in especially where it is required for the feeding system. Maintenance costs of specialist housing equipment such as effluent scrapers and straw choppers can also be high.

- Increased cost of milk production: Beukes et al. (2010) used a whole farm modelling approach to explore the relative profitability and risk of wintering strategies in the Southland region. They compared four wintering strategies which were feeding forage brassica crop on support land (i.e. separate from the dairy platform), grazing pasture on support land, and feeding pasture silage made on support land to animals confined either on a stand-off pad or a roofed shelter with a slatted floor. For both latter options, effluent was captured and utilised as fertiliser during the following milking season. Simulations were carried out over 35 years utilising recorded climate data and a milk price of $4.55/kg milksolids. The housed system had the highest mean operating profit over the 35 years and was also the least exposed to climate-induced risk. The brassica crop system had the most variable performance in terms of climate induced risk. They concluded that the housed and stand-off system were the most cost effective alternatives allowing a high level of control over cow feeding, body condition and comfort over winter, while also limiting the potential for environmental damage to occur.

- Public perception: the views of New Zealand citizens about off-pasture systems are largely driven by perception and contain paradox. There is strong community support for increased provision of shade and shelter for dairy cows, especially in southern areas where concerns about the welfare of cows in crop paddocks during wet conditions are frequently expressed within the wider community; however there is also concern about the welfare of animals managed in confined circumstances. Much of the negative public opinion stems from ignorance of the housing systems, including a perception that animals in barns are confined in "cubicles" similar to those used in indoor pig production. Some of this perception is further driven by welfare advocates that fully decry housing and confinement of any sort as factory farming or intensification.

The "unnaturalness" of confinement and housing systems for dairy cows is identified frequently in public surveys in Europe as a matter of concern in relation to the natural living dimension of welfare, especially where dairy cows spend all or most of their lives in housing (von Keyserlingk et al., 2009). Pasture grazing in situ is a key factor for the efficiency and economic success of the New Zealand industry. This is unlikely to change in the foreseeable future, and will limit the development of fully confined systems for lactating cows in most regions such that the predominant use of off-pasture systems will be for winter management.

Recently there has been controversy in the UK as consents are sought by Nocton Dairies for a large intensive dairy farming operation in which cows will be housed in barns. The focus of animal protection organisations that have campaigned against this development has been the unnaturalness of management systems that maximise milk production and the potential stress arising from an environment that compromises the expression of natural behaviours and increases the risk that animal suffer pain and fear. The Farm Animal Welfare Council was asked to provide an opinion for the Minister of State fror Agriculture and Food (Wathes, 2010).

The Council considered two questions: "Can a dairy cow that is housed all year round with little or no access to grazing have a satisfactory standard of welfare?" and "Can a dairy cow that is kept in a very large herd have a satisfactory standard of welfare. With respect to the first question, they agreed that in general housing all year round is easier for the farmer, and potentially place less nutritional stress on the high yielding dairy cow. A number of advantages (better ability to control feeding, protection from adverse weather, greater biosecurity and reduced risk of parasitic infection and summer mastitis) and disadvantages (unable to carry out natural foraging behaviour, limitations of space and movement, less environmental choice, absence of soft non-slip underfoot surfaces, and increased risk of physical injury, lameness and environmental mastitis) were identified. Concern was also expressed that there is insufficient knowledge of effects of year-round housing on the ability of dairy cows to express normal behaviour and the extent to which these impediments affect welfare (Wathes, 2010).

Herd size was not considered to be an issue. The Council noted that normal farm practice for large herds is to create smaller sub-herds (usually around 500 cows each) for ease of management, that managers of herds on larger farms make greater use of specialist advisory services and that staff management structures promote knowledge and stockmanship skills. Furthermore, where dairies are being developed, the sites are built from new using modern infrastructure and design principles that protect animal welfare compared to the free-stall barn systems designed thirty years ago. They concluded that there is opportunity for improved individual cow welfare cows in the emerging large herd operation, such as proposed by Nocton Dairies.

The Council further noted the developing dilemma in relation to the dairy industry and the wider environmental and economic issues of food production systems, and called for further research into the potential opportunities that confinement husbandry systems offer to improve waste management and mitigate climate change, and the impact that this may have on farm production animals (Wathes, 2010).

- Environmental impact: While housing systems can reduce environmental impacts by increasing control of effluent application to land, reducing soil and pasture damage and preventing stock access to waterways, large intensive systems have the potential to increase environmental damage. Full confinement systems result in a higher concentration of cows that need their feed harvested and transported to them. Increased levels of cropping or systems to harvest and store pasture may lead to an increase in fertiliser use. Further importation of feed from outside the farm system will add to nutrient discharges. The rate of manure application to surrounding land may increase so soil and ground water effects need to be monitored and fertiliser and effluent application rates controlled.

IV Critical success factors for good husbandry practice in off-pasture systems

IV.i Introduction

In this section the key factors that influence welfare outcomes in off-pasture systems will be considered. There is a wide range in performance of off-pasture systems and the extent to which they provide for animals' needs. Successful integration of off-pasture management within the overall farm system is influenced by the choice of facility, animal factors and the husbandry skills of the stock managers. Good stockmanship can overcome a range of deficiencies in design, suggesting that management is an important determinant of success for the animals (Bowell *et al*., 2003). Choice and design of a facility should consider the intended purpose and patterns of use (seasonality, frequency and duration) and the characteristics of the animals (stage of production cycle, breed). The key question then becomes whether the collective farm staff have sufficient knowledge and skill to monitor and manage the cows within the chosen system.

IV.ii Surfaces available for lying

IV.ii.i Why is lying important?

It is generally accepted that insufficient time spent lying results in physiological stress and behavioural signs of frustration in dairy cows and maximising lying times is an important objective in dairy management systems (Hristov, 2008). Reduced cow comfort leading to increased time spent standing on hard surfaces will also increase the prevalence of lameness (Cook and Nordlund, 2009b).

Munksgaard and Løvendahl (1993) compared cows housed in tie-stalls on mats with straw bedding (+/- visual/tactile isolation), and deprived of lying for 14h per day (in 2 blocks of 7h each), with cows kept in a pen of four on a slatted floor at 2.7 m^2/cow. Cows deprived of lying had lower basal growth hormone (GH) levels. Plasma cortisol concentrations following an adrenocorticotrophic hormone (ACTH) challenge were similar for all groups, but the GH response was blunted, suggestive of pituitary suppression. Munksgaard and Simonsen (1997) compared the behaviour of cows in tie-stalls with that of similarly housed cows that were also socially isolated or lying-deprived. Cows in the latter groups exhibited more grooming and idling behaviour, and spent more time leaning on stall structures. Stress axis hormones did not differ but the authors concluded that repeated lying deprivation is aversive to cows.

Fisher *et al.* (2002) compared cows in early lactation that were either prevented from lying for 16 h/day, or given free access to lie on rubber mats on concrete. Mean lying time for the restricted cows was 3.9 h/day compared with 8.1 h/day for the free-lying cows. Mean plasma cortisol concentration was greater in lying-restricted cows ($P<0.05$). Plasma ACTH and cortisol release following a physiological challenge with corticotrophin releasing hormone were lower in lying-restricted cows while the ratio of cortisol:ACTH was greater, evidence that the stress resulting from lying deprivation was sufficient to result in pituitary down-regulation.

IV.ii.ii How long should cows lie down each day?

Guidelines for lactating cows indicate that they should have around 10 lying episodes each day and lie for approximately 11 hours in total (Hristov, 2008). Lying times may vary for reasons other than the comfort of the lying surface. Cows may also have increased lying times because they are lame (Singh *et al*., 1993). Arab (1995) observed that lying times are influenced by photoperiod and the provision of artificial lighting in facilities. Miller and Wood-Gush (1991a) observed that cows that were provided with ready access to feed in a barn lay for longer than cows that went out to graze. They proposed that this was due to more time being available for lying, but also noted that lack of exercise may have made them less physically conditioned to stand for longer periods.

IV.ii.iii What do cows require to achieve adequate lying times?

There is a good deal of evidence that cows prefer dry comfortable surfaces to support adequate resting times (Fisher *et al*., 2003, Webster *et al*., 2007). Facilities where cows are held off-pasture for extended periods of time should provide lying areas that are comfortable, clean, well drained and dry (Hristov *et al*., 2008).

Facility design has a major effect on the time spent standing or lying, and time budgets are an important guide to cow comfort (Haley *et al*., 2000, Rushen *et al*., 2008). Surfaces should provide grip to support standing and lying movements but not be abrasive (Bell, 2007). The quality of the lying surface is determined by a combination of factors including the nature of the base substrate, e.g. concrete, concrete slats, limestone, gravel, deep litter or soil, the quality and quantity of bedding material provided, e.g. straw, sand, sawdust, bark chip or mats, and management efforts to maintain and refresh the bedding material.

IV.ii.iv What is the range of lying times achieved in different systems?

There are several New Zealand reports of the behaviour of cows in off-pasture wintering systems. Stewart *et al.* (2002) observed cow behaviour in a range of wintering systems on commercial farms in Waikato and Southland. On the nine Waikato farms where cows were stood off-pasture intermittently depending on weather conditions, lying times while off-pasture (total range of time between 19 and 24 h) were 2.4 h for concrete surfaces, 4.1 h on races, and 11.3 h on wood chip pads. On the nine Southland farms, all cows were off-pasture for the full 24 h each day. Average lying times were 10.2 h on covered sawdust pads, 11.5 h on uncovered sawdust pads and 11.2 h on brassica crop.

Fisher *et al.* (2003) observed cows with access to pasture for 3 h/day then held for 21 h on a wood-chip stand-off pad, concrete yard, farm race or a sacrifice paddock. Total time spent lying was greatest on the stand-off pad (11.9 h/day). Cows lay for 7.0 h/day on concrete, 5.7 h/day on the farm race, and 6.9 h/day on the sacrifice paddock. Lying bout durations were similar for all treatments, but the number of lying bouts was greater in the cows on the stand-off pad ($P<0.05$). Cows held on the concrete yard lost weight over the four day period while liveweight on the other treatments remained similar. Cows on the concrete yard also had significantly higher levels of faecal corticosteroid metabolites on the fourth day of treatment, indicative of a physiological stress response.

Webster *et al.* (2007) compared late gestation heifers with access to pasture for grazing for 6h each day then stood on concrete for the remaining 18h during two 7-day periods with similar animals kept continually on pasture. Following each treatment period, restricted cows were given full access to pasture for 7 days and their recovery monitored. Cows kept on pasture lay down more quickly after grazing (mean time to lie down was 2 h compared to 5.5h for cows held on concrete. Cows lay down less when on concrete (6.4 h vs 12.4 h/18 h period) and compensated for this by lying more during the time they were given access to pasture. The impact of standing-off was more severe during the second treatment week with 6% less time spent grazing during this period compared to the first treatment period. Cows that had been confined on concrete spent less time eating during the recovery period than cows kept at pasture (5.6 vs 6.4 h/day, respectively) and also had significantly lower liveweight gains. This was because they lay down more during the recovery weeks than the cows that stayed at pasture; but over the entire 4 week period, the total lying time of the two groups was equivalent. When challenged by an acute stressor (1 hour road transport) at the end of the 4 week period, cows which had been stood off on concrete had a greater cortisol response than control cows, indicating that repeated lying restriction may perturb the stress axis for an extended period, even though the cows had by then compensated for their low lying time while on concrete.

Non-lactating cows in Northland with access to graze pasture, then stood-off on concrete yards (15.8h/day) lay for 4.7 ± 0.6h/24h with half of that lying achieved while in the paddock, compared to cows stood-off on uncovered bark-chip pad which lay for 7.1 ± 0.6h/24h, predominantly during the night when on the stand-off pad (Wynn *et al*., 2011).

Case studies of continuously-housed cows in Southland winter management systems demonstrated daily lying times of 10.8 ± 0.6h in a deep-litter straw barn, 8.0 ± 0.6h/24h in a free-stall barn with conventional rubber mats, and 7.8 ± 1.9h/24h in a Herd Home® shelter with straw bedding (Verkerk *et al*., 2011).

IV.ii.v What features of a surface promote longer lying times?

Bedding quality and quantity both influence resting times (Rushen *et al*., 2008). Cow preference is generally for deep bedding, and lying times increase on preferred surfaces. Table 2, reproduced from Tucker and Weary (2004), shows results from several experimental comparisons of lying surfaces for cows. In all cases offering a softer lying surface supported an increase in lying times. Likewise, Powell (2006) observed the proportion of stalls occupied by cows where a variety of stall bedding systems were offered. Where the stall was concrete, the occupancy rate was only 39%, compared to 65% with mats, and 79% and 89% with sand and rubber-filled mattresses, respectively.

Table 2: Table of comparisons reproduced from Tucker and Weary (2004): * denotes that differences within comparison were significant to P<0.05

Comparisons involving lying surfaces	Difference in:			Citation
	Lying time (h)	Number of lying bouts	Duration of lying bouts (h)	
Concrete vs wood chips in a stand-off area	+4.9*	2.9*	0.1	Fisher *et al.*, 2003
Sawdust vs sand in free-stall	+3.4*	2.4*	0.1	Tucker *et al.*, 2003
Sawdust vs mattress in free-stall	+1.7*	2.0*	0	Tucker *et al.*, 2003
Straw vs sand in free-stall (summer)	+5.4*	5.1*	-1.9	Manninen *et al.*, 2002
Straw vs sand in free-stall (winter)	+9.7*	9.1*	-0.4	Manninen *et al.*, 2002
Concrete vs mattress in tie-stall	+1.8*	4.1*	-0.3*	Haley *et al.*, 2000
Rubber mats in tie-stall vs slatted floor in group pen	+3.7*	3.1*	NS	Munksgaard and Simonsen, 1995
Concrete in tie-stall vs mattress in group pen	+4.2*	5.4*	-0.3	Haley *et al.*, 2000

Other bedding systems that improve cow comfort in free-stalls include placing rubber mats onto concrete surfaces. This will increase lying times (Cook and Nordlund, 2009b). Mats made of dense rubber or ethylene vinyl, around 22mm thick, are a common solution. New, virgin rubber is a better product for use in mats as it is more malleable, providing better grip for the cow. Old or recycled rubber, such as is used for mine conveyor belts, is hard. It does not provide effective cushioning, and becomes very slippery when wet. Mats need to be fixed firmly so they do not dislodge as cows get up and down, but their use does increase comfort and lying times compared to bare concrete.

Mats can become slippery when wet and, in general, do not provide effective cushioning for the hocks which will show signs of damage. Putting a layer of under-felt between the concrete and the rubber mat will make the surface softer. Reluctance to lie on mats can be attributed to both the hardness and dampness of the surface. Management systems that involve spreading bedding materials onto mats, along with regular cleaning and disinfection, are widely promoted to improve lying times (Drissler *et al.*, 2005, Tucker *et al.*, 2009). Cleanliness, depth and distribution of bedding all affect lying times and cows show a clear preference for a dry lying surface. Cows given access to free-stalls with wet sawdust bedding spent 8.8 ± 0.8 h/d lying down, when kiln-dried sawdust was provided this increased to 13.8 ± 0.8 h/d. When wet bedding only was available, cows spent more time standing outside the stall (i.e. in alleys and the feed passages) which increased the risk of lameness (Fregonesi *et al.*, 2007b). The depth of bedding provided on rubber mats will also influence lying times. Tucker and Weary (2004) observed cows provided with bare mats, or with 1 or 7 kg of kiln-dried sawdust. Cows lay down for 1.5h more in the heavily bedded stalls, spent less time perching and had fewer hock lesions.

In practice, farmers use a range of bedding materials to spread onto mats and mattresses, and their choice is often dictated by materials that are readily available locally. Sawdust may form crusts on feet that result in heel damage, while coarse hardwood or kiln-dried sawdust can cause hock damage. Fine sawdust can blow away but is best for hock health. Sand has the advantage of being an inorganic substrate that does not support bacterial growth, and it also promotes grip as cows sit and stand. Sand should be fine, without small stones, and washed. Coarse sand is more abrasive and unwashed sand can set hard. Cows may also eat unwashed sand leading to gastrointestinal impaction. The implementation of sand bedding systems remains problematical. They need regular maintenance to keep the surface clean and cows will carry sand out of the bed area, into alleys and the effluent management system. Managing this requires separation systems so that sand can be re-used (e.g. a series of lagoons) while wear and tear on effluent scrapers and pumps increases maintenance costs (Bell, 2007).

Another approach to improve lying comfort has been the development of cow mattresses (Bell, 2007). A range of fillings have been used in mattresses including gels and water beds, but most commonly foam rubber and rubber crumb are used. Mattresses provide good cushioning and if well maintained the surface is not slippery. They have a finite life of 5-10 years as they become hard over time and may develop dips where urine or milk can pool. Care should be taken where mattresses are installed to ensure that the increased height of the step over the kerb does not discourage cows from entering the cubicle. Water beds have attracted publicity and provide excellent cushioning but cows need to learn to stand up on them and they are expensive (Bell, 2007).

Deep-bedded stalls are now the preferred option of researchers working to improve free-stall design, and within these, sand bedding is preferred over straw bedding (Bell, 2007). Deep-bedded stalls also require ongoing maintenance to ensure that cow comfort is retained and when sand is used it should to be raked daily. Unless bedding is regularly topped up, the stall will empty over time up as cows move the bedding to the outer edges of the stall.

When sand was used in deep-bedded stalls, the level dropped gradually over the observed 10 day period especially in the middle of the stall area. Lying times declined by 30 minutes each day for each 2.5 cm drop in sand level, and where sand beds were maintained below the level of the kerb, lying times were reduced by 2.33 h/day compared to stalls that were completely filled (Drissler, 2005). As bedding levels drop, udders and legs may be abraded where they contact the edges of the concrete kerb, and poorly maintained deep-bedded stalls are associated with an increase in hock lesions (Mowbray *et al*., 2003). Novel systems to retain bedding in deep-pack stalls are the subject of ongoing development since they are clearly preferable to cows. Laying tyres into the base of deep-bedded cubicles will reduce cows' digging behaviour. Rubber grids that can be filled with sand are also available for deep-bedded stalls (Figure 14). Cows can also be prevented from digging out sand in the base of the stall by placing mats over the sand bed, with additional sand on top, e,g. Pack Mats™ (Promat Inc, Canada; http://www.promatinc.com). Marin *et al*. (2007) found that lame cows lay longer in free-stalls with Pack Mats than with rubber-crumb filled mattresses.

IV.ii.vi What other design features affect lying times?

While soft and dry lying surfaces are significant motivators for cows to lie down, other aspects of facility design also influence lying times. Cows will lie down up to 2 h/day longer in bedded loose-house environments than in free-stall systems with mats (Livshin *et al*., 2005). Krohn and Munksgaard (1993) proposed that lying down and rising presented a more complex problem in the free-stall environment where cows also have to manoeuvre themselves into the stall space.

Providing larger stalls can increase lying times. Tucker *et al*., (2004b) observed cows were provided with stalls that were 42, 46 or 50 inches wide. Cows lay for an extra 42 min/day in the widest stalls, and also spent more time standing fully in the wider stalls rather than perching with only their front legs in the stall space. The position of the neck-rail influences accessible stall length. Placing the neck rail further forward also increased the time that cows spent standing fully in the stall, and smaller cows stood fully in the stalls more often (Fregonesi *et al*., 2009a). Positioning the neck rail so that cows at access to more length was associated with a reduction in somatic cell count and the prevalence of injuries and lameness, while lying times increased (Tucker *et al*., 2005b; Veissier *et al*., 2004; Bernardi *et al*., 2009). Incorrect placement and design of brisket boards can also discourage lying. Cows lay for 1.2 h/day less in stalls that had brisket boards, but stall cleanliness was improved (Tucker *et al*., 2006). Brisket board height of more than 15.24cm and presence of concrete in the area forward of the brisket locator were associated with a higher incidence of lameness (Espejo, 2007).

IV.iii Surfaces for standing and walking

While a great deal of emphasis is placed on ensuring that lying areas are comfortable, the floor surfaces where cows walk and stand to feed, drink and idle are also important. The forelimbs support 50-60% of the animal's weight (Vermunt and Greenough, 1996) and have a greater shock absorptive capacity because they are attached by muscular structures, in contrast to the hind limb which is directly connected to the pelvic girdle by bony structures. The forelimb serves more as a prop, with the hind limb providing the propulsive function, so the flow of mechanical stresses as the cow moves differs between the limbs (Mülling and Greenough, 2006). These differences likely account for the fact that some 80% of lameness occurs in the hind limbs (Vermunt *et al*., 2010).

The bovine foot has evolved in a pastoral environment where underfoot surfaces generally have some malleability; it is not well designed to cope with prolonged exposure to very hard surfaces, such as concrete, which generate higher levels of mechanical stress during the weight transfer process. Hinterhofer *et al*. (2006) simulated the biomechanical forces applied to the hoof capsule of a lateral hind-claw when placed in a range of positions on solid and slatted concrete floors. When the hoof was fully supported on solid concrete, load was distributed evenly across both the dorsal wall of the hoof and the bulb of the heel. Across the range of simulations of weight distribution on slatted floors, stress distribution was more uneven and maximum stress values in specific regions of the hoof were greater. Where claw placement had both axial and abaxial support, the loading transferred to the dorsal wall of the toe increased by 133% and 162% for 28 and 40 mm wide slats respectively, compared to placement on solid concrete. The simulated position which resulted in the greatest increase in stress occurred when the claw was placed over the gap such that only the axial wall was supported. In this position there was a 281% increase in pressure to the dorsal wall compared to placement on solid concrete.

The nature, quality (shape, hardness, friction, and hygiene) and maintenance of walking surfaces influence the health of feet and legs, so are important for both welfare and productivity (Vokey *et al*., 2001; Benz, 2007). Areas where cows walk should be easily cleaned, and provide adequate traction without being excessively abrasive. Cows show a marked preference for softer walking and standing surfaces (Bell and Huxley, 2009; Von Keyserlingk *et al*., 2009).

The compressibility and roughness of floors are important for determining normal stride characteristics of cows. A healthy cow walking on pasture will place her rear foot into the position vacated by her front foot on the same side. Where floors are slippery she will alter stride length and place her rear foot outside the track of the front foot. This provides more stability but places greater stress on the outside claw. Over time this will result in uneven wear across the bottom of the hoof which eventually alters the direction of weight transfer through the foot and leg and may result in lameness unless corrective hoof trimming is carried out (Anderson, 2008).

Concrete floor surfaces are associated with a higher risk of injury from slipping. The risk of slipping can be reduced by cutting grooves in concrete floors, but hygiene may be compromised as surfaces remain damp and the more abrasive surface may increase hoof wear (Powell, 2006).

Development of softer flooring systems in walkways and alleys is a subject of investigation in Canada on the basis that, even where systems are implemented to increase cows' lying times up to a theoretical maximum of 12-14 h/day (i.e. dry, soft beds and less restrictive stall designs), confined cows still spend a considerable time standing on concrete surfaces for 10-12 h/day. Concrete floor surfaces do not provide sufficient traction for good mobility and their hardness puts pressure onto hooves. Surfaces that absorbed shock and increased surface friction both improved cow mobility leading to an increase in walking speed and a reduction in the likelihood of slipping (Rushen and de Pasille, 2006).

Fig 15: Heifer in a Herd Home® shelter displaying a grooming behaviour (scratching her left eat with her left hind foot), expression of which requires secure footing (Photo: Tom Pow, Herd Homes® Ltd)

Rubber can often improve locomotion compared to that seen on concrete (Cook and Nordlund, 2009a). Cows prefer to stand and walk on soft rubber flooring compared to concrete (solid or slatted) and softer surfaces promote more normal gait (Benz, 2007, Telezhenko *et al*., 2007, Telezhenko *et al*., 2005). Vanegas *et al*. (2003) studied dairy cows confined to concrete feed pads in Californian and showed that the provision of rubber mats decreased the likelihood of lameness developing five-fold. Platz *et al*. (2008) reported a case study in which cow behaviours were observed in a free-stall barn with a slatted floor progressively covered with an elastic rubber mat (maximum deformity of 3.5mm) moulded to fit the profile of the slats. During the replacement process, cows showed a clear preference to walk and stand on the rubberised areas. Average step length increased from 58 cm on the concrete slats to 70 cm once the rubber flooring was in place ($P<0.01$), while total steps/day increased from 4226 to 5611 for concrete and rubber respectively ($P<0.01$). The incidence of slips during oestrous-mounting behaviour was greatly reduced while the display of self-grooming behaviours that depend upon firm footing, such as standing on three legs to perform grooming activities (refer Fig 15) were greatly increased (P<0.01) on the rubberised flooring.

Haufe *et al*. (2009) compared rubber-covered concrete, mastic asphalt and slatted concrete in areas where cows walked and concluded that the rubber-covered concrete was the preferable surface. Of the three surfaces, slatted concrete floors were the least suitable for cows based on standing times and gait quality. Slatted concrete floors reduce slipping but present similar challenges as solid concrete in terms of hoof wear. The width of the gap between the slats is a compromise between cow foot support and hygiene (Powell, 2006).

Floor hygiene is also important. If effluent pools because of poor drainage, if slurry is allowed to accumulate, or if floors remain wet, hooves are softer, dermatitis can develop on the skin of the feet and legs, and there is increased risk of transmission of infectious forms of foot disease (Powell, 2006). Where automatic scrapers are used to remove effluent, these should be activated at a sufficient frequency that slurry does not build-up and create deep bow waves that contaminate feet and legs (Powell, 2006).

IV.iv Impact of stocking density and space allowance

Competition for resources, particularly feed, water, and a comfortable place to lie, increases as stocking density increases wherever cattle are kept within a limited space. Miller and Miller & Wood (1991) observed that the occurrence of aggressive interactions was nine times higher when cows were housed indoors compared to when the herd was at pasture. Such an increase in the number of aggressive incidents in turn increases the chance of injury and lameness, social stress and mastitis (Cook and Nordlund, 2009b, Stafford and Gregory, 2008; von Keyserlingk *et al*., 2009). Consideration needs to be given to both facility design and management practices to find ways to limit these antagonistic behaviours.

IV.iv.i Access to feed and water

Stocking density influences access to feed and water. Waiting for access to feed and water resources can result in frustration and stress (Waiblinger, 2009), while engagement in aggressive interactions at the feeding table increases the risk of hoof heath problems (Leonard *et al*., 1998).

Stock density affects competition at feeders which is negatively correlated to feeding activity (Huzzey *et al*., 2006). Time spent eating and total feed intakes were influenced by the space available at the feeding table (i.e. bunk space). Where the feeding space was 1.0 m/cow there were fewer aggressive interactions and cows spent more time feeding than where the feeding space was 0.6 m /cow (Rushen *et al*., 2008). Increasing feeding space from 0.5 to 1 m/cow halved the number of aggressive interactions while feeding and feeding activity increased by 24% at peak feeding times, an effect that was strongest for subordinate cows (De Vries *et al*., 2004).

The design of the barrier between the feeding table and the cow alley can also influence the incidence of aggressive behaviours. By using a barrier with dividers (stanchions) to provide individual feeding spaces, the number of displacements from the feeding space was reduced, particularly for subordinate cows (DeVries *et al*., 2004, DeVries and Von Keyserlingk, 2006). Endres *et al*. (2005) found that the total time that cows spent eating (about 4.5 h/day) did not differ between post-and-rail barriers and barriers with dividers; but during peaks of feeding activity there were 21% fewer displacements and subordinate cows spent more time eating when the barriers had dividers. Barriers with dividers also ensured that subordinate cows consumed a more consistently formulated ration, rather than having to eat feed from which other cows had sorted and eaten the more palatable components.

Huzzey *et al*. (2006) demonstrated that, although the design of the feed barrier altered eating patterns, stocking density relative to the feeding space provided was the key determinant of feed intake. At low stocking densities (0.81 m/cow for post-and-rail or 1.33 spaces/cow with divider systems), cows spent approximately 1 hour longer eating than at higher stock densities (0.21 m/cow for post-and-rail or 0.33 spaces/cow), and there was less time spent waiting to gain access to feed. Despite higher rates of displacement from the feed barrier, especially at the higher stocking densities, cows spent longer at the feeding space with post-and-rail barriers than with divider barriers at equivalent densities.

Bolinger *et al.* (1997) investigated an alternative approach to reduce competition at the feed barrier by locking cows in stanchions for 4h/day. Restrained cows had similar total milk yield and dry matter intake as unrestrained cows, but the time they spent eating was less and milk protein concentration was lower. Other differences observed included behavioural changes following release from the stanchions - restrained cows spent more time lying, engaged in more aggressive interactions and spent more time grooming.

DeVries *et al*. (2005) investigated the effect of frequency of feed delivery on cow behaviour. They provided feed according to a range of regimes from once daily with three push-ups, twice daily with two push-ups, and four times daily without pushing up. Cows had 600 mm feeding space and one bed per cow. More frequent feed provision meant that cows had more even access to feed but there were no differences in the time spent lying or the incidence of aggressive interactions at the feed bunk. Subordinate cows were not displaced as frequently when fed more often. There was evidence of feed sorting with all treatments since the NDF of the TMR present in the freed bunk increased throughout the day, and the amount of sorting was reduced by increasing the frequency of feed delivery.

Using barriers with dividers may be more important where feed is provided as a supplement to grazed pasture rather than as a complete ration. They may also have application in situations where cows are held in an off-pasture system and fed only once or twice a day, as frequently occurs in New Zealand winter management systems for dry cows. When fresh feed was offered more frequently, subordinate cows increased their time spent feeding (Rushen, 2008). Some of this may also be resolved by increasing the frequency that uneaten feed is pushed back within the reach of the cows.

IV.iv.ii Access to lying space

The total number of beds and the stall ratio (cow:bed) are important factors in systems that provide individual cow beds (e.g. free-stall barns). Farmers may elect to stock at stall ratios greater than 100% to increase the efficiency of use of their capital investment in a facility on the basis that a proportion of cows will always be eating, at the water trough, or idling in alleys. Hill *et al*. (2009) found that where stall ratios were 1.5 or greater, mean lying times were reduced. At a ratio of 1.25, cows spent more time standing idle in alleys and walkways, and even when the ratio was 1.0, low ranking cows had shorter lying times.

Certain stall configurations appear to be less attractive to cattle. The reasons for this could be that they are further from the feed, may require navigation past obstacles such as narrow parts of alleys or the presence of more dominant cows. Gaworski *et al*. (2003) showed that stalls in the row closest to the feed alley were occupied 41% more frequently than stalls in more distant parts of the barn, and stalls in the centre of each row were used 12% more often than stalls in the periphery of each row. This difference may in part explain why cows in barn designs with four and six rows of stalls had lower production than barn designs with only two or three rows of stalls (Bewley *et al*., 2001).

Design factors that affect accessibility and limit escape routes, such as narrow passages and stalls located at the end of blind alleys, also influence the attractiveness of individual stalls and may aggravate competition in situations where the stall ratio is high (Rushen *et al*., 2008). Passages should be at least 2.4 m wide, or where they run alongside a feeding area, at least 3.6 m wide, to allow unhindered cow flow (Powell, 2006).

In systems where individual bedding areas are not provided, overall space allowance becomes important because of competition for safe lying space. Where stocking densities are high, cows do not achieve sufficient rest and this particularly affects cows that rank lower in the social hierarchy (Harner *et al*., 2007). Subordinate cows will stand and wait for dominant cows to move, so space allocation should also consider the social structure of the herd (Powell, 2006).

IV.iv.iii Aggression and social tension

Gross agonistic behaviours generally occur more frequently in confinement systems than at pasture, and the more submissive cows show a high level of avoidance of dominant cows which impedes their ability to move around between feed, water and lying surfaces. Heifers may have more lameness in competitive environments that discourage lying, but the interactions between social rank, stocking rate and lying times are not well understood (Cook and Nordlund, 2009a). Miller and Wood-Gush (1991) observed that there was less behavioural synchrony when cows were housed than when they were at pasture. Cows spent between 34% and 56% of their time watching each other while indoors, suggesting that they were in a state of "social tension". Aggressive interactions and risk of injuries were negatively associated with space allowance (Menke *et al*., 1999).

Grouping unfamiliar animals may result in increased aggression, social stress, locomotion behaviour and negative effects on feed intake and milk yield (Bøe and Færevik, 2003). Regrouping large herds housed in high density conditions may, therefore, be a problem. Reductions in milk production following regrouping are generally thought to occur because of reduced access to feeding places. The extent of this reduction is dependent upon the cows being regrouped, with evidence that primiparous cows being introduced to lactating cow groups are most affected. Reports on the extent to which milk production is reduced are highly variable depending upon the situations being investigated. Phillips and Rind (2001) cited five studies in which reductions were 19%, 8% over 10 days, 5% over 40 days, 4% for 5 days and 3% for one day, while two further studies reported no change. One further study (Hasegawa *et al*., 1997) found that milk yield was reduced following regrouping only in those cows that were low in the dominance hierarchy, and reported that these cows had a 5% reduction in yield for 2 weeks after regrouping.

Brakel and Leis (1976) demonstrated that the extent of milk yield reduction was not associated with the number of agonistic encounters, but rather with access to the food resource. Cows transferred between groups (4 cows transferred into a group of 24 cows) were involved in 9.6 agonistic contests in the first hour after transfer, almost twice the incidence observed for the group before regrouping. By day 2 the rate of agonistic contests decreased sharply but it was 7 days before the groups were back to baseline levels. Milk production fell by 3% in transferred cows on the first day of regrouping, but there was no change in production in the balance of the group. Dominance values were positively related to body weight but were not related to the number of agonistic interactions, and overall there were no changes in dominance rankings. Ensuring adequate access to feed spaces should limit the impact of regrouping cows.

De Vries and von Keyserlingk (2005) studied the effect of the time of feed delivery inr elation to milking. They compared the behaviours of cows when feed was delivered either while they were at milking or six hours after they returned from milking. When feed was delivered 6h after milking cows increased their total daily feeding time by 12.5%. Daily lying time was not affected, but the latency to lie down upon returning from milking was reduced by 20 minutes and there were fewer aggressive interactions in the feed alley on return from milking, when feed was delivered 6h after milking.

Von Keyserlingk *et al*. (2008) studied animals being re-grouped in a free-stall barn at average stocking rates. Cows that were re-grouped showed behavioural changes during the first 48 hours after re-grouping, but thereafter behaviour returned to previous patterns. Total daily feeding time did not change but feeding times were lower during the hour after delivery of fresh feed during the first 24 hours of re-grouping. The number of times that cows were displaced from the feeding area doubled in the first 24 hours and remained higher for two days, while the number of displacements that focal cows initiated remained similar. Re-grouped cows tended to lie less (13.1 and 12.4 h/d for average of 3 days before and day of mixing, respectively) and milk production dropped from 43.4 kg/day to 39.7 kg/day ($P<0.001$) on the day of re-grouping, but did not differ thereafter. Regrouped cows participated less in allogrooming (licking the body surfaces, except the ano-genital region, of another cow). Cows appear to be relatively robust to re-grouping compared to pigs which will take up to 5 days to resume normal behaviour patterns after re-grouping. One limitation of this work may be group size. The design was such that total group size was 12, with one cow introduced. While there were clear changes in behaviours, the smaller group retained much of its social integrity which may have limited the impact of the event on the study animals. Social structures and dominance relationships in larger groups are more complex and may be more difficult to maintain. Re-grouping on commercial farms is generally of a larger scale so may be more disruptive to cow behaviour than the research results suggest.

The clear preferences that cows select when offered choice indicates that they have the sensory capacity to distinguish between the options presented, and this also suggests where cows are forced to lie on unsuitable surfaces, that they will experience behavioural frustration (Tucker and Weary, 2004).

The cow’s familiarity with the facilities may also influence lying times. Lack of training or sudden changes in the facility or social grouping can lead to short-term alterations in lying times until cows become familiar with the new arrangements (Bell, 2007).

IV.v Impact of confinement on the expression of natural behaviours

The general focus of international animal welfare law is structured around ensuring the delivery of the Five Freedoms. While the reasoning behind four of the Five Freedoms is self-evident (freedom from hunger, thirst, pain, and disease), the freedom to express natural behaviours has challenged thinking, especially where production animals are managed in intensive systems with limited elements of naturalness in the context of the evolutionary origins of the animal species concerned. The use of off-pasture systems to manage dairy cows, especially when lactating, represents one such dilemma (Webster, 1994; Webster, 2000).

The recent development of welfare assessment methodology for animal production systems has, to some extent, clarified definitions of natural behaviour. Increasingly naturalness is considered as an assessment domain alongside assessment of biological function and affective state. In this context the domain of naturalness considers the level to which an animal's environment provides elements that are natural, including the opportunity to carry out important behaviours, the absence of which leads to frustration or other negative psychological states that would cause suffering (Fraser, 2009). This definition provides a framework within which key behaviours can be defined relevant to each production system. Group structure, space allowance and housing design all influence cows' ability to perform natural behaviours i.e. eating, resting, rumination, drinking and social behaviours (Kjallman *et al*., 2008).

IV.v.i Social behaviours

The impact of herd size on cows' performance of natural behaviours and their experience of social stress is not well documented. Rind and Phillips (1999) investigated the effects of group size on grazing and social behaviour, with a comparison of group sizes of four, eight and 16 cows. They chose these group sizes on the basis that feral cattle populations have been observed, in extensive grazing situations, to subdivide naturally into distinct subgroups of 10 to 40 animals, and that such grouping depended mainly on the abundance and distribution of food. This is thought to be a strategy to ensure that forage resources are exploited efficiently. Cows were managed in a rotational grazing system and observed over a 53 day period in summer. Grazing times and production levels were not affected by group size, but cows in groups of eight had the highest bite rates while cows in groups of four had more lateral head movements while grazing, suggesting a higher level of vigilance. Cows in groups of 16 walked more during morning grazing periods, but there was no difference between group sizes for afternoon grazing periods. Cows in groups of four spent more time ruminating and cows in groups of eight spent more time lying. Social interactions were more frequent amongst cows in larger groups (7.3 aggressive incidents/cow/day for groups of 16 cows compared to 2.7 and 2.9 for groups of four and eight, respectively; $P<0.01$). The frequency of self-grooming was higher in groups of eight and 16 (9.2, 14.8 and 15.9 incidents/cow/day for groups of 4, 8 and 16 animals, respectively; $P<0.001$), but the frequency of allo-grooming was similar. Cows in the larger group maintained a greater distance from their nearest neighbour (6.5, 10.7 and 13.8 m for groups of 4, 8 and 16 animals, respectively; $P<0.001$). The authors concluded that group size affects the expression of some behaviours but not production and that there was evidence of greater levels of social tension in larger groups.

Synchrony of herd behaviour is considered part of the normal behaviour repertoire of herd-living animals such as dairy cattle but there is disagreement as to how much of this synchronicity is driven by the cows themselves and the extent to which circadian patterns are imposed by the synchronicity of management activities such as mustering for milking, or provision of supplementary feed.. Free-stall barns lead to a reduction in behavioural synchronicity, especially where access to feeding tables is a limited, forcing subordinate cows to wait for access to feed (O'Driscoll *et al*., 2008).

Palmer *et al*. (2010) compared oestrous detection and characteristics of oestrous behaviour in cows kept in a free-stall barn and at pasture. Fewer cows in the housed treatment expressed standing oestrous behaviour than in the pastured cows. Efficiency of oestrous behaviour detection was higher in the cows at pasture ($P<0.05$) but accuracy was similar, irrespective of whether the method was visual observation, tail paint or using HeatWatch, a radio-telemetric tool for detecting oestrous behaviour. Reduced mounting behaviour in housed systems was associated with slippery floors, lameness and social stress from close confinement. Where few cows are in oestrous at the same time, the expression of oestrous behaviour i.e. mounting activity, often involves non-oestrous animals. In this capacity the non-oestrous animals are engaging in 'altruistic behaviour' i.e. they have no nett benefit themselves; the main beneficiary is the oestrous cow that is endeavouring to attract a bull. Palmer *et al*. (2010) proposed that housed cows may perceive the cost of performing mounting behaviours as too great for receipt of nil benefit.

IV.v.ii Shelter-seeking behaviours

Cows' preferences are complex and may change depending on current conditions in each specific situation. Cows are not averse to buildings per se and, where given choice, patterns of use vary particularly with seasonal weather conditions. When temperature and humidity increased outdoors, more cows elected to remain indoors during the day, going to pasture at night (Legrand *et al*., 2009). Variable preferences for indoors vs outdoors were also highlighted by Krohn *et al*. (1992) who found that during summer cows spent 17.2 h/day at pasture compared to 4.8 h/day during winter, while on days when the outdoor temperature was close to 0°C, cows remained indoors all day. Lying behaviour also changed on a seasonal basis. In winter cows preferred to lie indoors (on deep bedding), but in summer they preferred to lie out on pasture.

IV.v.iii Walking

Cows have a strong motivation to walk, and walking can be considered part of their normal behavioural repertoire; but the extent to which reduction in walking associated with confinement systems produce frustration and consequent stress is uncertain. While tethered cows experienced behavioural frustration as a consequence of their inability to walk, this was not associated with either acute or chronic physiological stress responses, and behavioural frustration was reduced when cows were provided with access to an exercise area (Veissier *et al*., 2008). Waiblinger (2009) further argued that the increased occurrence of walking and running, seen when cows are released after a period of confinement, is evidence that confined cows experience behavioural frustration associated with lack of exercise.

IV.v.iv Grooming

Cleanliness is used as an indicator of welfare. A recent study has shown that cows actively avoid contact with fresh faeces where possible; housing systems that prevent cows from expressing this behaviour may induce psychological stress (Whistance *et al*., 2007).

Allogrooming (licking the body surfaces, except the ano-genital region, of another cow) is a form of non-agonistic behaviour, considered to be an important affiliative behaviour in cattle (Fraser and Broom, 1990). In non-human primates it is considered a means to reduce social tension within the group. In cattle, allogrooming is most often initiated by socially subordinate individuals, but kin relationships also influence the frequency of its occurrence (Sato *et al*., 1993). Sato *et al*. (1993) also observed that individuals that grazed alongside each other at pasture were more likely to carry out allogrooming behaviour when the herd was confined. These observations support a view that allogrooming is not purely altruistic, but that it facilitates the maintenance of social bonds in cattle.

Von Keyserlingk *et al*. (2008) found a short-term reduction in allogrooming when cows were regrouped in pens in a free-stall barn. Fewer allogrooming events were initiated by re-grouped cows for two days following re-grouping (7.5 and 1.3 events/day for average of 3 days before and day of mixing, respectively). Re-grouped cows were the recipients of fewer allogrooming events on the day of re-grouping (5.2 and 1.7 events/day for average of 3 days before and day of mixing, respectively). Regrouped cows initiated allogrooming on fewer occasions during the 2 days following regrouping, and were recipients of fewer allogrooming interactions on the day of regrouping.

IV.v.v Explorative and play behaviours

The contribution of explorative and play behaviours to the welfare state of cattle, and their potential for use as indicators, is not well understood. Play behaviour may be more important for young animals so most studies of cattle have focussed on calves. From a very young age, confined calves showed lower levels of play behaviour as stocking density increased (Jensen and Kyhn, 2000, Jensen *et al*., 1998).

Provision of novel objects and devices to encourage interaction and play behaviour are postulated to enhance the quality of life experienced by animals. Schulze Westerath *et al.* (2009) investigated the use of a novel object by beef bulls housed in groups on slatted floors. They attached a metal toggle to the head stall bars by the feed table as a means of environmental enrichment, and observed the level of interaction of the bulls. During the first week of observation, animals kept in environments without bedding materials were more likely to interact with the toggles, but interest waned after about one week regardless of the extent to which bedding was provided.

Grooming brushes are a common feature of European housing systems. These are promoted by commercial companies as improving cleanliness and skin health, but also provide environmental enrichment (DeLaval, 2006).

IV.vi Impact of management systems on cow genotype

Management systems have had a major influence on genetic selection and significant interactions between the management environment and cow genotype have been identified (Macdonald *et al*., 2007).

Off-pasture systems offer more opportunity to provide energy-dense feed supplements to support higher milk yields. This has been a key driver of the divergence of genetic selection policies between North America, Europe, and New Zealand (Miglior *et al*., 2005), and North American cows produce on average twice as much milk as New Zealand cows. Higher-yielding North American Holstein-Friesian animals respond better to feed supplementation with concentrates than New Zealand Holstein-Friesians (Dillon *et al*., 2006).

The amount and nature of the feed, and the total time available for feeding differs for housed cows compared to those managed on pasture. Furthermore, the provision of shelter improves efficiency of energy use so more energy is available for milk yield. It can be speculated therefore, that increased use of housing systems in New Zealand might promote similar trends in genetic selection. This could, in itself, have an impact on cow welfare since higher milk yields are associated with higher incidence of a range of conditions including udder oedema, mastitis, displaced abomasum, ketosis, cystic ovarian disease, and lameness (Goff, 2006).

IV.vii Interactions of diet and housing

A key driver in the development of New Zealand off-pasture management systems has been the flexibility to provide supplementary feed during periods when pasture is insufficient to meet the nutritional needs of the cows. Pasture remains the predominant source of feed (approx 90% of total dairy cow intake) on most farms, but a small number of farms utilise a high proportion of non-pasture feed, e.g. horticultural by-products, with maize silage and pasture as forage sources.

Dietary change away from pasture has a number of implications for housed cows. The proportion of the diet fed as concentrate is positively associated with the incidence of rumen acidosis which may contribute to an increased incidence of lameness (Rushen, 2008). An increased prevalence of sole haemorrhages was observed in heifers fed concentrates that was more marked in animals kept in free-stall housing than on straw yards (Livesey *et al*., 1998). While rumen acidosis is an acknowledged risk factor for increased lameness, it may be a less important driver than housing design (Laven and Holmes, 2008a).

High-producing cows fed energy dense rations with low fibre content produced more urine and manure which resulted in their environment becoming wetter. Factors that increase the fluidity of manure and reduce cow cleanliness increase the risk of both mastitis and lameness (Ward *et al*., 2002).

Increasing the proportion of fermentable carbohydrates in the diet, for example by feeding grain, may increase the rate of enteric bacterial growth and the subsequent concentration of coliform bacteria in faeces. When the proportion of starch in the diet is high, a proportion will escape microbial digestion in the rumen. Ruminants have low pancreatic amylase activity, so the starch passes to the colon where its fermentation supports bacterial multiplication. The concentration of coliform bacteria excreted in faeces was 100-fold higher when cattle were fed a high starch ration compared to hay. This increases the bacterial load in the environment and may increase the risk of mastitis from environmental pathogens. Diets with high starch content are also reported to favour the multiplication and shedding of enterotoxigenic bacteria, e.g. *E. coli* subtype O157::H7 which poses special food safety risks (Callaway *et al*., 2003).

The risks of diseases such as ketosis, fatty liver and metritis are highest during the calving transition period (the period from three weeks before to three weeks after calving) and have been linked to inadequate feeding. Maintaining individual cow feed intake during transition is important to establish productive lactations and maintain cow health. Reduced feed intakes are most often observed in subordinate cows. Von Keyserlingk and Weary (2008) reported that the odds ratio for developing metritis was directly proportional to average daily time spent feeding during the week before calving. Risk increased by 1.72 for every 10 min decrease in average daily feeding time, and each 1 kg decrease in dry matter intake increased the risk of diagnosis with metritis nearly 3-fold. Cows diagnosed with subclinical ketosis in the week following calving were also found, retrospectively, to have had reduced feed intakes during the week before calving and the affected animals were more likely to be subordinate in their feeding behaviours i.e. they displaced fewer cows at the feed table during peak feeding periods in the week before calving (von Keyserlingk and Weary, 2010).

IV.viii Thermal stress from adverse environmental conditions

Cold, wet and windy conditions can have a negative impact on health and productivity, and off-pasture systems create opportunities to protect animals and reduce the maintenance energy demand (Webster *et al*., 2007; Webster *et al*., 2008; Bryant and Matthews, 2010). Conversely during summer, off-pasture systems can provide access to shade and reduce the negative impact of thermal stress on feed intake and milk production. Cows at pasture with free access to shade spent more time grazing at night, and had 3% higher milk production than cows without access to shade (Fisher *et al*,. 2008).

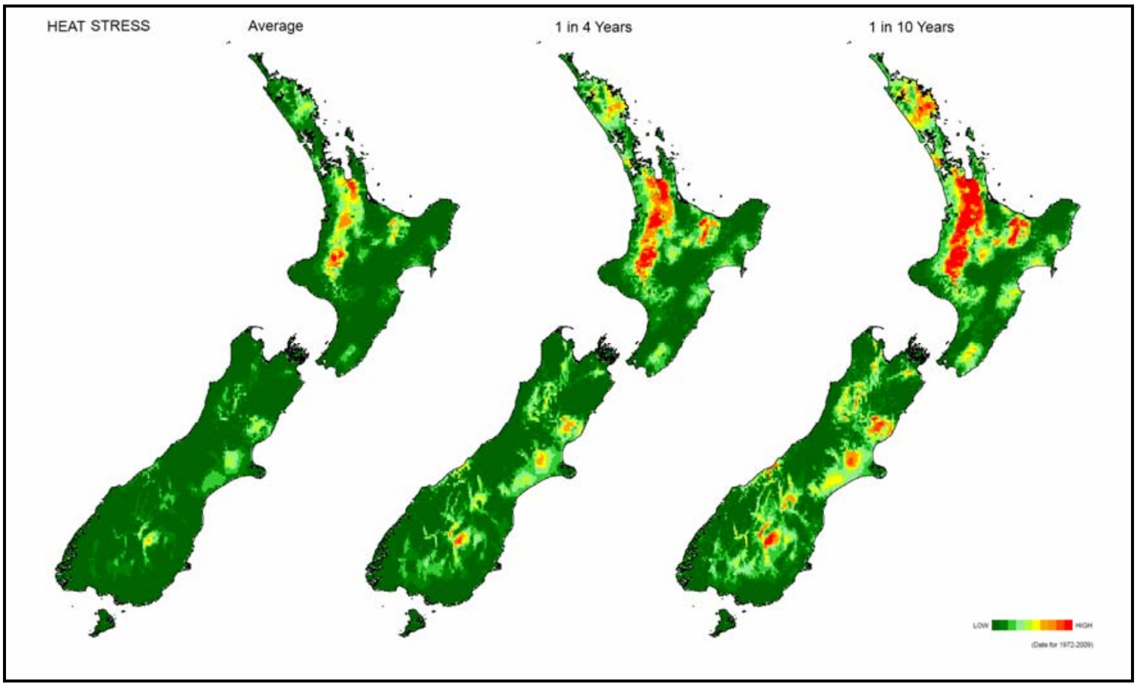
Even temperate climates such as New Zealand's have periods when adverse weather events have the potential to impact on animal welfare, but the extent to which this occurs is a subject of debate. A recent review by Laven and Holmes (2008b) concluded that the benefits derived from housing under New Zealand conditions where the number of days that weather conditions are challenging are relatively few, do not outweigh the cost of providing housing systems in terms of both capital outlay or the increased challenges to animal health and welfare that housing systems inherently present.

This opinion is supported for most areas by Bryant and Matthews (2010), who have quantified the risk of both heat and cold stress events using a model based on weather data for the past 40 years. Figure 1 shows their risk map for cold events that require 5 or more MJ/day of additional energy to maintain core body temperature. Figure 16 depicts the risk of heat events in which heat load index (a composite index, similar to temperature-humidity index (THI) but which includes factors for wind and solar radiation) will exceed a threshold of 68. In the areas identified as being subject to more extreme weather conditions i.e. red areas on the maps, conditions exceed thermal stress thresholds for at least 22% of the days of the relevant season, and some benefit from thermal stress protection might be expected in these locations.

Pasturing systems expose cows to a range of alternate stressors including variable degrees of climatic stress (heat and cold), parasite load, nutritional inadequacies and competition for food (Rushen *et al*., 2008). Cows at pasture were more likely to be exposed to nutritional and metabolic stress in early lactation than housed cows, but these did not translate to an overall impact on health or fertility, and overall welfare provenance was considered to be better for pastured than housed cows (Olmos *et al*., 2009b).

The use of off-pasture facilities to provide shade during hot weather is not without risk. Poor facility design, especially where ventilation is inadequate, may lead to an increase in the risk of heat stress. Environmental conditions that result in even mild heat stress (i.e., temperature-humidity index (THI) above 70) will affect lying times. Standing to increase convective heat loss to the air is an early behavioural mechanism that cows employ to reduce the impact of increasing THI (Igono, 1987). Overton (2002) reported that the proportion of cows lying decreased as pen temperatures increased, with 86% lying at the lowest recorded temperature of 58.8°F. Cows moved away from the sun and into the shaded part of the barn. Cook *et al*. (2007) observed cows in a free-stall barn as mean pen THI increased from 56 to 74, indicative of conditions that cause mild heat stress. Lying times decreased from 10.9 h/day to 7.9 h/day, cows spent more time standing in the alleys (2.5 h/day vs 4.5 h/day), and time at the water trough increased from 0.3 h/day to 0.5 h/day.

Figure 16: Risk maps of heat stress events for the summer months of December, January and February based on the model of Bryant et al. (2010). Evaluation is based upon an assessment of the risk that weather conditions would exceed a heat load index of 68, above which cows will exhibit behaviour and physiological changes in order to maintain thermo-neutrality. Colour gradients indicate the number of days that thresholds are exceeded during the total 3 month period (red = more than 20 days; dark green = 0 days). The map on the left represents average risk across all years; the centre and right maps represent conditions during 1-in-4 and 1-in-10 year events, respectively.



Where off-pasture facilities are used during summer months, the risk of heat stress should be assessed and options such as fan and water cooling systems considered. Sufficient water to wet the coat to skin level is needed for evaporative cooling to be fully effective, while fans may be required to increase air circulation and prevent increases in relative humidity which contribute further to the development of heat stress (Collier *et al*., 2008).

IV.ix Manipulation of photoperiod

Lighting within enclosed confinement facilities is an environmental factor that should also be considered. Where lighting levels are low, cows will alter their stride length and foot placement to ensure stability, similar to their response to slippery floors. This can contribute to uneven hoof wear and may contribute to lameness (Phillips and Morris, 2001, Phillips *et al*., 2000; Anderson, 2008). Sufficient light should be provided for their safe movement around facilities.

More sophisticated confinement facilities for lactating cows also create an opportunity to increase milk production by manipulating photoperiod with artificial lighting (Dahl *et al*., 2000). Increasing light exposure from less than 12h light/day to 16-18 h/day enhanced milk production by an average 2.5 kg/cow/day. As production increases there is an associated increase in feed intake to balance energetic demand, but this increase follows rather than drives the changes in production. While the mechanism for this effect has not been fully elucidated, long day length, e.g. 16h light:8h dark, is thought to stimulate hormonal changes in the somatotrophic axis that promote milk secretion. Such manipulation is most successful when used in concert with cows' endogenous circadian rhythm of hormone release. Circulating melatonin levels increase at the time of natural dawn, and the most successful lighting regimes utilise this natural rhythm to set the start of the light phase, and then extend natural day-length by providing artificial lighting as dusk approaches (Dahl *et al*., 2000).

Photoperiod can also be manipulated during the dry period to increase production in the subsequent lactation but this requires exposing cows to a lighting regime with short day-length, e.g. 8h light:16h dark, during the final two months of gestation. This effect is mediated through endocrine change associated with increased responsiveness of the developing udder tissue to circulating prolactin levels (Auchtung *et al*., 2005).

IV.x Animal health

Off-pasture management systems increase the risk of animal health problems including mastitis and lameness (Rushen *et al*., 2008). A survey of New Zealand farmers with stand-off facilities found that 51% directly associated their use with animal health problems. While none of the farmers that used concrete facilities for stand-off considered mastitis to be an important animal health issue, 75% of the farmers with woodchip stand-off pads expressed concerns about mastitis management. In contrast, all farmers with concrete pads reported lameness as a major health issue compared to only 25% of farmers with woodchip pads (Stewart *et al*., 2002).

IV.x.i Mastitis

Environmental mastitis is mainly due to organisms that live in the cow's intestinal tract and environment, such as *Streptococcus uberis* and *Escherichia coli*, and are closely associated with faecal contamination of the teat end. Infectious mastitis, due to organisms such as *Staphylococcus aureus* that are directly passed from cow to cow, is transmitted almost exclusively during milking, although other direct exposure to infected milk, e.g. by contact in lying areas, can also result in transfer of infection (Hogan, 2010). More bacteria on the teat end are associated with an increased incidence of clinical mastitis (Pankey, 1989).

Confinement systems greatly increase the risk of mastitis compared to grazing systems, because the pathogen loading in the environment is usually greater (Barkema *et al*., 1999, Sumner, 1991, Hogan, 2010). This risk is particularly relevant for lactating cows in which the teat canal provides less defence against penetration by environmental pathogens. Clinical mastitis occurs more in the first two months of lactation however, and many of these infections are attributed to penetration of the teat canal during the dry period; for example, Smith *et al.* (1985) reported that 65% and 56% of coliform and streptococcal infections, respectively, occurring during the first two months of lactation were from intra-mammary infections originating in the dry period.

The overall incidence of clinical mastitis in New Zealand is appreciably lower than the UK (13% and 40%, respectively) where dairy cattle are routinely housed in free-stall systems for five to seven months during winter and fed pasture silage and concentrates (Laven and Holmes, 2008a). In the United States of America, the rate of clinical mastitis in housed cows was 1.8 times that of cows at pasture, and culling for mastitis was 8-fold higher (Washburn *et al*., 2002). The majority of clinical mastitis in cows housed in free-stall barns during winter in the UK was caused by *E. coli* and *S. aureus*, while *S. uberis* and Klebsiella spp. accounted for only a small proportion (Barkema *et al*., 1999). By comparison in New Zealand, most clinical mastitis is due to *S. aureus* and *S. uberis* with only a small number of cases attributed to *E. coli* or Klebsiella spp. (McDougall, 1999, Petrovski *et al*., 2009).

Facility design and management both contribute to the level of exposure to mastitis-causing bacteria and maintaining cow hygiene is very important for reducing mastitis (Breen *et al*., 2009). Barbari and Ferrari (2007) reported a detailed study of cow cleanliness in a range of housing systems in Italy and found that both housing system and bedding type influenced dirt scores. Cows housed in free-stalls were cleaner than cows housed on straw yards, or concrete (scores max score = 10; 3.3 vs 4.5 vs 5.2, respectively; $P<0.01$). The amount of bedding provided also affected dirt scores. Cows provided with ≥2 kg/cow/day had lower scores than cows provided with ≤1kg bedding/day, while cows provided no bedding were dirtiest (2.5 vs 3.7 vs 4.7, respectively; $P<0.01$). Labour and machinery requirements for managing bedding were noted as significant in this study.

Factors associated with reduced incidence of *E. coli* mastitis included pasturing cows at night, use of slatted floors to reduce the accumulation of excreta, provision of more feeding space, and quarantine of diseased cows (Barkema *et al*., 1999). While the warm humid conditions found within enclosed environments promote bacterial growth and increase bacterial loading, one study found exposure rates were higher in outdoor loose yards than in stalls (Smith *et al*., 1985).

The nature and management of the lying surface are important determinants of the number of bacteria on the udder. Regular maintenance of bedding areas so that they are clean and dry is a critical control point (Hogan, 2010). Mats and mattresses should be cleaned and disinfected frequently so that faeces do not accumulate, and ventilation should ensure that lying surfaces can dry out which will also limit bacterial multiplication. The type of bedding material also influences this - inorganic materials such as sand offer less favourable conditions for bacterial growth. For this reason, inorganic materials are recommended over organic bedding materials such as straw and saw-dust in mastitis control programmes (Zdanowicz *et al*., 2004).

While mastitis is primarily a concern where cows are lactating, the role of the dry period in establishing new infections needs to be considered because most of these will persist to lactation and become clinical cases. Dry and transitional cows in confinement environments will also benefit from provision of a clean, dry environment (Hogan, 2010). Prophylactic products that create a barrier at the teat-end during the dry period may protect dry cows from bacterial invasion that later results in clinical mastitis (McDougall and Compton, 2010).

IV.x.ii Lameness

Confinement systems are associated with increased lameness in dairy cows (Rushen, 2008) but there is a wide variation in the incidence of lameness within each management system (Cook and Nordlund, 2009a). Walking and exercise on soft surfaces such as pasture are considered beneficial for claw health (Loberg *et al*., 2004). When cows on pasture were compared with those housed in free-stall barns, there was a lower incidence of clinical lameness and severe hoof disorders, cows were more mobile and lying times were longer and less disrupted (Olmos *et al*., 2009a). Providing lame cows with access to a non-concrete area was reported to improve recovery rates (Rossi *et al*., 2003). Cows housed for longer periods of the year have more lameness – the prevalence of lameness in cows grazed for 9 months each year was 6%, compared to 29% where cows were grazed for only 5 months each year

(Rutherford *et al*., 2009). The incidence of lameness in New Zealand is 30-50% lower than in countries where housing is commonplace (Chesterton *et al*., 2008).

The nature of lameness in housed cattle differs from that seen in pasture systems (Laven and Holmes, 2008a). Common causes of lameness and hoof lesions in housing systems include infectious disease (foot rot, heel necrosis, and both digital and inter-digital dermatitis associated with exposure to excreta), physical trauma (bruising/haemorrhage progressing to sole ulcers and white line disease) or digestive/metabolic upset (laminitis subsequent to ruminal acidosis; Phillips, 2010; Rushen, 2008). Digital and inter-digital dermatitis, and sole ulcers, account for over 40% of lameness in the UK (Hedges *et al*., 2001) but less than 2% in New Zealand (Chesterton *et al*., 2008).

The origins of lameness in confinement systems are generally considered due to the increased time that cows spend standing and the nature of the hard surfaces where they must stand and walk (Cook and Nordlund, 2009a). Important risk factors include concrete floors, restricted access to pasture or other soft areas to stand, and facility designs that make cows reluctant to lie down (Cook and Nordlund, 2009a). Lameness is more prevalent where cows walk mainly on concrete because of excessive and uneven hoof wear, bruising and impact lesions of the hoof capsule and digital pads, while excessive slopes and steps are also associated with an increased incidence of sole lesions (Rushen, 2008).

Exposure to hard surfaces can change hoof conformation over time. Vermunt and Greenough (1996) compared claw conformation of dairy heifers in their second year of life during which they were kept either in a free-stall barn or outdoors on a dry lot. The free-stall barn had concrete slatted floors in alleys and feeding areas, and rubber mats with a small amount of bedding straw were provided in stalls. Hoof dimensions were similar in both groups at 12 months old, and significant effects of age were observed in both groups, but at calving the heifers maintained outdoors had longer toes and wider lateral claws on both front and hind limbs, than heifers kept indoors ($P<0.05$). Positive correlations between claw lesions and claw measurements have been reported, and morphological claw parameters are related to the frequency of claw disease in later life.

O'Driscoll *et al*. (2007) compared hoof health and locomotion scores in a study of four Irish winter management systems. Cows were allocated to treatment at drying off (before which they had been kept on pasture) of either wintering in a free-stall barn with rubber mats in the stalls, wintering on uncovered and covered woodchip pads with feed provided on adjacent concrete feed tables, and wintering on a woodchip pad upon which pasture had been ensiled so that cows had continuous access to feed. Cows on the covered pad had harder hooves than cows in the other three treatments including the free-stall barn. These cows had the driest feet; even though the free-stall barn was scraped regularly, surfaces remained wet. The incidence of sole lesions and clinical lameness, and overall locomotion scores were similar for all groups during the wintering period. Heel erosion scores and interdigital dermatitis increased during wintering and at calving more cows on the self-feed pad showed signs of dermatitis than in the free-stall barn ($P<0.01$) or on the covered pad ($P<0.05$). By 14 weeks after calving, these differences were not significant. Carry-over effects of the wintering system on lameness after calving were also observed even though all cows are put onto pasture at calving (O'Driscoll *et al*., 2009). Locomotion scores after calving were higher in cows that had been housed in the free-stall barn than in cows kept on the covered woodchip pad. The highest incidence of sole lesions was seen in cows that had been housed on an uncovered woodchip pad but these cows also had the lowest locomotion scores. It was proposed that this could be because the cows on the woodchip pads may have been able to exercise more while confined because of the softer surface.

Cows using free-stalls but with access to pasture had less lameness than cows restricted to free-stalls alone suggesting that the total time spent in the free-stall environment is a risk factor for lameness (Cook and Nordlund, 2009a). Cows in a free-stall system spent more time standing on hard surfaces than cows in a deep litter barn where they preferred to stand on the bedding areas (Fregonesi *et al*., 2009b). Cows in deep litter systems had less lameness but required hoof trimming when housed for extended periods. Digital dermatitis and foot rot may become problems in deep litter systems if bedding conditions promote bacterial accumulation, and particulate bedding such as straw can irritate the interdigital skin (Phillips, 2010). Fregonesi *et al*. (2009b) found increased risk of lameness and a higher incidence of specific aggressive behaviours that contributed to a greater likelihood of lameness in free-stall barn systems than in deep-litter systems. Where free-stall design and lying surfaces did not provide sufficient comfort, cows spent more time standing in alleys; but provision of rubber in walkways and alleys was not recommended as a solution because it encouraged cows to lie in alleys to the detriment of hygiene (Vokey *et al*., 2001). The design of the free-stall itself may also influence the incidence of lameness. Cows housed in free-stalls on mattresses had a higher incidence of lameness (24%) than those housed on deep-bedded sand stalls (11%; Cook *et al*., 2004).

Effluent accumulation on concrete and a range of design factors that promote poor ventilation result in wetter surfaces and increase the probability of lameness. Cattle manure is highly corrosive and this will predispose to dermatitis if cows are required to stand in it for extended periods (Manske *et al*., 2002). Where cows stand on wet floors, the claws absorb water and become soft, increasing the risk of sole wear (Borderas *et al*., 2004) and sole lesions (Chapinal *et al*., 2009). Grooved floors reduce damage from slipping, but may increase the prevalence of digital dermatitis because they do not dry fully. Hooves may be drier where cows are kept on slatted floors, but the impact of reduced lying times may negate this advantage (Rushen, 2008).

The design and management of the feeding area will also influence the occurrence of lameness through the level of competition at the feed face. Cows engaged in aggressive interactions at the feed bunk had a higher risk of hoof health problems (Leonard *et al*., 1998). Feed table design can also reduce the stress on cows’ hooves – if the surface of the feed table is constructed to be 100mm above the level of the floor where the cow stands, there is less weight transfer onto the front feet during feeding (Powell, 2006).

Floor surfaces that discourage lame cows from lying may further aggravate lameness problems possibly because the experience of pain as they endeavour to lie down and rise on hard surfaces discourages them from further endeavours to lie. Sand bedding is promoted as an ideal surface for lame cows to lie on because it cushions and also improves traction when lying and standing. Lame cows had longer resting times when provided free-stalls with sand beds than with rubber mats. Sand beds are recommended in management protocols as a means to maintain normal daily activity during recovery from lameness (Cook *et al*., 2008, Cook and Nordlund, 2005, Cook and Nordlund, 2009b).

Dietary provision of trace elements and vitamins for maintenance of horn quality is another nutritional influence on lameness (Cook and Nordlund, 2009a).

IV.x.iii Other leg conditions. injuries and wounds

Skin lesions and swelling of the hocks and knees, and swollen pasterns, are seen more frequently in confined cows than in cows on pasture. Hock lesions were observed more often on farms using solid rubber mats for bedding and least often with deep-bedded stalls, with mattresses being intermediate. In one Canadian study more than 75% of housed cows had hock lesions (Rushen, 2008). Cows on farms with mattresses and little bedding have more severe hock lesions (Wechsler *et al*., 2000).

Skin abrasions and infections on wither and along the back arise more often in free-stall systems where space allowance is inadequate, forcing cows to repeatedly rub against metal pipe work. Abrasions and wounds on the neck arise where cows push against feed barriers. These may be aggravated where cows are only fed intermittently, and where food is not pushed up close. Shoulder injuries may also develop where cows are fed through stalls that incorporate headlocks which have bolts that protrude.

IV.x.iv Respiratory disease

Although respiratory disease is reported as a major problem in beef feedlot systems, it is not generally considered a problem of confined dairy cows (Rushen, 2008). The design of modern dairy systems aims to incorporate a lot of ventilation i.e. barn walls tend to be open or only covered with windbreak cloth to promote air flow. Furthermore cow populations on dairy farms tend to be stable, with only limited introduction and mixing of animals from different sources which probably limits the spread of conditions such as shipping fever which present a considerable challenge to health in beef feedlots.

IV.x.v Calving

During the transition period (from 3 weeks before to 3 weeks after calving) the cow experiences major nutritional, physiological and social changes and is more vulnerable to infectious and metabolic diseases. While it is generally accepted that there is a decline in feed intake during this period (Drackley, 1999), this may be magnified in confinement systems that do not provide well for the animals' needs. Huzzey *et al*. 2005 observed cow behaviour in a free-stall barn during transition and found a tendency for the number of meals to be higher after calving, but the total time spent eating was lower (87 vs 62 min/day). This was thought to reflect competition, social group changes and altered energy composition of the ration as cows moved into the fresh-cow barn. Drinking times increased from 5.5 min/day to 6.8 min/day. Total standing time was similar through the period observed, but highest at calving (14.4 h/day). There were 21.8 standing bouts on the day of calving compared to 11.7 and 13.1 bouts/day for pre- and post-calving, respectively.

Where cows are calving off-pasture, facilities should take the increased number of standing bouts into account and provide a non-slip surface, increased space allowance (minimum 10 m2/cow) and adequate clean bedding to ensure that hygiene and comfort needs are met (Tucker and Weary, 2004). Floor surfaces should also accommodate the needs of the wet slippery new-born calf. For slatted floors there should be ample bedding and the gap width should be small enough to prevent a calf's legs from becoming wedged, particularly where smaller sized animals are kept, e.g. Jerseys.

IV.x.vi Biosecurity

The higher concentration of animals in confinement systems may increase the risk of disease spread, and strict biosecurity plans should be implemented. Animal pests, including rodents, flies and birds, can transmit a range of diseases including leptospirosis and salmonellosis. Pest control programmes should be implemented, and pests excluded from feed storage areas as far as is practicable. Systems should also be designed to limit wildlife access to buildings and feed bins and tables, but this may be difficult given the requirements for good ventilation.

Human visitors may act as passive carriers of disease organisms on boots, clothing and vehicles. Rules should be implemented to ensure these risks are managed, including measures to manage contaminated vehicles and machinery coming from other farms. Imported feed supplements may also carry a biosecurity risk and assurance should be sought from feed suppliers that feed is safe and has been protected from contamination during storage and transport to the farm.

V WELFARE RISK ASSESSMENTS OF DAIRY HOUSING SYSTEMS

The welfare of housed dairy cattle has attracted attention from animal welfare advocates over the past two decades, especially in European countries where lactating cows are often housed for extended periods of time. In 2005, a survey of consumer and producer attitudes was conducted in seven European countries (Kjarnes *et al*., 2007). It was found that 69-87% of respondents (variation by country) indicated that animal welfare was important, but the way in which it affected their food purchasing decisions was variable. Most concern was expressed for the welfare of poultry and pigs, while only 3-15% of respondents indicated concerns about dairy production systems.

Rushen and de Pasillé (1992) published the first scientific review of the impact of housing systems on animal welfare. This review was in part a response to new regulations being implemented in response to Council of Europe directives that animal housing systems must cater to animals' behavioural needs. The intention of their review was to focus on the difficulties of scientific assessment of welfare provenance and to address concerns that the use of legislation to resolve issues causing anxiety to the general public could force the introduction of economically inefficient husbandry systems which might actually reduce animal welfare. Their overall conclusion was that farming systems are complex, with many factors influencing the outcomes for animals. Any focus on legislative controls alone cannot account for factors such as the quality of stockmanship delivered and its potential influence on the well-being outcomes for the animals concerned. Scientific studies may not, on their own, resolve complex decisions that involve ethics, politics and economics. Agreement as to which standards are valid, and what level of delivery is acceptable are also difficult because scientific knowledge of many issues is incomplete, while the complex nature of animal welfare is such that some sectors of the public will simply not accept scientific evidence that supports a practice that in their perception is indefensible.

In 1997 the Farm Animal Welfare Council of the United Kingdom published a comprehensive report on the welfare of dairy cattle (Spedding, 1997). This covered many aspects of dairy cow management including an analysis of the advantages and disadvantages of housing systems and concluded with a series of recommendations for the design and management of free-stall and loose-house systems, which they proposed would improve the welfare of dairy cows in these systems. The recommendations largely focus on design features (e.g. suggested minimum width of passageways of 2.4m), husbandry (e.g. slurry in passageways should be controlled by scraping at least twice daily), and provision of behavioural freedom (e.g. where cows are housed throughout the year free access must be provided to an exercise field adjacent to the housing area). Many aspects of these recommendations have subsequently been incorporated into detailed industry standards such as the UK Milk Development Council's publication Housing the 21st Century Cow (Powell, 2006).

V.i University of Bristol

In the 1990s, the RSPCA introduced a farm assurance scheme into the United Kingdom. Its intention was to improve and certify animal welfare standards both on farm and during transport and slaughter. Farms achieving the necessary standards could have their products sold under the "Freedom Food" label. Farms were required to comply with relevant standards and were inspected by assessors generally on an annual basis.

Researchers at the University of Bristol undertook a project to compare the welfare state of animals on RSPCA-certified farms with that observed on conventional farms. Whay *et al.* (2003) described the process used to develop the welfare assessment protocol, based on an iterative review of expert opinion. Welfare was assessed by evaluating both husbandry provisions (e.g. diet, housing and management systems) and indicators of welfare outcomes (e.g. disease and behaviour). These were then incorporated into a series of observations and records-related measures which were compiled during a farm visit. The impact of the assurance scheme on dairy cattle welfare was then assessed by comparing results from 28 certified farms with 25 that had not undertaken any previous assessments. Based on the outcome measures, lameness and housing/lying area discomfort were found at high levels irrespective of whether farms were enrolled in the assurance scheme. Although most enrolled farms were compliant with the Freedom Foods scheme, their failure to deliver good welfare outcomes serves to highlight the importance of using outcome-based assessment measures to improve conditions for animals (Main, 2006).

V.ii European Food Safety Authority

Prompted by a request from the European Commission in 2008, the Animal Health and Welfare Panel of the European Food Safety Authority (EFSA) provided a series of scientific opinions on the welfare of dairy cows (Anonymous, 2009b-f). Members of the expert panel were asked to assess the impact of housing, feeding, management and genetic selection on four separate aspects of dairy cow welfare (legs and locomotion, behaviour including fear and pain, metabolic and reproductive disorders, and udder problems) as well as an overall opinion as to whether current farming and husbandry systems comply with the requirements for and welfare of dairy cows. The expert panel identified and described hazards for cows under four management systems (free-stall barns, tie-stall barns, straw yards and pasture). Each panel member was then asked to provide an independent assessment of the level of exposure in terms of likelihood and magnitude, from which data the risks were characterised (Candiani *et al.*, 2009).

The EFSA expert group concluded that the major factor causing poor welfare, and in particular health problems, was long-term genetic selection for high milk yield (Anonymous, 2009f). Increased cow size associated with selection for milk yield was considered to have increased spatial requirements which increased vulnerability for skin wounds and damage to feet and legs. Increased milk yield was also viewed as having increased susceptibility to lameness, mastitis, metabolic and reproductive disorders. It was the panel's opinion that there is urgent need for genetic selection programmes to reduce their emphasis on production traits and focus instead on traits for fertility, health and longevity. The risk of exposure to hazards that impact negatively on cow welfare were assessed as higher in tie-stall and free-stall barns than in straw yards or at pasture, and the panel recommended that dairy cows and heifers should be given as much access as possible to pasture or other similar outdoor conditions, at least during summer and dry weather conditions. Leg and locomotion disorders were the major welfare problems identified, and the most important risks were housing design and management factors, in particular, inadequate provision for lying, standing and walking in barns, and management failures in monitoring locomotion and caring for feet (Anonymous, 2009f).

Subsequent to the findings of the expert group described above, the EFSA Panel on Biological Hazards was asked to provide an opinion on food safety aspects of dairy cow housing and husbandry systems (Anonymous, 2009g). This panel considered the findings of the expert group on welfare and concluded that there was insufficient evidence of a quantifiable relationship between welfare factors and the food safety of milk or beef. They did, however, support the general principle that good farming and hygiene practices that seek to optimise welfare would enhance animals' resistance to infection and reduce the on-farm spread of food safety hazards. They also commented that some husbandry practices that may improve welfare, such as providing access to outdoor spaces, could increase food safety risk by increasing exposure to environment- and wildlife-associated hazards, and called for multi-disciplinary research on these relationships.

VI Good practice recommendations (good husbandry indicators)

A wide range of potential indicators are reported in the literature against which dairy cow welfare can be assessed. These include:

- Lying times and lying behaviour including the number and length of lying bouts
- Herd behavioural synchrony
- Incidence of clinical mastitis
- Milk somatic cell counts
- Incidence of clinical lameness
- Locomotion and gait scores
- Hock, knee and leg damage – infections, swellings, abrasions and hair loss
- Abnormal rising behaviour, e.g. front end first
- Wounds on backs and necks – sores, swellings, rubs and hygromas
- Incidence of animals becoming stuck in facilities or lying out of bedding areas
- Abnormal lying and standing behaviour in free-stalls (perching, dog-sitting, lying half-in/half-out, reverse standing)
- Incidence of cows standing in alleys not lying or eating
- Uneven distribution of animals within the facility indicative of draughts, poor lighting, or uneven heating/ventilation
- Observing if cows can lie down without touching the sides of stalls or kerbing
- Anderson (2008) documented the specific behaviours considered to indicate that cows are not comfortable in confinement systems as follows:
    - Idle standing – pointless positioning of all four feet in the free-stall (+/- failed attempts at lying
    - Hesitation waltz – standing in free-stall swinging head repeatedly to left and right
    - Stereotypy – excessive repetition of an apparently purposeless behaviour, e.g. nose pressing against stabling equipment and grasping pipes with mouth

  - Perching – front feet in stall and rear feet on alley (may also be lying in/out) – bouts may last for several minutes or more than an hour – considered an important indicator of inadequate lunge space
  - Diagonal standing/lying – corner to corner use of the stall – suggests that there is insufficient space to stand squarely
  - Lying backwards – learned when heifers or calves are raised in ill-fitting stalls or to avoid frustrating or painful stall features
  - Kneeling cow syndrome – kneel on fore-knees while standing on back legs – may be related to obstructions to normal rising or lying especially in the lunge space
  - Dog sitting – sit on hindquarters with front legs extended (also described as "horse rising behaviour") – may indicate injury to knees or associated with stall features that are uncomfortable especially lunge space. May persist for several minutes before a cow rises or be associated with failed attempts to rise.
  - Long bouts of lying – suggests pre-existing injury or lameness
  - Restlessness – getting up and down and moving frequently - behaviour associated with uncomfortable lying conditions
  - Bunching – water troughs on summer, temperature variation through barn.
- Behavioural assessment should be done at a constant time each day; just turning up and looking for a short period may not give good information. The observation time should also be selected with consideration of environmental temperature at the time of observation as this will also affect behaviour patterns. Intermittent observations of stall usage rates do not necessarily reflect actual lying times achieved, but do indicate the amount of lameness (Cook, 2004, 2005). Overton (2002) advises assessing stall usage one hour before morning feeding or milking.
- In recent years the design of confinement facilities for dairy cows has had an increased focus on cow comfort and a range of new solutions are available. The general principles of barn design increasingly endeavour to replicate the important characteristics of outdoor living which are seen to benefit the animals. Confinement systems should ensure they maximise light, space and ventilation, underfoot conditions must be comfortable, and design and management systems should maximise access to feed, water and rest.
- Other important principles include:
  - Providing and maintaining dry soft surfaces for cows to stand and lie down
  - Keeping floor areas where cows stand as dry and clean of excrement as possible
  - Designing feeding and lying areas, including adequate space provision, to reduce competition and aggression between cows
  - Protecting the subordinate animals which are most at risk by ensuring their access to feed and resting surfaces, by establishing stable social groups and by avoiding frequent re-grouping
  - Providing reserved areas for lame animals and animals that do not adapt to the confinement system
  - Providing heifers with training over several weeks (ensuring that lying comfort is maximised to encourage their learning during this time)
  - Providing free-stalls with long lying area and lunge space – but avoid using these for training heifers because they will learn to walk through
  - Using the knee test to test bedding comfort - a human should be able to drop from a standing position directly onto their knees on the bedding surface without pain

VII APPENDICES

VII.i Key international reference sites for good housing practice

- Anderson N, 2010. Free-stall dimensions for dairy cows. Ontario Ministry of Agriculture, Food and Rural Affairs (http://www.omafra.gov.on.ca/english/livestock/dairy) - detailed information on calculation of stall dimensions
- Best Practice Manual for Herd Homes® Systems: Guidelines for owners and operators. ISSN 1179-8408 (http://www.herdhomes.co.nz) – planning and using Herd Homes® shelters
- Cow Signals Training Company (Jan Hulsen and Joep Driessen) -– information on husbandry practises, hoof health and barn design (http://www.cowsignals.com)
- DeLaval, 2006. Efficient cow comfort – management advice for planning and managing housing systems (http://www.delaval.co./Dairy_Knowledge/)
- Milk Development Council (UK), 2006. Housing the 21st Century Cow
- Moran J, McDonald S, 2010. Feedpads for grazing dairy cows. CSIRO Publishing. (ISBN# 636.21420994)
- National Milk Producers Federation (USA), 2010. Animal care manual – management procedures, herd health planning and assessment of dairy cattle (http://www.nationaldairyfarm.com)
- University of Bristol - http://www.cattle-lameness.org.uk

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