final report

Project code: B.GBP.0001

Prepared by:
Michael McGowan, Geoffry Fordyce, Dave Smith, Kieren McCosker
Tamsin Barnes, Roger Hegarty, David Mc Neil, Nigel Perkins
Joe Miller, Kylie Schooley, Wendy Brodie
Rebecca Comiskey, Dan Lynch, Geoff Murrell
Alister McClymont

Date published: 17 November 2017

PUBLISHED BY
Meat and Livestock Australia Limited
PO Box 1961
NORTH SYDNEY NSW 2059

Development of candidate management interventions to reduce calf wastage in beef herds in northern Australia

Meat & Livestock Australia acknowledges the matching funds provided by the Australian Government to support the research and development detailed in this publication.

Abstract

Losses between confirmed pregnancy and weaning (calf wastage) have been identified as one of the most important problems confronting the beef industry in northern Australia. A list of management interventions likely to reduce calf wastage was developed from the findings of a recent scientific review, PhD, and scientific papers describing the factors contributing to calf wastage. An expert opinion workshop was held to map out the proximate and more distal factors affecting calf wastage. From this, causal webs were developed to facilitate assessment of the impact of listed management interventions. A basic economic model was then developed to estimate the impact of each intervention on beef breeding business profit. Nine researchers, eight agribusiness personnel and 22 beef business owners/managers representing all country types across northern Australia then applied this model to rank 23 management interventions. Those ranked highest for research by this panel were improving phosphorus supplementation, improving calf husbandry, reducing paddock size, enhancing mothering, improving nutritional management of pregnant yearlings to reduce dystocia, and controlling infectious diseases. Using the output from this project a budget was generated to progress appropriate activities to evaluate the impact of priority interventions on the occurrence of calf wastage and business performance.

Executive summary

Losses between confirmed pregnancy and weaning (calf wastage) represent one of the most important problems confronting the beef industry in northern Australia. The Cash Cow project found that in a quarter of breeding mobs studied calf wastage was at least 15%, three times higher than what is potentially achievable. Further, it has been recently estimated (Project B.AHE.0010) that the death of calves in the first 2 weeks of life conservatively costs the northern industry $54M annually.

Calf wastage is a complex problem. Many different environmental-, property/herd management-, animal- and disease-level factors or causes are known to contribute to the problem. Some of these factors/causes occur close in time to the loss (proximate factors), whereas others are more distant in time relative to death of the foetus or calf (distal factors). It is the latter group that are critical to understand to reduce the incidence of calf wastage because in most cases in an extensive grazing situation management interventions must be applied strategically and at a mob or herd level. For example, a calf may die of dehydration due to scours caused by a bacterial infection of the intestines. The most proximate factor to death of the calf in this case is dehydration. However, the key question here is not 'what is the specific bacteria that caused the infection', but rather 'what predisposed this calf to developing this infection in the first place'. The major factor predisposing a calf to scours is failure to consume sufficient good quality colostrum within the first 12 hours after birth. This may be due to either the cow not having any or enough colostrum, and/or the calf not being able to suckle effectively. It is well recognised that the body condition score of cows at the time of calving has a major impact on colostrum production and quality. The Cash Cow project found that cows in the northern forest in poor condition at the time of pregnancy diagnosis (a good example of a distal factor) had significantly higher calf wastage than those in good body condition. To ensure cows calve in good body condition weaning must be conducted before cows lose significant condition, and they then must have access to sufficient adequate quality pasture to recover body tissue reserves lost during lactation. It is only through having a thorough understanding of the pathway to the problem that management interventions likely to reduce the problem can be identified. This example demonstrates why the project team concluded that a systems-based approach must be used to develop practical, cost effective methods of reducing calf wastage.

Thus the objectives of the current study were to:

1. Develop an industry reference group to provide strategic guidance for this project and subsequent projects.
2. Review current knowledge and understanding of the causes of calf wastage for immediate application of best practice, and identify candidate interventions for research by:
   a) Further epidemiological analysis of existing datasets (Cash Cow Beef CRC etc.)
   b) Determining for each known cause of calf wastage current knowledge, knowledge gaps, impacts on productivity and business outcome, and interventions likely to mitigate these impacts
   c) Further investigation of Cash Cow herds that consistently had very low or very high incidence of foetal/calf loss.
3. Identify and evaluate methods to investigate the impact of management interventions to control calf wastage in extensively managed beef herds.
4. Develop a fully costed proposal for investigation of the outcome of implementation of selected management interventions.

Six commercial beef cattle producers (3 men and 3 women) representing family and corporate (small and large) owned businesses located in the major beef breeding regions of northern Australia were selected to form the calf wastage project industry reference group. The criteria for selection were that producers undertook routine monitoring of herd performance and production in their business

and had a strong interest in identifying strategies to reduce calf wastage. The industry reference group played an integral role in identifying potential management interventions and determining which ones were the highest priority to be researched.

The findings of a recent scientific review, a PhD, and scientific papers describing the causes of, and factors contributing to calf wastage were used to develop a list of known and potential management strategies. This list was used to draft a series of technical notes describing potential management interventions. A systematic review of the published literature was then conducted to compile evidence for the impact of each management intervention on the occurrence of calf wastage and herd business performance. This review demonstrated that the major knowledge gap was the very limited published evidence defining the effectiveness of most potential management strategies.

A one-day expert opinion workshop was held to map out the proximate and more distal factors affecting foetal survival, calf survival in the first 2 weeks of life and then to weaning, and pregnant heifer/cow survival. A series of causal webs were created and used to assess the likely impact of each identified management intervention. In addition, a pilot survey was conducted to identify management practices employed on properties with consistently low calf wastage. Further, to gain a better understanding of where in the reproduction cycle greatest loss typically occurs, and what impact calf wastage had on lifetime cow liveweight production, a series of epidemiological analyses were conducted using the Beef CRC database.

The twenty-three identified management interventions were then ranked. Initially a basic economic model was developed to estimate the impact on business profit of implementing each candidate intervention. At a project workshop held in north Queensland, 9 scientists, 8 agribusiness personnel, and 22 beef business owners/managers responsible for 0.4M cattle and representing all country types across northern Australia then used this model to rank each management intervention. The management interventions rated to have highest priority for research were as follows:

- improved phosphorus supplementation,
- improved calf husbandry,
- reduced paddock size,
- enhancing mothering,
- improved nutritional management of pregnant yearlings to reduce dystocia,
- control of major infectious causes of calf wastage, and
- improved strategies to manage the risk of predation

The application of a remote livestock management system to provide research quality data on cow performance, and to enable in-paddock investigation of nutritional interventions was evaluated on a commercial beef cattle property near Richmond in north Queensland. The major limitation of the use of this technology occurs during the wet season when a high percentage of cows that calve fail to come into the fixed water-points. A desktop evaluation of five commercially available crush-side data capture and data processing systems was conducted using the following criteria: usability, affordability, scalability, data flow and security of data, and user support. Overall, the KoolCollect system best met these criteria.

A fully costed proposal was submitted in April 2017 for review by the expert panel. The proposal focussed on a whole-of-system evaluation of the impact of implementation of selected high priority management interventions to reduce calf wastage in commercial businesses in northern Australia.

Table of contents

1 Background

Optimum calf output from a beef breeding herd requires that the majority of cows cycle while lactating, are successfully mated, and then the majority of conceptuses develop normally to birth, resulting in delivery of live vigorous calves that are suckled to weaning. **Calf wastage**, the term that will be used throughout this report, describes the total loss that occurs between confirmed pregnancy and weaning. It includes losses due to abortion, premature birth and still birth (prenatal mortality), calf deaths in the first 2weeks after birth (neonatal mortality), and losses of older calves including those associated with branding, dehorning, and castration. Death of pregnant heifers and cows is also a part of calf wastage.

Losses between confirmed pregnancy and weaning continue to be one of the most important problems confronting the north Australian beef industry and have been rated as a high priority for research. McGowan et al (2014) demonstrated in the Cash Cow project that in 25% of heifer mobs losses were 18% or greater, and in 25% of cow mobs losses were 14% or greater. Lane et al (2015) recently estimated that calf losses in the first 2 weeks after calving conservatively cost the northern industry $54M annually.

Over the past 15 years in particular, MLA has invested significant funds in research (Beef CRC and Cash Cow) to define the factors contributing to or causing losses between confirmed pregnancy diagnosis and weaning in beef breeding herds in northern Australia. Over a period of 11 years the Beef CRC monitored the performance of mobs of selected Brahman and tropical composite heifers and cows managed according to ‘best practice’, which included vaccination to control the majority of endemic infectious diseases. Low birthweight (<29kg), cow age ≤ 4years, poor rear teat and/or udder conformation, male calves, and country type were all factors identified as significantly increasing the risk of calf deaths in the CRC herds. The Cash Cow project monitored the performance of 142 breeding mobs over 3 to 4 years and demonstrated that the major factors contributing to calf wastage included failure of cows to lactate in the previous reproductive cycle, mustering pregnant heifers/1st lactation cows around the time of calving, exposure to very hot/humid conditions around the time of calving, and grazing wet season pasture deficient in phosphorous. Cash Cow also found that calf wastage was likely to be significantly increased where property owners/managers considered wild dogs were a problem, where the prevalence of recent infection with bovine pestivirus was high, and where there was strong evidence of Vibriosis.

The sub-tropical/tropical rangelands of northern Australia present major challenges to the new born calf. It must be born fully adapted to extra-uterine life and be able to quickly get to its feet and repeatedly suckle successfully from its mother. Any factor that adversely affects this critical process will increase the risk of calf death. Recently, Fordyce et al (2015) has demonstrated that at an ambient temperature of 40°C, a calf that fails to suckle will become severely dehydrated within 24hours. This calf may die of a number of different causes, for example predation (too weak to escape), or septicaemia (weakened immune response), which highlights the limitations of relying primarily on post mortem examination of dead calves as the basis for determining how to prevent calf wastage.

Having identified many of the factors affecting/causing calf wastage in beef herds in northern Australia the key question producers want answered is ‘what can be done to sustainably and profitably reduce calf wastage’. This is the focus of the present project, which has been conducted by a project team consisting of commercial beef cattle producers and researchers from across northern Australia. Over a period of approximately 12 months the project team developed robust methodology to identify and prioritise for research management interventions to reduce calf wastage.

2 Project objectives

1. Develop an industry reference group to provide strategic guidance for this project and subsequent projects.
2. Review current knowledge and understanding of the causes of calf wastage for immediate application of best practice, and identify candidate interventions for research by:
   a) Further epidemiological analysis of existing datasets (Cash Cow Beef CRC etc.)
   b) Determining for each known cause of calf wastage current knowledge, knowledge gaps, impacts on productivity and business outcome, and interventions likely to mitigate these impacts
   c) Further investigation of Cash Cow herds which consistently had very low or very high incidence of foetal/calf loss.
3. Identify and evaluate methods to investigate the impact of management interventions to control calf wastage in extensively managed beef herds.
4. Develop a fully costed proposal for investigation of the outcome of implementation of selected management interventions.

3 Methodology

The primary research question pursued in this project was, 'What is the evidence that potential management interventions will cost-effectively reduce high calf wastage in north Australian beef herds?'

To begin with the project team was balanced to include an industry reference group.

The research question was then addressed using multiple methods:

- Causal webs for calf wastage were constructed to understand the detailed complexity of calf wastage
- Potential management interventions for control of calf wastage were reviewed
- A review presented current best-practice for mitigating calf wastage
- A thorough review of international literature was conducted for available evidence on efficacy of potential calf wastage mitigation options applicable to northern Australia
- A rapid assessment method for risk of calf wastage against risk factors of significance was developed and tested
- Potential risk factors for calf wastage and cow productivity were analysed using pre-existing data-bases

Outputs from the above were enhanced by:

- Prioritising calf wastage intervention research through development and application of a method that assesses potential business impact
- Review of methods to collect and manage data in calf wastage and cow productivity research
- Assessment of the use of remote technology for calf wastage research to further investigate mitigation options

All project activities then contributed to development of a Phase II calf wastage research proposal.

3.1 Establishment of a calf wastage project industry reference group

A group of six producers representing most of the beef cattle breeding sector in northern Australia was sought. The key selection criteria were producers with experience in RD&E or in industry representation, balanced representation of regions (southern, central and northern Qld, NT & WA), business size (large, moderate, small), business type (private, company) and gender (female, male).

The major objective for the group was to guide development and conduct of the project, including making recommendations on candidate interventions to be researched, reviewing proposed studies during the course of the project, representing the project to stakeholders, reviewing the draft final report and contributing to the recommendations for a major new project.

The project team used their industry network to identify producers who met the selection criteria and then these producers were invited to join the reference group. This was a relatively-quick and very effective method. Only one invitee declined, but was able to nominate another producer who was equally suitable.

3.2 Development of causal webs for calf wastage

3.2.1 Overall approach

Calf wastage is a complex problem. Many different environmental-, property/herd management-, animal- and disease-level factors or causes are known to contribute to the problem. Because of the nature of contemporary research, it is proximate risk factors, those particular exposures or circumstances close in time to the outcome, that are most readily identified. While such findings are useful, a deeper understanding of a complex problem requires looking further back in time at more distal factors, those associated with the proximate risk factors and then in turn the factors associated with those factors, at both individual and group levels. This can be achieved using a systems-based approach using a causal web that incorporates factors at multiple levels, allows for processes that are not necessarily linear and sequential, and may involve feedback and interactions (McMichael, 1999).

Causal webs are tools used to illustrate causal relationships among a set of variables in a system. There are two main types of causal webs, those that can include loops (causal loop diagrams) and those that are acyclic (directed acyclic graphs). Causal loop diagrams were used in this study as causal loops can be used to visualise dynamic processes and allow assessment of the complexity of biological systems over time. A similar approach has been used to understand the dynamics of neonatal mortality in humans (Rwashana et al, 2014).

The key components of a causal web are variables and arrows (Maani and Cavana, 2007). Variables can influence and can be influenced by other variables and they can be binary (e.g. loss after calving – yes/no), quantitative (e.g. milk intake) or qualitative (hard to measure directly e.g. favourability of vegetation and topography). Each arrow represents a causal association between two variables and that association may be either positive or negative. If the association is positive, assuming all other variables are held constant, an increase in the variable at the tail of the arrow will result in an increase in the variable at the head of the arrow, and correspondingly a decrease will result in a decrease (e.g. dystocia increases the probability of a calf being born dead; lack of dystocia i.e. normal birth reduces the probability of being born dead). Such an association is represented in a causal diagram by an arrow with a plus (+) sign. In contrast, if the association is negative, assuming all other variables are held constant, an increase in the variable at the tail of the arrow will result in a decrease in the variable at the head of the arrow, and correspondingly a decrease will result in an increase (e.g. bottle teats reduce milk intake). Such an association is represented in a causal diagram by an arrow with a minus (-) sign. Single arrows usually represent a relatively rapid causal association. If there is a notable delay between cause and effect this is represented by the inclusion of the delay symbol (||) on the arrow (e.g. the development of immunity following infection with bovine viral diarrhoea virus). Within the structure of causal loop diagrams, combinations of variables and arrows may form causal loops where a path leads from one variable through a series of arrows and variables back to the starting variable. These loops may be reinforcing or balancing (Maani and

Cavana, 2007). Reinforcing loops are positive feedback systems and can represent growing or declining actions e.g. with all other factors constant, if a calf is vigorous it will consume more milk and in turn become more vigorous, but if it is lacking in vigour it will consume less milk and become less vigorous. Balancing loops eventually lead to stability through self-correction e.g. with all other factors constant, a cow in good body condition will produce more milk, but that will lead to a decrease in body condition and she will then produce less milk. Understanding the feedback loops in the system is useful for the identification of leverage points to make a lasting impact on the system.

The aims of this study were to develop causal webs to facilitate the understanding of the complex set of factors influencing calf wastage and to use these causal webs to identify possible leverage points for interventions.

3.2.2 Causal web development for calf wastage

An expert opinion workshop involving members of the project team with many years of experience in research in the Australian northern beef industry was held in April 2016. A group model building process was used to develop a series of causal webs focussing on three key outcomes: born dead (loss of foetus or calf between confirmed pregnancy and the day of parturition), loss around calving (death of calf within 14 days of live birth) and heifer/cow mortality (death of heifer or cow following confirmed pregnancy). Due to the complexity of loss around calving, two separate webs were developed, one looking at causes of calf vigour and focussing on other proximate causes of loss. Boundaries were set to restrict the system e.g. predation was recognised as a factor, but the potentially large number of factors influencing the risk of predation were not included in the diagrams. Due to lack of time a fourth outcome, loss after calving (death of calf between 14 days after live birth and weaning), was only discussed briefly.

After the workshop, each web was recreated electronically using Vensim®. As many of the variables were common to two or more of the webs and linkages existed between outcomes, a single web was created. Each variable was assigned to a group (outcome, animal, disease, nutrition, management, or environment) and these groups were used to colour-code the diagram. This diagram was complex and cluttered so a series of reduced diagrams were created. One diagram was created for each outcome of interest including only the variables that were a maximum of three arrows removed from the outcome, with variables colour-coded based on the closest connection to the outcome (blue – one step, green – two steps, black – three steps). All arrows interconnecting these variables were also retained. Diagrams were also created where balancing or reinforcing loops were identified in the main diagram. These diagrams also included the variables directly connected with each variable in the loop. The full series of diagrams was then examined to assess the likely impact of proposed interventions.

3.3 Review of potential management interventions to reduce calf wastage

A review was conducted to identify candidate interventions for research. Most relevant published research has identified risk factors for reproductive wastage, but not the interventions that modify the risk factors; e.g., if body condition is a major risk factor, an intervention is required to manage body condition because by itself, body condition is not an intervention. Almost all interventions to ameliorate the impacts of risk factors involve actions to manage the feed base, lactation, health and stress, and/or breeding. Interventions with the potential to achieve cost-effective control of calf wastage were identified, and for each, evidence was reviewed for known effects on calf wastage, knowledge gaps, and impacts on productivity and business outcome.

The interventions were then prioritized for potential research using the following criteria:

- They should be expected to have clear effect on risk factors that in turn have a useful level of effect on reproductive wastage. Assessment was assisted by causal loop diagrams.

- The prevalence of the risk factor should be sufficient to warrant controlling it.
- An interim economic analysis suggests the intervention has potential to improve reproductive wastage, herd productivity, and business profit.
- Previous research has not been able to discern the specific effect of the intervention on reproductive wastage.
- The intervention should be a practical option in a commercial environment, even if this may not be until a future date.
- The research should be possible within the constraints of available resources and skills, and should cost much less than expected future benefits.

3.4 Compilation of current recommended management practices to control calf wastage

The current recommended practices to control calf wastage in northern Australia were prepared in beef industry language. Most of the major recognised risk factors for calf loss in northern Australia were considered. Particular emphasis was placed on identifying causes that are important (large positive or negative effect on risk of foetal/calf loss), common, and are able to be controlled through an intervention that is practical and cost-effective. The objective was to provide a document in a format suitable for transformation into extension support materials, i.e., can be used by beef advisers to prepare targeted recommendations for beef cattle producers.

The recommendations were drawn from national and international literature and expert opinion; most of the relevant literature originated from northern Australia (Burns et al 2010; Bunter et al 2014; McCosker, 2016). Where there was an absence of data for northern Australia but existing data from Southern Australia or elsewhere, expert opinion was used to estimate the impact. The review structure presented generic aspects of calf wastage, including its description and how to investigate it, and then used published information to review the known impact of each risk factor before presenting known or potential management options to ameliorate its impacts. A highly-experienced beef industry consultant was contracted to produce the first draft of the review using the guidelines above. Project team members then edited the review into its final form.

3.5 Systematic review of published literature on interventions to control calf wastage

The project team contracted a highly-respected consultancy business, AusVet, to conduct a thorough systematic literature review. Initially AusVet was provided with the review of current ‘best practice’ recommendations for control of calf wastage, which guided the method of sourcing available evidence for potential mitigation strategies.

Firstly, the exact research question was refined. Calf wastage mitigation strategies were compiled. The risk factor for each mitigation strategy, derived from fact sheets or from further review, was recorded against the mitigation strategy. Where commonalities in risk factors existed between mitigation strategies these were grouped together—similarly to a factor analysis. The managerial activity or measurement the farmer in northern Australia would most likely use for the risk factor was used to name each group. This approach allowed similar or the same mitigation strategies to be reviewed together and increased the likelihood of identifying other possible mitigation strategies from the literature that had not been included. The following principle for evidence was used throughout the review: if the mitigation strategy is effective there would be a decrease in the associated risk factor and a demonstrable decrease in calf loss reported in the relevant paper/s.

Relevant literature was identified by thorough searching of the Web of Science website, Google Scholar database, and Meat and Livestock Australia (MLA) website. The literature search was limited to animal studies and papers that had abstracts in English or translations were available. Opinion based and papers that did not present any new information, or letters to editors were excluded. Information from all relevant papers was used to prepare summary reviews of the impact of potential mitigation strategies and associated risk factors on calf wastage.

3.6 Development of a survey method to determine risk of calf wastage

The objective was to produce a method to be used by a herd health professional that could achieve rapid and accurate assessment of the risk of calf wastage and/or the risk factors associated with known or potential calf wastage in a beef herd. In structuring the method, it was recognised that it would be invaluable for future research to identify businesses at risk of calf wastage, as only a small minority of businesses have data to define prevailing levels. The method would also be a valuable part of routine veterinary evaluation.

A survey questionnaire was developed using the project's reviews of all known risk factors of significance in northern Australia. These risk factors were grouped against all primary management / interventions, which were in four classes. The presence, absence or level of risk factor prevalent as it related to calf wastage was classed at 2-4 levels, allowing a rapid selection. Key descriptors of the business were included as these were in themselves indicative of risk.

Surveys were then conducted with beef producers whose herds consistently had low calf wastage during the Cash Cow project. This was considered the best test of the survey, as if these businesses showed low levels for each risk factor, it would reinforce the evidence for low calf wastage in the absence of risk factors of significance.

3.7 Analyses of risk factors for calf wastage and cow productivity using pre-existing data-bases

The Beef CRC dataset was subjected to additional analyses to test specific questions arising from the development of causal loop diagrams. The available data included full details on cow performance and productivity and a range of management and environmental factors over multiple years. The project team included individuals with extensive experience in advanced multivariable statistical analyses, including those with direct experience with analyses conducted as part of the Cash Cow and Beef CRC projects. Risk factors in the CRC data varied somewhat to Cashcow data due to size of paddock, controlled mating, husbandry procedures, time of mustering and vaccination against reproductive diseases in these well controlled smaller research herds.

The potential for analyses to answer research questions from the Beef CRC data and multiple other data sets is immense. In this project, the objective was to produce some key understandings of the biology associated with calf wastage. Further targeted analyses will be conducted during future projects. Primary analyses conducted included the following:

- The timing of calf wastage between approximately 5 weeks of gestation and weaning was detailed as a basis for targeting key periods to control loss.
- Complex epidemiological analyses of pre-, peri- and post-natal loss were conducted by constructing analytical models using event-orientated directed acyclic graphs developed from the causal loop diagrams with the aim being to produce least-biased estimates for 22 available risk factors.
- Using a similar method, the impact was analysed of available risk factors, including calf wastage, on the cow annual productivity measures of weaner weight, cow live weight change, and live weight production.
- A method and its error for predicting weight of calf at weaning from standard risk factors, primarily foetal ageing, was developed. This is a way of measuring and therefore analysing

live weight production for a multitude of datasets that do not include either calving date or pedigree, thus enhancing understanding of calf wastage on productivity and profitability.
- Predicting growth curves for cows as a function of primary risk factors, including reproductive outcomes such as calf wastage. As live weight is a critical component of beef business production and profit, the aim was to enhance the ability of using multiple datasets that may have incomplete live weight data for measuring the impacts of risk factors such as calf wastage on productivity and ultimately profitability.

3.8 Development of a method to enable objective prioritization of calf wastage intervention research

It has been common practice to use subjective methods to define priority for research options. However, it appeared possible to develop a unique method that used a basic economic analysis for objective prioritization of research options. The aim was to develop a method that could be used for other research targets, and to test it by prioritising research of possible interventions to mitigate calf wastage.

From reviews conducted by the project, 23 interventions with potential impact on calf wastage were selected. In each case, a situation with and without the intervention was described. Most interventions were known to have many secondary impacts and these are all considered when assessing overall impact. After briefings and discussion, new practice vs current practice for each intervention was assessed for change in growth, survival, reproduction, costs and product value (outcomes) using a 7-point scale ranging from a large reduction to a large increase.

Herd modelling was used to establish the relative impact on EBIT due to variation in growth, mortality, reproduction within country type (which together = production), product value and costs (details provided in full report). Calculation of impact on business of a change in practice was conducted by summing the products of impact rating and relative impact on profit. As each option comparison is a basic economic analysis, a negative value indicates the change is likely to reduce profit, a value around zero may have marginal impact on profit, and the more positive the value is, the more profitable the change is likely to be. The influence of changes in herd inventory with each intervention was not included in the calculations, primarily because herd size was fixed in the analysis. Impacts across northern Australia were weighted by the relative cattle populations estimated to be within each country type. The range of values for business impact was adjusted upwards by the same value so the lowest was zero. Each adjusted economic analysis was then multiplied by both the relative incidence (0-3) of the risk factors being impacted and researchability (0-3) of the comparison (already done; ease of research that has multiple facets) to derive the final priority value. A sensitivity analysis was conducted by measuring the change in ranking when the relative impacts of changes in each business element were altered by up to 20%.

The prioritization process was conducted by 3 groups who provided impact ratings in small sub-groups by consensus:

- Scientists drawn from Queensland (5), New South Wales (2) and the Northern Territory (2) and the industry reference group (6 producers). This constituted most of the project team. Ratings agreed by the project team to prioritise interventions for research were applied to business impact evaluations by all groups.
- Beef business representatives (16) from central Queensland through to the central Northern Territory, large and small business, private and company business, owners and managers, and men and women. These participants collectively have responsibility for an estimated 0.4 million cattle, which is about 0.3% of the north Australian beef herd.
- Agribusiness (8) representatives.

3.9 Evaluation of crush-side data capture technology for calf wastage and cow productivity research

A desktop review was conducted of five commercially available data capture systems and associated support technologies by a member of the project team with extensive hands-on practical experience. The purpose was to determine which was likely to be most accurate and efficient for monitoring impact on business performance of selected management interventions aimed at reducing calf wastage. Each system was assessed for:

- Useability, which included the skill or training required to enable the collection of required data at commercial processing rates in a remote environment.
- Scalability.
- Affordability considered the costs associated with the application of each system and included computer versus enterprise licensing, data storage costs, and annual support costs.
- Data flow and security, which focused on the ability to accurately record the required data, and transfer data safely between local and remote data stores.
- User support, which focused on direct access to system technical support including after hours. The range of features offered and the likelihood of parent companies being prepared to incorporate modifications or address limitations of their systems were also considered.

Once a candidate system was identified, other existing technologies that could potentially improve the usability of this system were assessed.

3.10 Evaluation of the practical application of remote monitoring technology for calf wastage research

To assess the efficacy and practical application of remote livestock management systems (RLMS) for calf wastage interventions research, the project linked with the University of New England's "*Dietary nitrate reduces methane emissions from beef cattle"* project, which was developing and testing methods for application of treatments within paddocks under extensive grazing conditions typical of commercial beef businesses in north Queensland. In this project 600-800 tropically-adapted cows with bulls were grazing an 8,000 ha paddock in which 2 of 5 possible controlled waters were used at any one time. The dynamic weighing system (previously called walk-over-weighing) used was a custom version of an 'off the shelf' product from Precision Pastoral. Two RLMS units each fitted with a four-way draft were placed at 2 of the 5 possible water sources (bores/dams). Animals had to come through each RLMS unit to access water during the study as the other controlled waters were fenced off.

The 12-month evaluation included:

- Assessment of suitable hardware and software to achieve accurate electronic auto drafting within paddocks of all animals into separate treatment coolers during variable seasonal conditions.
- Assessment of the accuracy and completeness of data captured by RLMS.
- Efficacy of training cattle to the system.
- Ability to achieve remote data capture, and especially to evaluate the potential use of walk-over-weighing as a means of monitoring the occurrence of calving and presence or absence of the calf.

3.11 Development of a Phase II calf wastage research proposal

The full team considered all outputs produced during the project in formulating a Phase II proposal. Previously, a 3-phase process was developed in consultation with representatives from industry, RD&E agencies and MLA for research, development and adoption of interventions to cost-effectively and sustainably reduce calf wastage across north Australia. A Phase II proposal incorporated RD&E, projecting to a Phase 3 proposal which is planned to be primarily scaling out, i.e., adaptation of recommendations across northern Australia.

The primary elements of the proposal were to:

- Develop a suitable team and framework for collaborative RD&A across northern Australia.
- Test interventions identified as having highest priority in achieving business benefits. This would be done in commercial situations identified as having high risk of calf loss using the methods produced in the Phase I project.
- Developing a process and industry capacity to apply recommended practice change emanating from the research.
- Complete the phase within 5 years with a total budget (MLA + research organisations) of approximately $1M annually.

A preliminary proposal for funding of Calf Wastage Phase II was submitted to MLA in late December, 2016 as part of MLA's annual call for levy funded research. This proposal was supported by the industry panel and thus subsequently a full proposal was developed and submitted to MLA in April 2017.

3.12 Further investigation of Cash Cow herds which consistently had very low or very high incidence of foetal/calf loss.

A pilot survey was conducted on selected properties from the Cashcow project that experienced very low levels of calf loss during the Cashcow project.

4 Results

4.1 Calf wastage project industry reference group

A critical objective of this project was to ensure that there was direct input from industry representatives on what calf wastage management strategies should be researched, and what strategies have already been adequately researched and should be adopted by producers. Six commercial beef cattle producers (3 men and 3 women) representing corporate and family (small and large) owned businesses located in the major beef breeding regions of northern Australia were invited to form the calf wastage project industry reference group; all agreed to participate. The industry reference group functions similar to a company board directly advising and overseeing the development and reporting of research conducted by the project team. Two workshop meetings of the project team and industry reference group were held in 2016—one at The University of Queensland Pinjarra Hills farm and one at Richmond, with the latter being extended to include an industry forum. The industry reference group played a critical role in validating the methodology developed to identify candidate management interventions and to prioritise those that should be researched.

4.2 Causal webs for calf wastage

4.2.1 4.2.1 Overall web

The causal web incorporating all three outcomes of interest, namely born dead (loss of foetus or calf between confirmed pregnancy and the day of parturition), loss around calving (death of calf within 14 days of live birth) and heifer/cow mortality (death of heifer or cow following confirmed pregnancy) and associated variables is shown in Fig. 1. A total of 76 variables were identified and each was assigned to one of five groups. Those in the animal group were accident, age at first calving, birth weight, blood flow to the placenta, bottle teats, calf vigour, colostrum quality, congenital defect, consumption of poisonous plants, cow age, dystocia, environmental adaptation (cow), environmental adaptation (calf), exercise, foeto-pelvic disproportion, gestation length, hip height, immunity, inherited defect, lactation, mothering, non-sucker, parity, pelvic size, placentome weight, separation, teeth, twins, udder confirmation, urea poisoning, uterine adaptation, water intake, weak, and septicaemia. Those in the disease group were akabane, bovine ephemeral fever (BEF), botulism, bovine viral diarrhoea virus (BVDV), campylobacter, clostridia, external parasites, ixodes, leptospirosis, mastitis, neospora, tick fever and infectious disease (to cover a range of less common infectious diseases). Those in the environment group were mud, rainfall, soil quality, temperature humidity index (THI) during the third trimester, THI at calving and vegetation/topography. Those in the management group were animal density in usable area, drinking water quality, fluorosis, genetic selection, mob size, mustering time, method and handling, new to area, pasture availability, pasture quality, pathogen exposure, poisonous plants, predation and urea supplementation. Those in the nutrition group were body condition score (BCS), dry season phosphorus (P) intake, early gestation nutrition, feed intake (cow), late gestation nutrition, milk intake, P reserve (cow), wet season P intake and vitamin A (cow). A brief description of each variable and interpretation of each arrow is provided in Appendix 1. The team acknowledged that most of the factors associated with loss around calving would have a similar association with loss after calving (death of calf between 14 days after live birth and weaning) but that several additional variables should also be considered, namely branding, dehorning, weaning, internal parasites (e.g., *Haemonchus*), coccidiosis, trauma, navel infections, genetic diseases (e.g., Pompe's) and hernias.

While the complexity of this web makes close inspection of individual relationships challenging, it clearly shows that a large number of factors are involved in calf wastage and that many of these factors are interconnected. This highlights the importance of understanding the whole system; a change made to any single factor shown in this diagram is likely to affect many other factors in addition to those directly connected to it in the diagram. These possibly unexpected additional impacts need to be considered when evaluating possible interventions.

This web also shows that many of the variables can act through multiple pathways and affect more than one of the three outcomes. Furthermore, several pathways can lead from one variable to one of the outcomes. Different pathways may not all act on the outcome in the same direction; one pathway may reduce the likelihood of an outcome whereas another may increase it. The net effect of that variable on the outcome will depend on the relative strengths of each pathway.

Cow body condition provides a good example of multiple pathways influencing multiple outcomes. Cows in better body condition are likely to produce more milk, and correspondingly calves will be more likely to drink more milk, more likely to be vigorous and less likely to die around calving. Cows in good body condition are less likely to become weak and less likely to die. Through two pathways they are less likely to experience dystocia (through weakness or uterine inertia) so their calves are less likely to be born dead, but through one pathway (foeto-pelvic disproportion) they are more likely to experience dystocia so their calves are more likely to be born dead.

Pasture quality is another good example. Higher pasture quality allows better late gestation nutrition, leading to calves being heavier at birth, more likely to be vigorous and less likely to die.

However, through a similar pathway, higher birth weights can increase the risk of dystocia and thus the likelihood of both cow mortality and a calf being born dead.

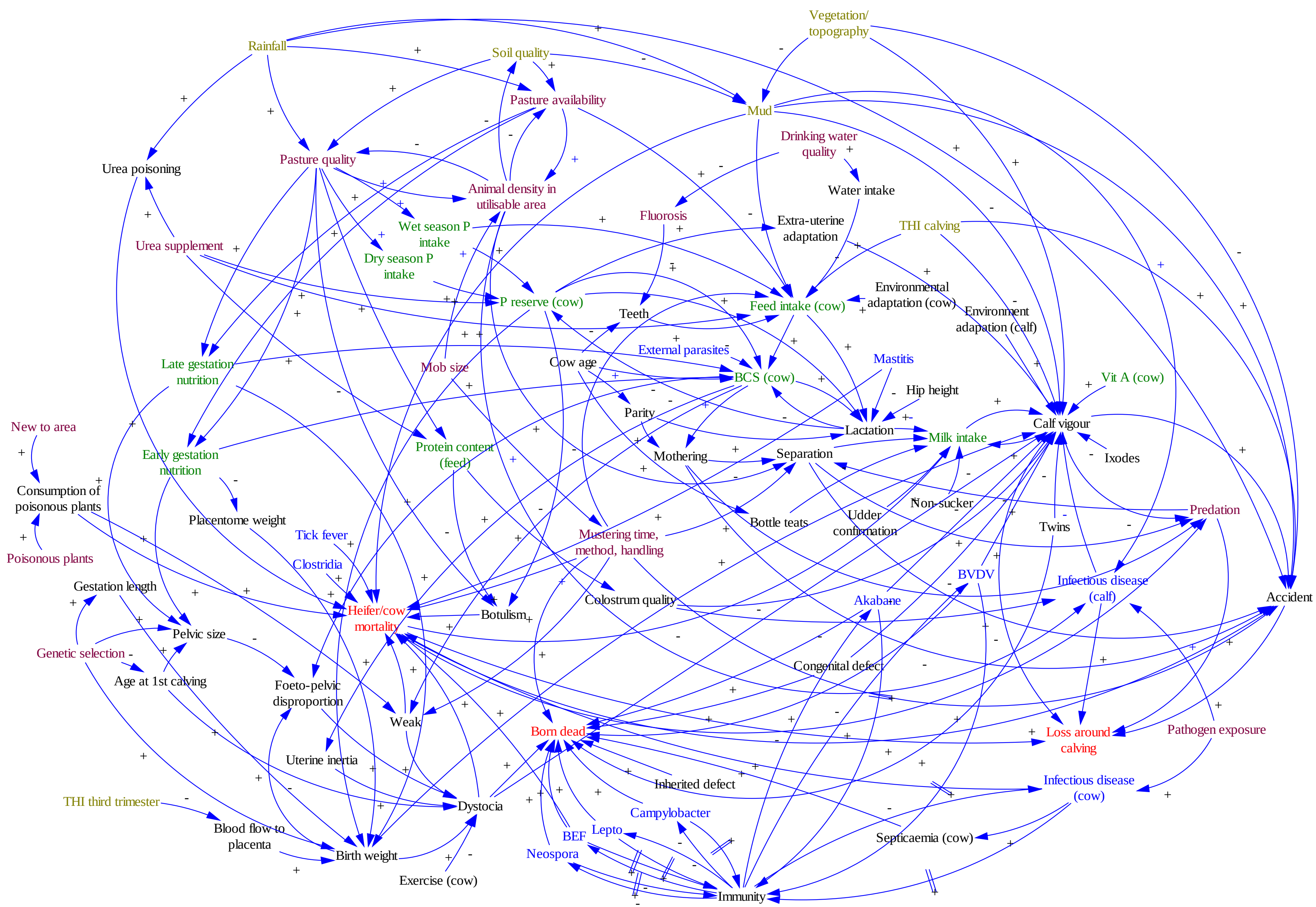


Fig. 1: Causal web for the three key outcomes (in red) with variables colour-coded by group (animal – black, disease – blue, environmental – brown, management – purple, nutritional – green and outcome – red).

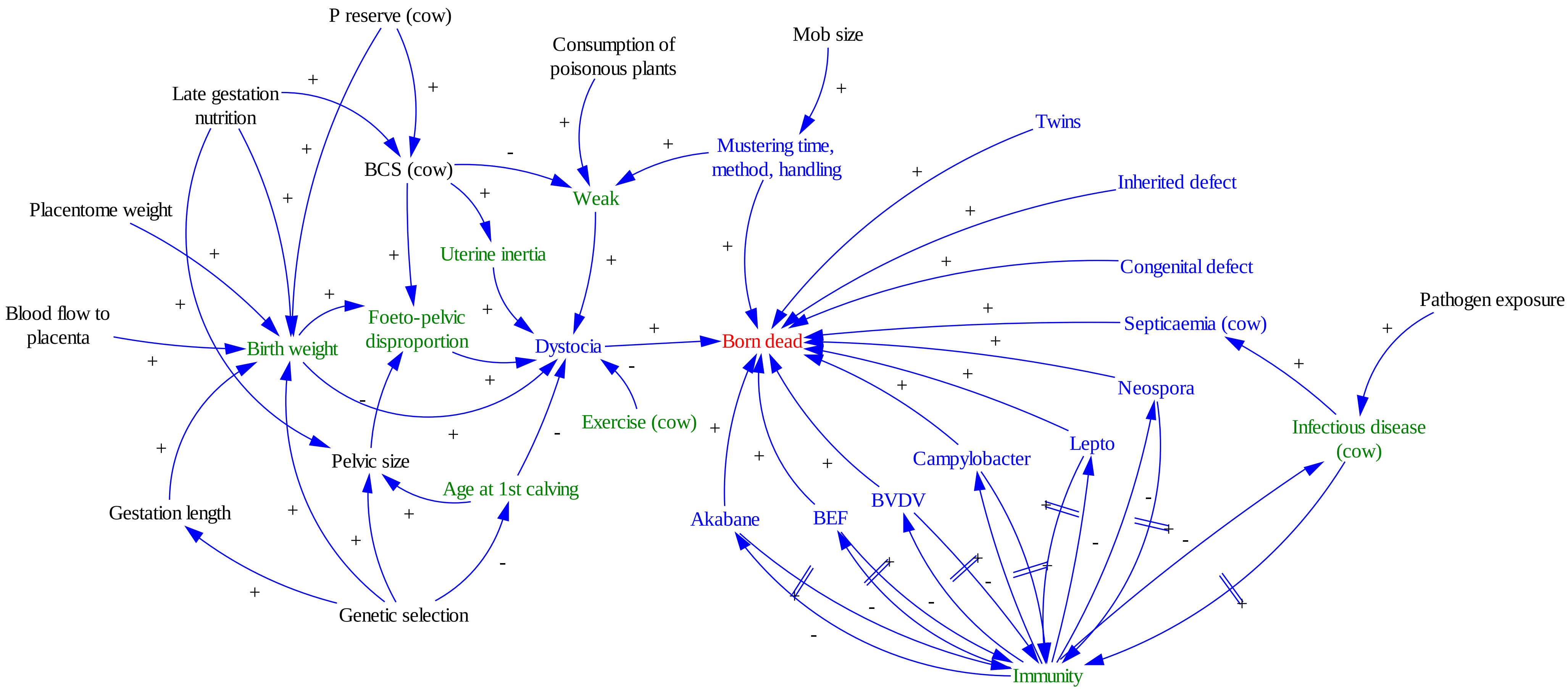


Fig. 2: Causal web for the outcome "born dead" (loss of foetus or calf between confirmed pregnancy and the day of parturition) with variables colour-coded by proximity to the outcome (directly connected – blue, separated by a minimum of one other variable – green and separated by a minimum of two other variables - black).

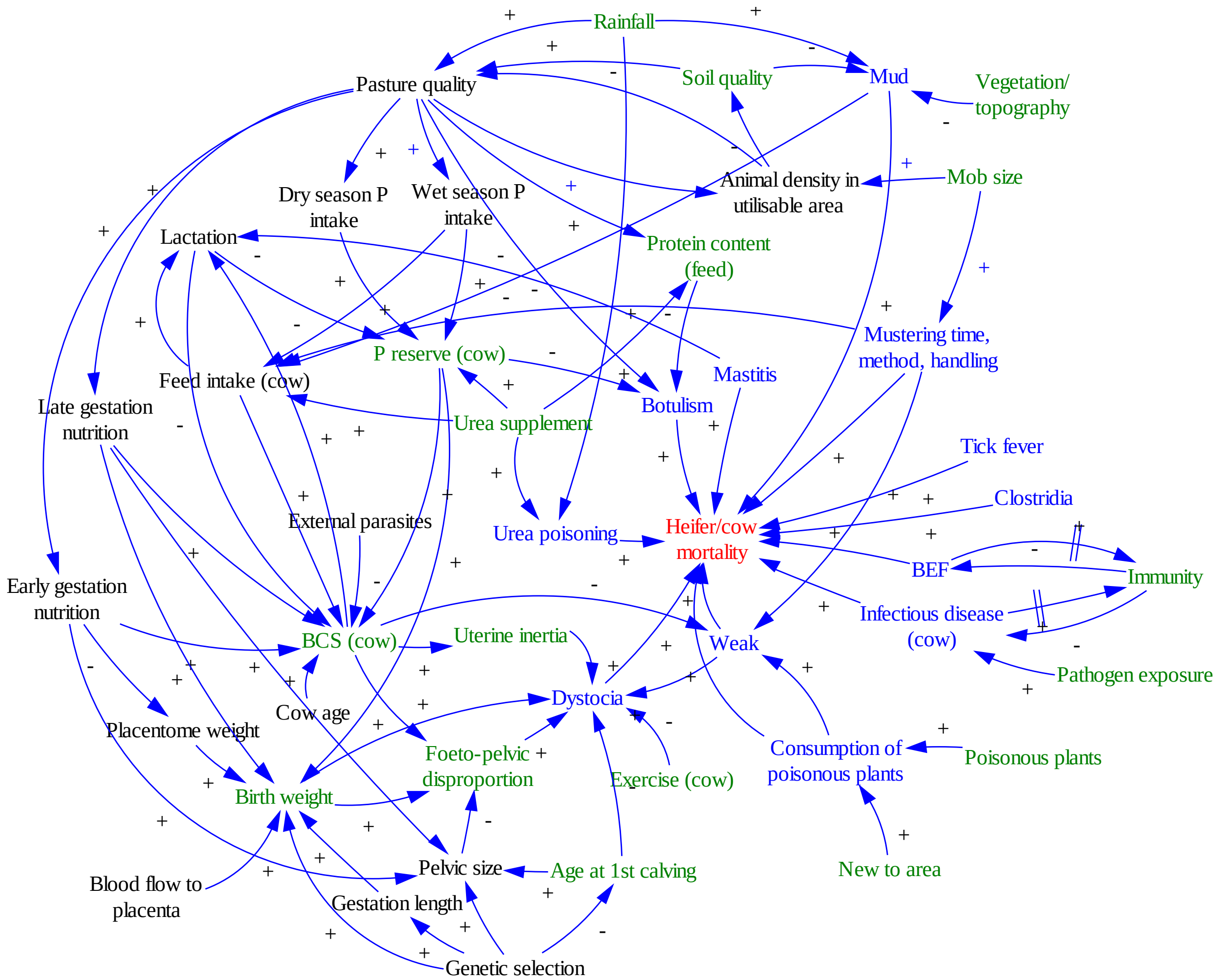


Fig. 3: Causal web for the outcome "heifer/cow mortality" (death of heifer or cow following confirmed pregnancy) with variables colour-coded by proximity to the outcome (directly connected – blue, separated by a minimum of one other variable – green and separated by a minimum of two other variables - black).

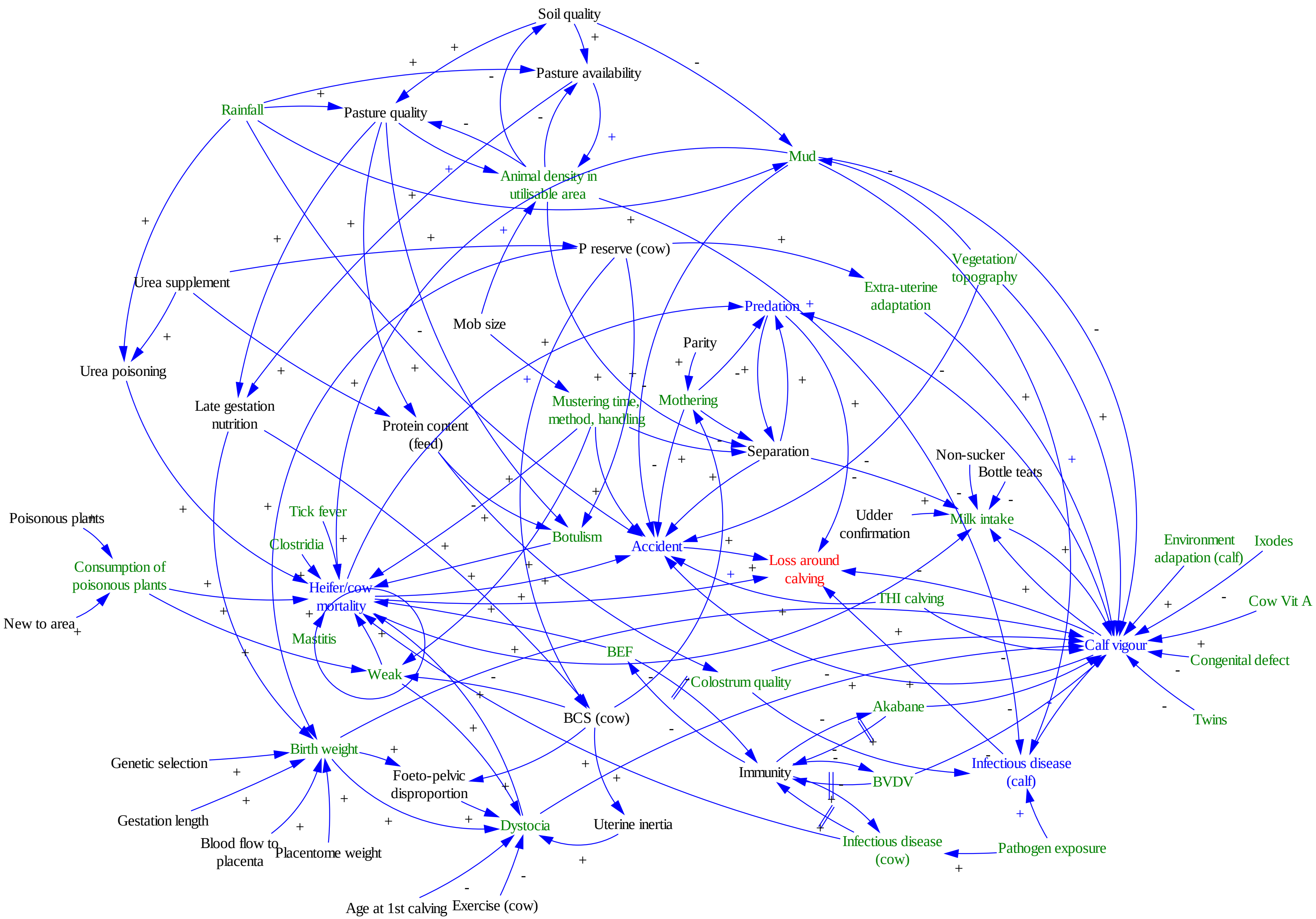


Fig. 4: Causal web for the outcome "loss around calving" (death of calf within 14 days of live birth) with variables colour-coded by proximity to the outcome (directly connected – blue, separated by a minimum of one other variable – green and separated by a minimum of two other variables - black).

4.2.2 Partial webs and loops

Partial webs for each outcome are shown in Fig. 2, Fig. 3 and Fig. 4. These include only the variables that were a maximum of three arrows removed from the outcome along with interconnecting arrows between these variables. The large number of variables included and their interconnectedness clearly illustrates the complexity of the system.

Several feedback loops were identified in the full causal web. These can be used to identify potential leverage points. Balancing loops were identified between pasture quality and animal density in utilisable area (B1), and between soil quality, pasture quality and animal density in usable area (B2, Fig. 5). Equivalent loops were also identified for pasture availability (B3 and B4, Fig. 5). To improve cow nutrition, it is desirable to improve pasture quality and quantity. It is common management practice to increase the stocking density when pasture quality and quantity are good; this exerts a stabilising influence. Improvement of pasture quality and quantity is a potential leverage point in the system.

Balancing loops were also identified between cow phosphorus reserve and amount of milk production (B5), cow body condition and amount of milk production (B6) and all three variables (B7, Fig. 6). Milk production reduces body condition score and drains phosphorus reserves. As greater milk production is desirable, improvement of cow body condition and phosphorus reserves are two potential leverage points.

A set of balancing loops were also identified between a range of infectious diseases and immunity (B8, Fig. 7). Although immunity is primarily disease specific, for simplicity one general variable for immunity was used in the main causal web. In these loops there is a delay between infection by the pathogen and the development of immunity. As it is desirable to minimise disease, reducing the risk of infection and improving immunity to a range of pathogens are other potential leverage points.

A reinforcing loop was identified between calf vigour and milk intake (R1, Fig. 8). As it is desirable for the system to maintain the virtuous cycle of increasing milk intake and calf vigour these are both key leverage points; factors positively influencing each of these factors will support the virtuous cycle.

Another reinforcing loop was identified between separation and predation (R2, Fig. 9). As it is desirable for the system to minimise the vicious cycle of increasing risk of separation and increased risk of predation these are both key leverage points; factors negatively influencing each of these will reduce this vicious cycle.

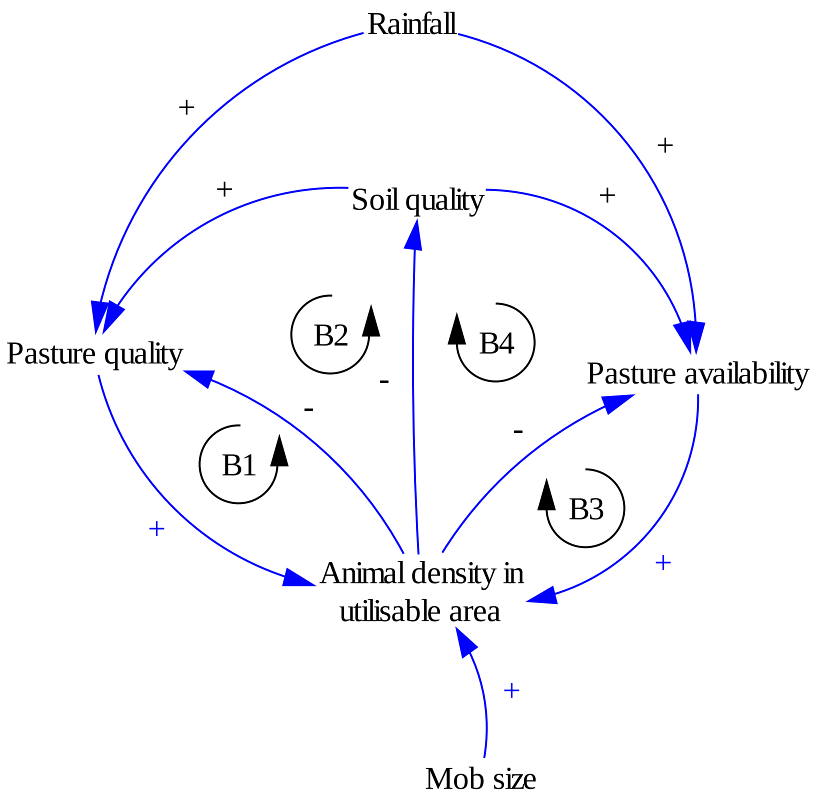


Fig. 5: Balancing loops (B1 – B4) involving pasture quality/availability, soil quality and animal density in utilisable area. Variables directly influencing those in the loops are also shown.

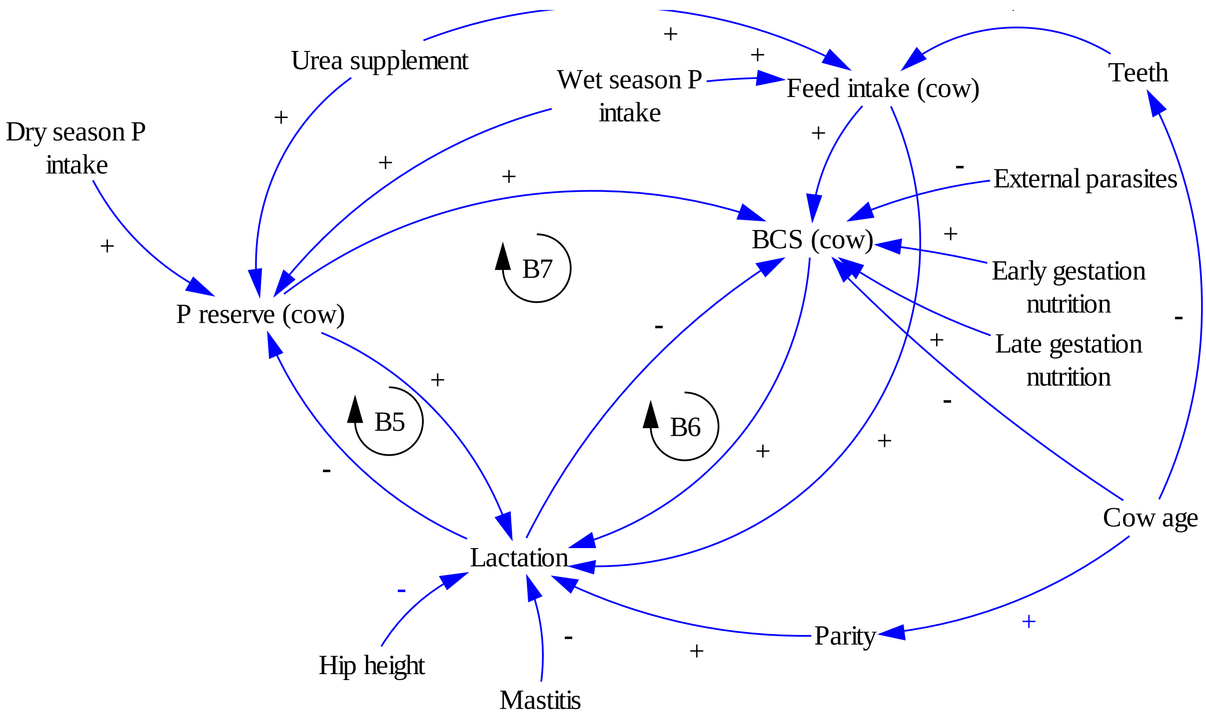


Fig. 6: Balancing loops (B5 – B7) involving cow body condition score (BCS), cow phosphorus reserve (P) and amount of milk production (lactation). Variables directly influencing those in the loops are also shown.

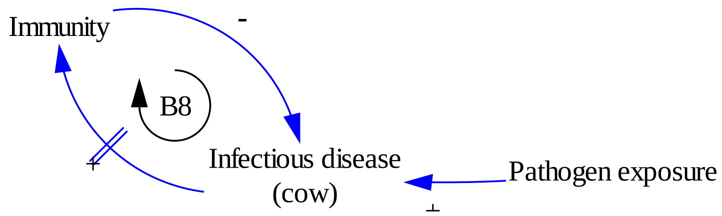


Fig. 7: Balancing loop (B8) involving infectious disease and immunity. Variables directly influencing those in the loops are also shown. The || sign represents a time delay.

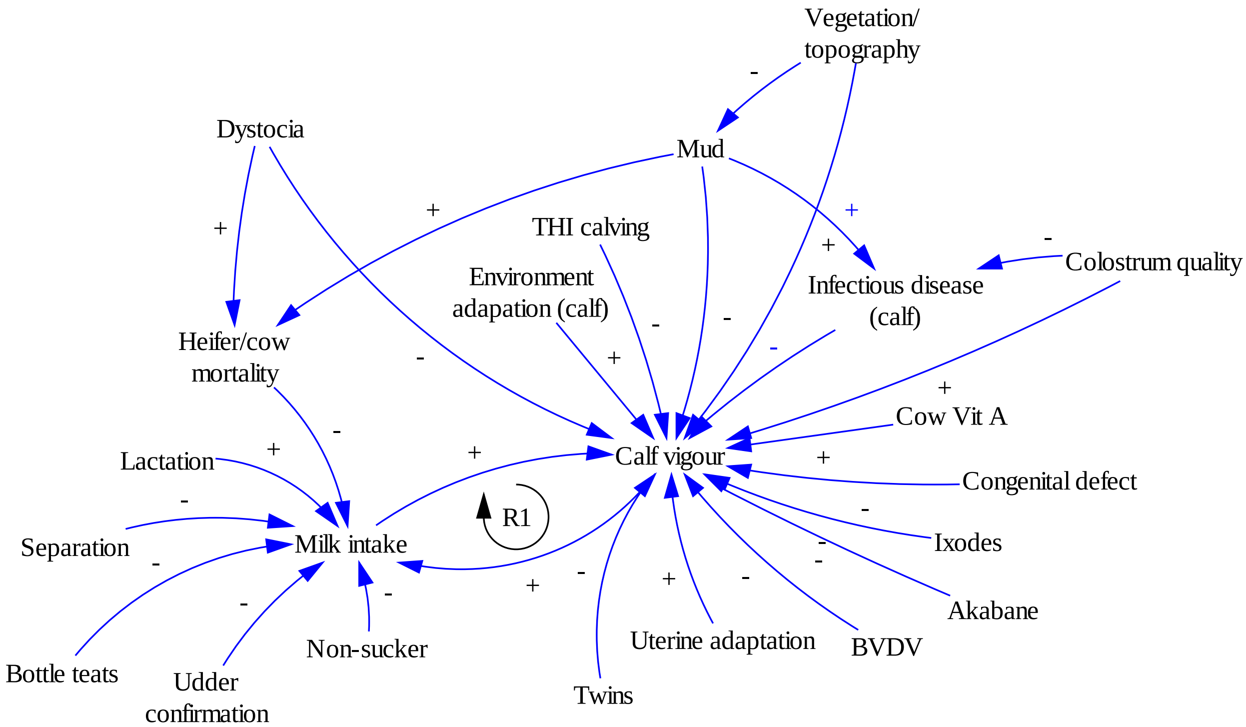


Fig. 8: Reinforcing loop (R1) involving milk intake and calf vigour. Variables directly influencing those in the loops are also shown.

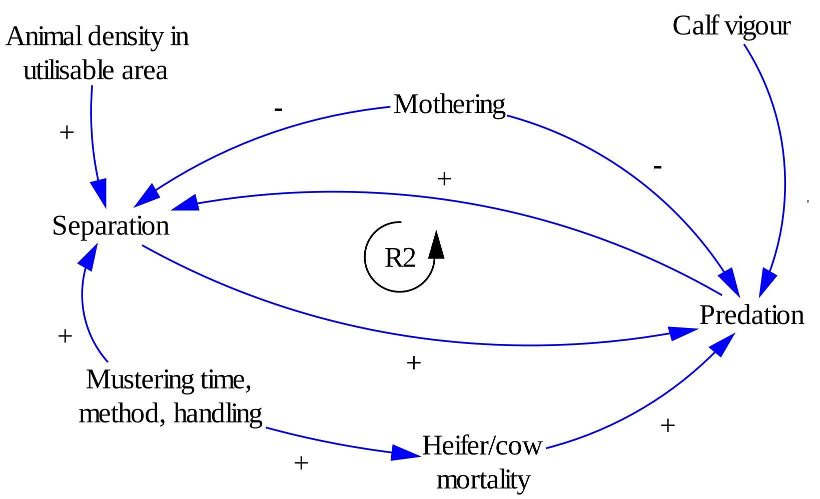


Fig. 9: Reinforcing loop (R2) involving separation and predation. Variables directly influencing those in the loops are also shown.

4.3 Potential management interventions to reduce calf wastage

Potential interventions to ameliorate the impacts of these risk factors are summarised below. Each intervention is aimed at addressing a specific risk factor or cause of calf wastage, and will only be of benefit in situations where they are significantly contributing to calf wastage. A full description of the potential impact of each intervention on calf wastage, including both negative and positive outcomes is provided in Appendix 2.

4.3.1 Interventions to manage the feedbase

Nutrition is the primary driver of livestock performance and productivity. Specific diet interventions that warrant consideration in breeding cow systems include the following:

- Sustainable and profitable pasture utilisation: this strategy involves flexible grazing management to maintain pasture utilisation at a sustainable level—estimated at 25% of annual pasture growth.
- Reducing distance to water: this strategy is based on research data that showed 90% of grazing occurs within 3 km of water, and has overlapping impact with reducing management group sizes and sustainable pasture utilisation. The strategy is only useful in areas where distance to water is known to exceed 3 km.
- Phosphorous supplements: ameliorating phosphorous deficiency improves feed intake, growth rate and body condition scores in the growing season. Phosphorous deficiency has been shown to be associated with calf wastage through a number of different mechanisms but is primarily linked to the body condition of the cow..
- NPN supplements: the impact of non-protein nitrogen supplements (urea) on calf wastage has not been demonstrated per se, but supplementation during prolonged dry periods will save the lives of pregnant and lactating females.
- Energy and protein supplements prior to calving: dry season protein adequacy has been shown to be associated with lower calf wastage. Although “spike” feeding can increase conception rates during the following lactation, its effects on calf wastage are not established.
- Above maintenance nutrition for pregnant yearlings: the incidence of dystocia increases in poorly grown pregnant heifers that have experienced sub-maintenance nutrition during pregnancy. The incidence of dystocia also increases in heifers that have experienced planes of high protein intake during mid gestation. This intervention aims to reduce dystocia and thereby reduce cow and calf loss.
- Vitamin A injections for cows without access to green feed: extended drought can result in cows having limited access to green pasture over an extended period of time, resulting in significant calf losses.

4.3.2 Interventions to manage lactation

- Calving period segregation: using foetal aging and segregating cows into calving periods reduces the need for mustering of pregnant animals and thereby reduces stress related abortions and mis-mothering. Controlled joining also address this issue.
- Flexible weaning to manage cow body condition: strategic weaning to manage cow body condition has been shown to be a powerful strategy for improving the survival of cows and weaning rates.
- Controlled mating: mating for a defined period to control calving so as to minimise dry season lactation makes a large contribution to preserving cow body condition and increasing survival.

- Enhancing mothering: adding mature pregnant cows to pregnant heifer mobs may improve the mothering abilities of the heifers through role modelling, and thereby calf survival.

4.3.3 Interventions to manage environmental factors

- Predator control: the impact of baiting prior to and during the calving season has to date been poorly tested to determine biological and financial impacts.
- Managing group size: anecdotal evidence suggests that smaller management group sizes reduces calf loss, but this has not been validated through research.
- Providing shelter: although the impact of weather extremes on calf wastage has been demonstrated, the magnitude of productivity and business benefit from provision of shelter is unknown.
- Improved calf husbandry: branding, dehorning, and castrating using methods that provide better welfare and surgical outcomes for the animals will result in fewer stress-induced calf deaths.

4.3.4 Interventions to manage breeding

- Selection and culling on cow and calf survival: selection of replacement breeding cattle based on heritable traits with known impact on calf wastage, such as teat score, is expected to reduce calf wastage. Selection of cows based on their ability to rear calves to weaning may warrant further research.

4.3.5 Interventions to control infectious disease

- Vibriosis: controlled by vaccination of bulls and in some cases heifers prior to mating.
- BVDV: controlled by vaccination, and biosecurity measures.
- Botulism: vaccination where cows experience nutritional deficiency will prevent cow and calf deaths.
- Trichomoniasis: controlled by removing infected animals from the herd.
- Leptospirosis: controlled by vaccination in environments with more water and pigs.
- Ectoparasites: targeted tick control in endemic areas will prevent cow and calf deaths.
- Akabane vaccine – used to be available and no doubt if proven to be a significant risk, could again be re-introduced with positive market pressure.
- Bovilis Rotavec Corona Calf Scours Vaccine may have application in southern and central Qld.
- Clostridium perfringens Type E – presumably a vaccine could be manufactured if proven to be a significant risk factor – especially during the wet season.

4.3.6 Benefits, disadvantages and researchability of each intervention

Available information pertaining to each of the above interventions was assessed to ascertain the potential effect on calf wastage, the potential benefits and disadvantages, the potential economic benefit, and the feasibility of conducting research to demonstrate the impact of the intervention (Summarised in Table 1).

Table 1: A summary of potential interventions to reduce calf wastage: benefits, disadvantages and researchability.

Management Intervention	Incidence of affected risk factors	Likely impact on reproductive wastage	Potential impact on productivity	Potential cost-benefit	Researchability (Doable and cost-effective)
Phosphorus supplements	High	High	High	High	High
Infectious disease control	High	High	High	High	High
Weaning on cow condition	High	Mod	High	High	High
Reduced pasture utilisation	High	Mod	High	High	Mod
Pregnant yearling nutrition	Mod	High	Mod	Mod	High
Controlled mating	High	Mod	Mod	High	Mod
Improved calf husbandry	High	Mod	Mod	Mod	High
Enhancing mothering	High	Mod	Mod	Mod	Mod
Reducing distance to water	Mod	Mod	Mod	High	Mod
Calving period segregation	High	Mod	High	High	Low
Management group size	Mod	High	High	Mod	Low
Predator control	High	Mod	Mod	Mod	Low
Shelter for cows and calves	High	Mod	Mod	Low	Low
Dry season NPN supplements	High	Low	Low	Low	High
Pre-calving energy & protein	High	Low	Low	Low	High
Ectoparasite control	High	Low	High	High	Low
Ameliorating Vit A deficiency	Low	High	High	High	Low
Selection for cow and calf survival	Low	Low	Low	Low	Mod
Mustering strategies					

4.4 Current recommended management practices to control calf wastage

Full descriptions of a series of recommended management practices are presented in Appendix 3. For each measure an attempt has been made to identify the potential strengths and weaknesses. The recommended management practices are summarised below under 4 key areas of management which not only are likely to impact of the incidence of calf wastage but also on lactating cow pregnancy rate and cow survival.

4.4.1 Manage the feed-base

Cattle can only achieve net live weight production if energy and protein intake is above that required for maintenance. Beef breeding businesses are built on ready access to productive, palatable, nutritious pastures and good quality water. The principles of 'best practice' grazing management must be understood and implemented.

Key management practices include:

- Budgeting available feed to meet short and medium term cattle requirements.
- Good grazing management to allow pasture recovery, eg, rotational grazing, or in tropical rangelands deliberate withholding of grazing of selected paddocks over the wet season.
- Limit grazing distance from water to <2.5 km where possible.
- Active pasture development and rehabilitation.
- Fencing to control overutilization of preferred land types including riparian zones.
- Use supplements that augment sound basic management. For example, establishing the P status of all the breeding paddocks and supplying P over the growing season to all paddocks that are acutely deficient. As well as feeding supplemental phosphorous to late-pregnant and lactating cows where risk of phosphorous deficiency is high. If good grazing management and lactation management practices are implemented then feeding of nitrogen supplements during the dry season in arid tropical rangelands may only be necessary during periods of severe drought.

4.4.2 Manage lactation

Cows have amazing capacity to meet their energy, protein and macro-mineral requirements from available pasture and mobilisation of their own body tissue reserves. However, where cattle draw down on their body tissue reserves (eg, during lactation) this must be followed by a period of re-alimentation in preparation for the next reproductive cycle. Thus the timing of weaning is critical because cows must have sufficient access to pasture of adequate quality to replenish body tissue reserves prior to the next calving event.

Key practices

- Manage weaning to conserve body condition of cows in preference to achieving high live weight weaners, i.e., the decision on timing of weaning should be made on the basis of cow body condition, not an average weaning weight target.
- Use pregnancy diagnosis and foetal aging to segregate cattle for different nutritional management and efficient weaning. It is particularly important that heifers are managed as a discrete group until they are confirmed pregnant after calving for the first time. Also in continuously-mated herds identification of heifers and cows likely to calve at a time when pasture quality and quantity is very limited is critical to minimising cow and calf mortalities.
- Wherever possible mating should be controlled to ensure heifers and cows calve close to the time when the likelihood of significant improvement in seasonal pasture quantity and quality is high. Alternatively, in continuously-mated herds use foetal aging to segregate cows

into approximately 3-month calving periods which can be matched with feed available, handling, and husbandry.

4.4.3 Manage cattle health & stress

This primarily involves implementation of evidence-based control strategies to prevent infectious causes of heifer/cow death (e.g., clostridial diseases including botulism, babesiosis), clinical illness (eg, bovine ephemeral fever), subclinical disease (e.g., external/internal parasites), and infectious causes of embryonic and calf wastage (campylobacteriosis, trichomoniasis, bovine viral diarrhoea virus). Also breeding females and their offspring may be exposed to a wide range of environmental stressors which can severely impact on both survival risk of the calf and the dam.

Key practices include:

- A risk-based approach to control of infectious diseases should be used, involving assessment of the immune status of the dams including determination of whether the herd or management group is endemically infected, and risk of introduction of infection.
- Provide protection from environmental extremes (floods, blizzards, heat wave), especially for young calves and their dams.
- Where possible, avoid handling calves less than one month of age.

4.4.4 Manage breeding

Bull fertility and genetics have a profound effect on business outcomes and herd productivity.

Key practices include:

- Establish a genetic improvement program to achieve long-term increases in fertility as well as traits such as polledness, and adaptive traits in harsh environments.
- Select replacement bulls that have passed a breeding soundness evaluation. Select physically-sound bulls with at least average scrotal circumference for breed and live weight, and greater than 70% normal sperm.
- Replacement bulls should be introduced to the farm at least 4 months prior to use. They should be vaccinated against known causes of death, illness, and reproductive loss.
- Mate at no more than 2.5% sound bulls.
- Select bulls from dams that have weaned a calf from their first two mating opportunities.
- Bulls should be managed to ensure they maintain satisfactory body condition (at least BCS 2.5 - 1-5 scale). Treatments to control external and internal parasites are recommended as bulls generally carry higher burdens of both.
- Herd bulls should undergo at least a general physical examination and detailed examination of the external genitalia annually prior to mating and bulls should be considered for culling when they reach 8-9 years of age.

4.5 Systematic review of published literature on interventions to control calf wastage

In general, there were papers identified for most of the topic areas relevant to the mitigation strategies for reducing calf wastage in the north Australian beef industry (for full details see Appendix 4). However, there was frequently little evidence supporting the effectiveness of the mitigation strategy. This maybe because there was no data presented in the paper, the support for a mitigation strategy was opinion based, studies had very small sample sizes of insufficient power to detect an effect, confounding of studies, or because research in the area was not formally published.

For example, there is little published data supporting the use of the following factors for mitigating calf wastage:

- Biosecurity (although there is good evidence of impacts of infectious diseases on calf wastage generally).
- Environment (including Botulism, neosporosis, leptospirosis, tick fever). Interestingly there is published data suggesting that calf wastage is higher in areas of wild dog control compared with no control.
- Protein supplementation (although there is a large volume of general literature on this topic).
- Husbandry (there is some evidence that de-horning can lead to higher mortality, but little evidence for other husbandry procedures being associated with increased mortality).

However, there was some evidence supporting the use of some mitigation strategies, including:

- Vaccination (there was little support for vaccination reducing calf wastage, apart from a high quality Canadian study where vaccination was useful to reduce IBR/BVDV virus abortions in highly mixed cattle herds).
- Pestivirus. Although there is little evidence that vaccination, do nothing, enhancing natural transmission and culling persistently infected (PI) cattle reduces calf wastage, there is good evidence that vaccination reduces the number of PI calves born.
- Phosphorus. There is little evidence of the effect of phosphorus supplementation on reducing calf wastage but extensive data on phosphorus use in beef production.

In addition, there were four areas where the literature is relatively extensive and the research question only broadly defined.

- Body condition: This is associated with calf wastage through many risk factors. As body condition increases, calf wastage declines.
- Genetics: There was a lot of literature exploring the link between reproduction performance and genetics. There was evidence for breed selection and selecting bulls based on EBV in reducing calf losses. However, there was little literature examining the question, 'do polled genetics have reduced calf wastage compared to genetics requiring dehorning of calves'?
- Herd structure and management of females: There is some general evidence that younger cows have higher losses of calves (e.g. mismothering), but this is offset by a higher lifetime production if heifers are mated as yearlings.
- Herd structure and management of males: There is little evidence assessing the impact of bull management on reducing calf wastage.

4.5.1 Conclusion

Although there is published literature on the topics that comprise currently recommended calf wastage mitigation strategies, in general this information provides little objective data to support these strategies.

Importantly, this does not mean that the current recommendations are not useful, just that there is little research conducted on the impact of specific mitigation strategies on calf wastage. It is possible that industry knowledge and practices are supportive of the mitigation strategies because they work, or are the industry norm. However, for some mitigation strategies there was no evidence at all of their impact on calf wastage.

4.6 A survey method to determine the risk of calf wastage

Four properties from three different country types (Northern, Central and Southern Forest) agreed to be interviewed using the new calf wastage survey tool (Appendix 5). The survey results are summarised in Table 2. The interviews were well received and answers to all questions readily provided.

Table 2: A summary of responses to a survey on calf loss interventions.

Section	*Interventions*
General	• Very few (<5%) of their female breeding herds were aged cows >10 years • The late dry average BCS of cows that weaned a calf that year was 3.3/5
Managing the feed base	• Pasture end of dry was mostly >1500 kg/ha (av 2200kg/ha; min 750 kg/ha) • The cattle per water point was moderate to low (av 156; max 350) • The average distance between waters was within current recommendations (av 1.7 km; max 3 km)
Managing reproduction	• There was no herd segregation on foetal age • The bull:cow ratio was <3% on average
Managing stress and health	• All use horses as primary mustering tool • All had tree shelter • All cow paddocks had firm, well-drained soil & were well sheltered for calving • Mob sizes were all <500 AE, 75% <250 AE • 75% had a mustering distance of less than 5 km to yards • All vaccinated bulls for Vibriosis • All vaccinated females for leptospirosis • There were no specific practices to control bleeding at branding • Most cows were either born on property or had lived there more than 5 years
Managing breeding and genetics	• 75% of properties routinely culled cows that fail to rear a calf • The frequency of poor udder and teat structure was low (<2%) • All selected bulls for maternal traits for fertility improvement
Other comments from interviewees	• Routinely grazing older cows with heifers for dingo control & Pestivirus management found to be useful • Low stress handling practiced by all but did not necessarily attend the official course • Bulls routinely vaccinated for 3-day sickness • At branding, calves are put back with cows and often left in yards or in a grassed cooler/holding paddock overnight to mother up • Pregnancy test through to branding is the main period of calf wastage • Wedge tail eagles are contributing to losses • Positioning of yards - reduced distance to muster important • Least time spent in yards the better was common - 24hrs max

There was remarkable consistency in how the selected beef producers managed their cattle to achieve consistently low calf wastage. The managers/owners of these properties appeared to have a high-level of understanding and knowledge of the recent research findings on the topic. There is a need to execute this survey on properties which consistently had a high percentage of calf wastage.

The style of questionnaire was easy to execute and is expected to be effective in assessing management practices likely to be associated with calf wastage, either for research or in commercial investigations. Additional comments from the interviewees will be used to improve the questionnaire, which is hoped to be standardised for use in Calf Wastage Phase II.

4.7 Risk factors for calf wastage and cow productivity

4.7.1 Timing of calf wastage

Intensive monitoring throughout pregnancy and lactation of >2,000 Brahman and tropically-adapted cows in the four main country types of northern Australia in the Beef CRC provided the ideal data set to define the distribution of calf wastage. However, the herds were all controlled mated and were vaccinated against Leptospirosis, Pesti virus and vibriosis and size of paddock, time of mustering and body condition would not have been major causal factors of calf loss..

There were 9,681 pregnancies confirmed in the study. Of these 400 were lost in the pre-natal period, and 901 between calving and weaning. The rate of loss of conceptuses was highest during the first third of pregnancy (Fig. 10a). Between days 35-104 of gestation, the rate of loss was approximately 25% per month. This reduced to 14% per month between days 105-166 of gestation and thereafter to calving the rate of loss was only 3% per month. Almost half of all calf deaths occurred within 1 day of birth (Fig. 10b); 8.3% of live born calves died on day 2, and then 2.8% per day on days 3-7 after birth. The rate of calf deaths then halved between days 8-12 to 1.4% per day, and then further reduced to 0.7% per day from days 13-18. Thereafter to weaning the rate of calf deaths was only 0.1% per day.

With 1,301 failures to wean a calf after confirmed pregnancy, and 422 of these losses occurring within a day of calving and a further 201 lost in the next 6 days, the primary focus of research must be on preventing calf deaths during the neonatal period. During pregnancy, the main focus for research should be on the first trimester when 233 losses were recorded. Further details on the analysis conducted and the results obtained are provided in Appendix 6.

a) b)

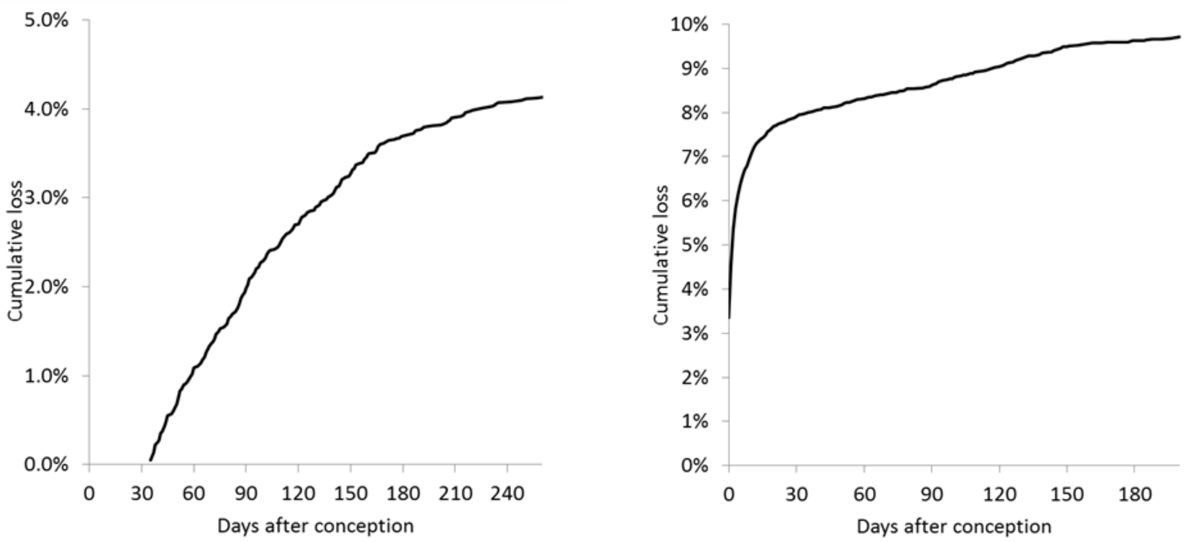


Fig. 10: Cumulative loss of (a) conceptuses following confirmed pregnancy in 9,681 cows and (b) of calves following parturition of 9,281 cows of tropically-adapted breeds in northern Australia.

4.7.2 Factors associated with calf wastage in control mated cows

This section summarises the outcome of analyses focussed on factors associated with pre-natal and peri-natal calf loss. Details on the analysis conducted and the results obtained are provided in Appendix 6. Further analyses and publication of the findings in internationally refereed scientific journals will be undertaken after publication of this final report.

Analyses of pre-natal losses found the following significant associations:

- Cows that experienced a pre-natal loss had 9% higher losses in subsequent pregnancies
- Mature cows had 1-3% units less loss than cows up to 4 years of age
- Cows in prime condition at mating had 2% higher loss

Analyses of peri-natal losses found the following significant associations:

- Reduced by 3% from first to third calf and beyond
- About 3% higher in cows that previously experienced calf loss
- Fat, heavy and tall cows all had about 1% higher loss than other cows; light cows also experienced higher loss
- Increased by about 1% for each score increase in either teat or udder score at calving
- Bull calves had 1% higher mortality than heifers, and loss of twins was 10% higher than singles
- Vitamin A deficiency caused >25% extra calf mortality
- The lightest 25% of calves at birth had twice the mortality rate of the heaviest

These results highlight some key factors that need attention in cow management, which can be validated by management interventions research:

- Young cows experience greater reproductive wastage. This is presumably because they are more likely to be nutritionally-compromised while growing and reproducing. Cows reach mature skeletal size at approximately 4.5 years of age.
- Further potential evidence of under-nutrition causing higher calf loss are the increasing loss with small calf birth weight. Previous research clearly shows the large impacts of pregnancy nutrition on calf birth weight.
- Abortion and calf loss are repeatable, with the latter only lowly repeatable. The losses in fatter and taller cows may be a consequence of previous losses, i.e., previous losses have resulted in these cow outcomes and analyses could not completely discriminate this effect. This supports the strategy of culling cows that fail to rear a calf from pregnancy to weaning.
- As teat and udder scores are heritable, selection for smaller size in both will reduce calf mortalities.
- The instance of Vitamin A deficiency causing high calf loss is an infrequent feature of treeless plains, i.e., northern downs. Provision of green feed over each wet season period is required to counter this.

4.7.3 Reproductive outcome impacts on live weight production

Live weight production is a primary index of beef breeding herds as it is the major driver of income. This was highlighted in a recent report on global beef systems (Behrendt & Weeks 2017) in which the low productivity of northern Australian cow herds and its potential for improvement was cited. The primary limitations to productivity were considered to be associated with nutrition and genetics. To define the opportunity to improve live weight production from breeding cattle, an understanding of what regulates it is needed, as well as the variation that exists. The Beef CRC dataset provided an ideal platform for investigating this.

Each of 11,181 cows' mating outcomes from the first to sixth was defined as being either non-pregnant, weaned a calf, or lost a calf. The latter refers to losses during pregnancy and calving, a majority of which occurs in the first two weeks after calving. Cows that lost a calf, but raised another cow's calf were classed as having weaned a calf; the cow whose calf was reared by another was classed as losing a calf. The weights of twins were combined for weaner weight calculation. Live weight production was calculated for each cow using annual date of weaning for the cohort as the start and end point. Live weight production is the sum of weaner weight and the change in cow live weight over the year, with each of these being used as a dependent variable.

Large variation existed in weaner weight (205±37 kg), annual cow live weight change (22±69 kg/year), and live weight production (175±71 kg/year) with weaner weight contributing ~87% of productivity between 2.5 and 8.5 years of age.

Weaning a calf in consecutive years achieves the highest live weight production. Any 2-year sequence of mating outcomes involving calf loss results in lower live weight production than comparable sequences involving either rearing a weaner (~140 kg lower) or being non-pregnant (~40 kg lower). The reason for the latter is likely to be that non-pregnant cows are in lower body condition because of calf rearing. These results confirm the large cost of losing a calf when the production effect is valued per kg. Over extended periods, calf loss and failure to conceive appear to have similar effect on lifetime live weight production. Further details on the analysis conducted and the results obtained are provided in Appendix 6.

4.7.4 Predicting weaner weight of cows with no mothering up

To evaluate the productivity of individual cows requires the live weight of their weaner plus the cows' live weights annually. Unless DNA fingerprinting is used (only typically in studs), then calves will not usually be mothered up. Only mob productivity would be calculable. If weaner weight for individual cows could be calculated, we know it will have some error, but it still may be useful for business decisions, and certainly for research analyses. An example of the latter is the Cash Cow data set where only mob-level production indices have been calculated, but it may be possible to explore this data further by deriving individual-cow productivity.

The Beef CRC data set was used to predict weaner live weight using a method that matches conception pattern to weaner weight pattern, which provides an estimate of average daily gain from birth taking account of known breed effects on birth weight and gestation length. The standard deviation of error in predicting weaner weight was 18.8 kg or 9.2%.

This method has not been applied to the Cash Cow data set or others. Further details on the analysis conducted and the results obtained are provided in Appendix 6.

4.7.5 Growth curves of breeding cows

An understanding of growth curves as a function of breed, age, reproductive status and nutrition enables more accurate statistical and business analyses. At present there are very limited data published that readily allow prediction of live weight and body condition at any time, and changes in these for tropically-adapted genotypes in northern Australia as a function of reproductive outcomes. Analyses of data from the Beef CRC will provide initial growth curves. The CRC data is considered an excellent set for this due to regular weighing, standardised weighing protocols, one site in each of the four principle country types in northern Australia, and inclusion of all age groups across a range of seasons.

As stage 1, the data from one property, Brian Pastures in the southern forest, has been analysed before analysing data from all four CRC sites. These interim results show large variation in live weight but consistent growth patterns for individuals (e.g., **Error! Reference source not found.**) and reproductive state (***Error! Reference source not found.***).

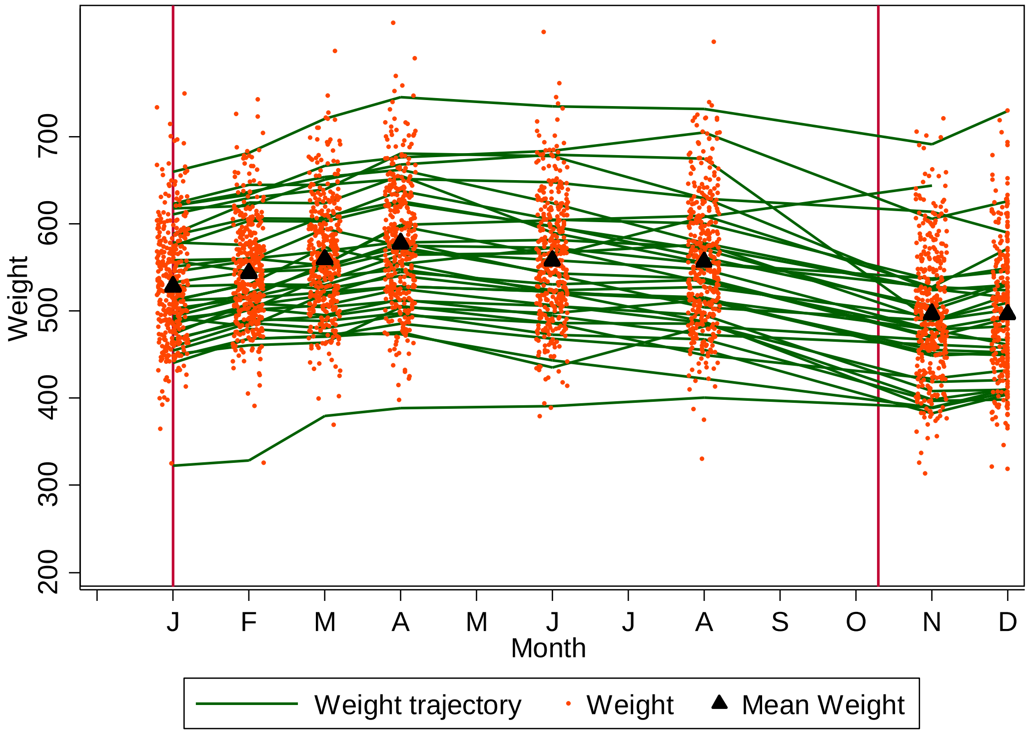


Fig. 11: Trajectory plots of weights for a random sample of 30 cows (green lines) superimposed on a dotplot of weights for all cows calving in their second mating cycle that were either empty or lost a calf in the previous mating cycle (orange dots) and the mean weight (black triangles) for all of those cows weighed at each time point. Vertical red lines show standardised conception (mid-January) and birth (late October) dates.

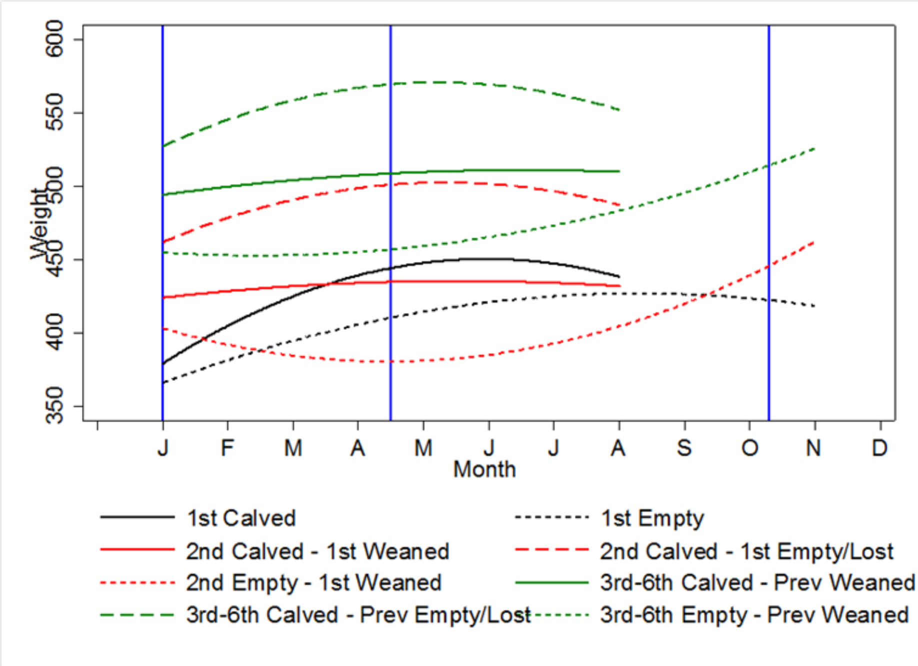


Fig. 12: Growth curves for cows calving in their third to sixth mating cycle that were either empty or lost a calf in the previous mating.

4.8 A method to enable prioritisation of calf wastage intervention research

For full details of the outcome of the prioritisation of interventions see Appendix 7.

Overall the calf wastage management interventions that were rated to have **greatest business impact** (Fig. 13) by producer and agribusiness representatives and the project team were **improved calf husbandry, improved phosphorus supplementation, improved predator control, weaning to manage cow condition, calving-period segregation, and improved nutritional management of pregnant yearlings to reduce dystocia.**

Taking into account how big each problem being addressed by specific management interventions is and how researchable it is, the calf wastage management interventions that were rated to have **highest research priority** by producer and agribusiness representatives and the project team were **improved phosphorus supplementation, improved calf husbandry, reduced paddock size, enhancing mothering, improved nutritional management of pregnant yearlings to reduce dystocia, and infectious disease control** (Fig. 14). A number of interventions were considered to be likely to have a big impact on business outcome, but did not warrant further significant research investment. Most notable of these were the use of sustainable and profitable grazing management practices, weaning, predator control, and use of NPN supplements. Participating beef producers in particular considered these practices were already well-researched and demonstrated, with no need for further research to assess the impact on calf wastage. Development of strategies to improve adoption of these management recommendations is strongly recommended.

Sensitivity analyses demonstrated that the priority rankings were quite robust, and most sensitive to changes in cost compared to other components of business impact.

The validity of the method used to determine these research priorities was exemplified by the general participants' satisfaction, and that the conclusions reached on business impact through basic economic analysis were consistent and in broad agreement with participants' general perceptions.

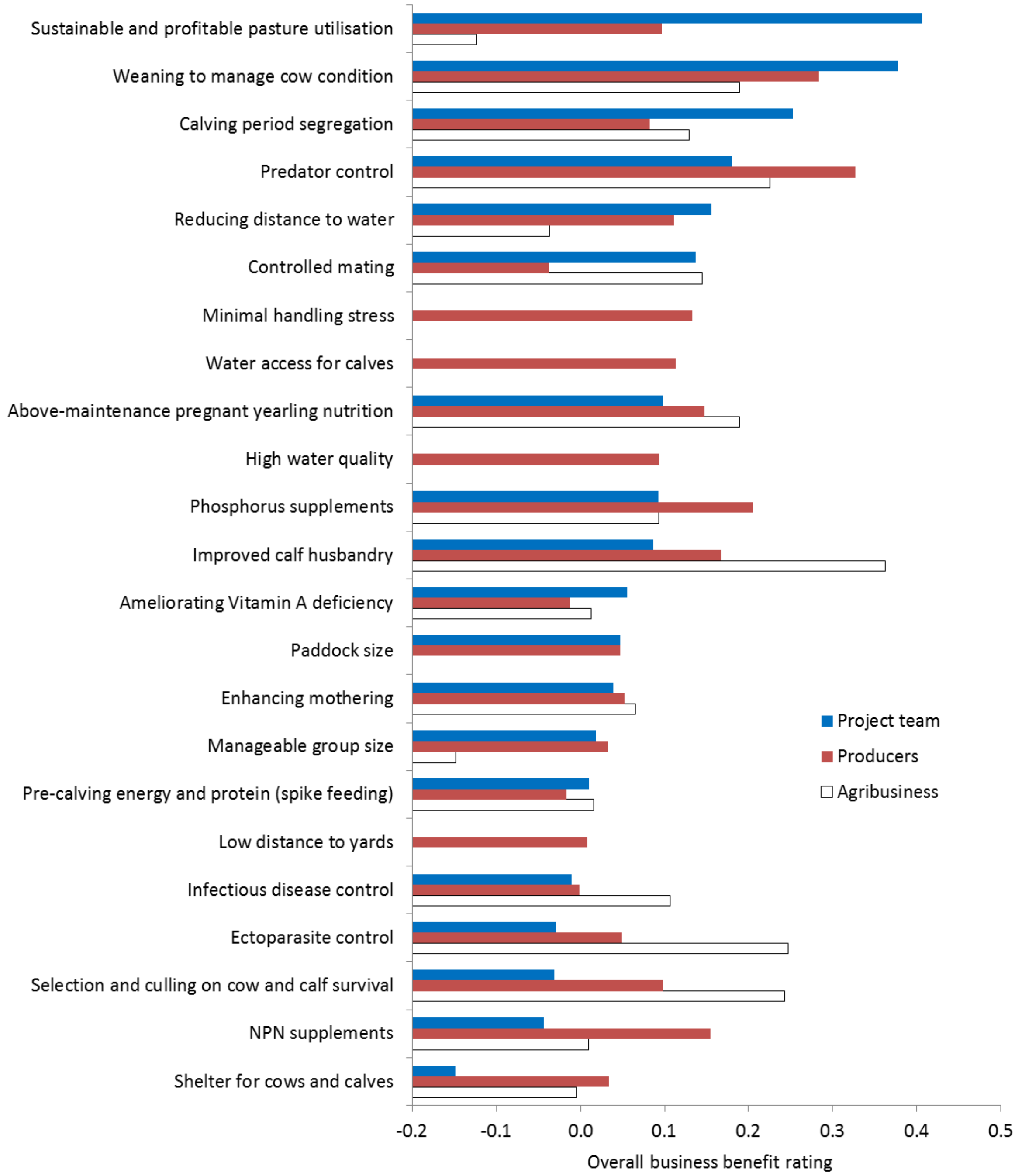


Fig. 13: Rating of business impact of management interventions to reduce calf wastage.

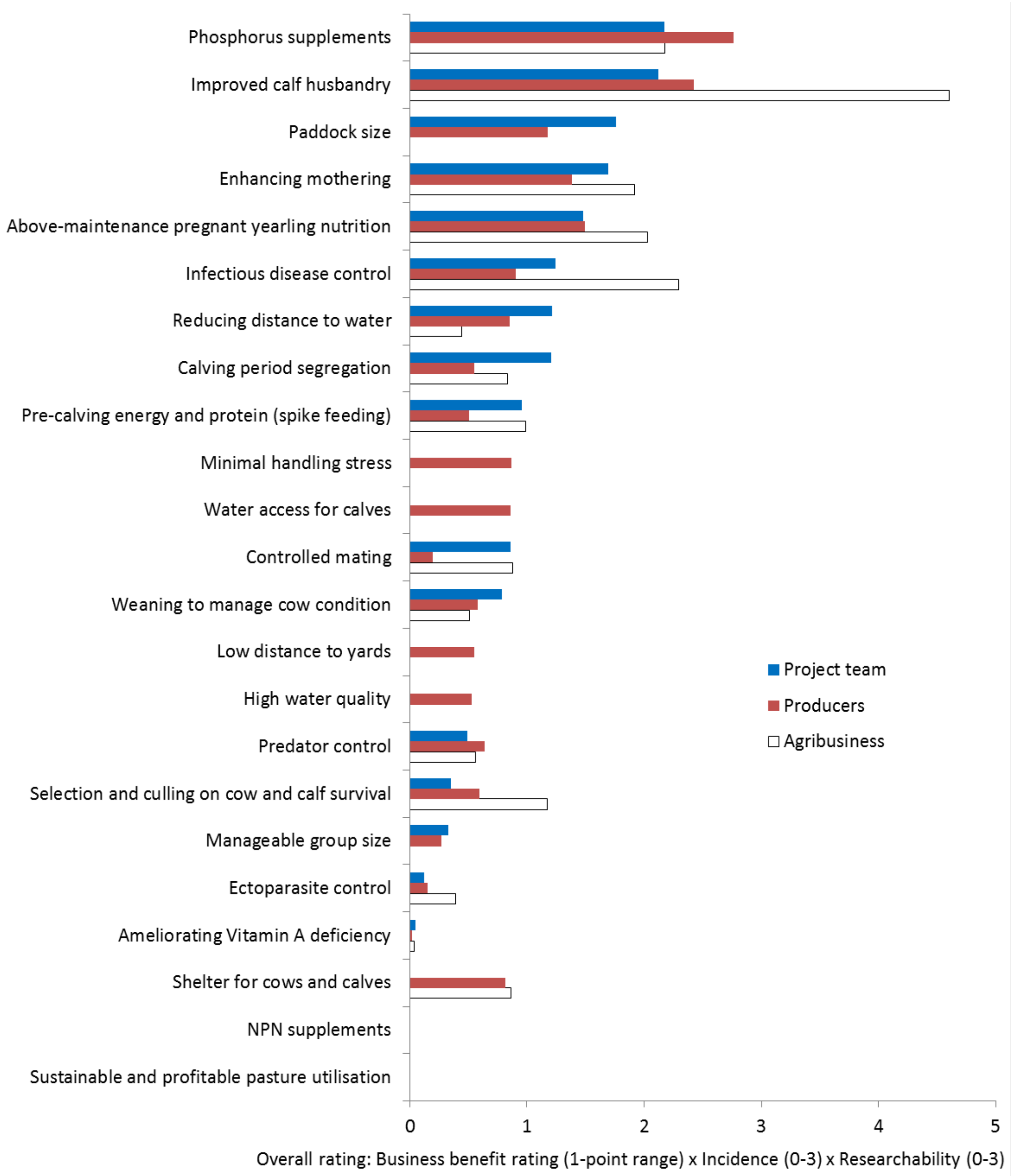


Fig. 14: Rating of research priority for management interventions to reduce calf wastage.

4.9 Crush side data capture technology for calf wastage and cow productivity research

4.9.1 4.9.1 Data capture systems

All systems assessed can successfully capture animal-level data crush-side. Individual systems vary largely in sophistication and useability. As advice was received that support for the Livestock Exchange StockIT would discontinue in the future, this program was removed from any further evaluation.

Based on the selection criteria Sapien technology's Kool Collect was identified as the system best suited to supporting the data capture required for Calf Wastage Phase II. The main reasons this system was selected include:

- Limited training required to train users to collect basic data (Fig. 15)
- Ability to rapidly enter data. Lifetime data can be rapidly changed or entered at equal speed as 'muster' data
- Double entry system for life-data records. Records old versus updated data
- Using satellite internet services, the program was successfully installed
- Centralised data system supporting the flow of data across multiple devices
- Data was rapidly transferred and backed up to cloud based systems using satellite internet services
- Automated applications in-built into the program that allow the rapid integration of data collected by all major systems (Truest, Gallagher Tsi)
- Ability to turn-off 'functions' within the system to increase useability and reduce risk of confusion or intimidation of the less confident users
- Data rapidly downloaded to *csv files from local and cloud data stores. Access to cloud based data stores
- Quickly generates summary muster reports

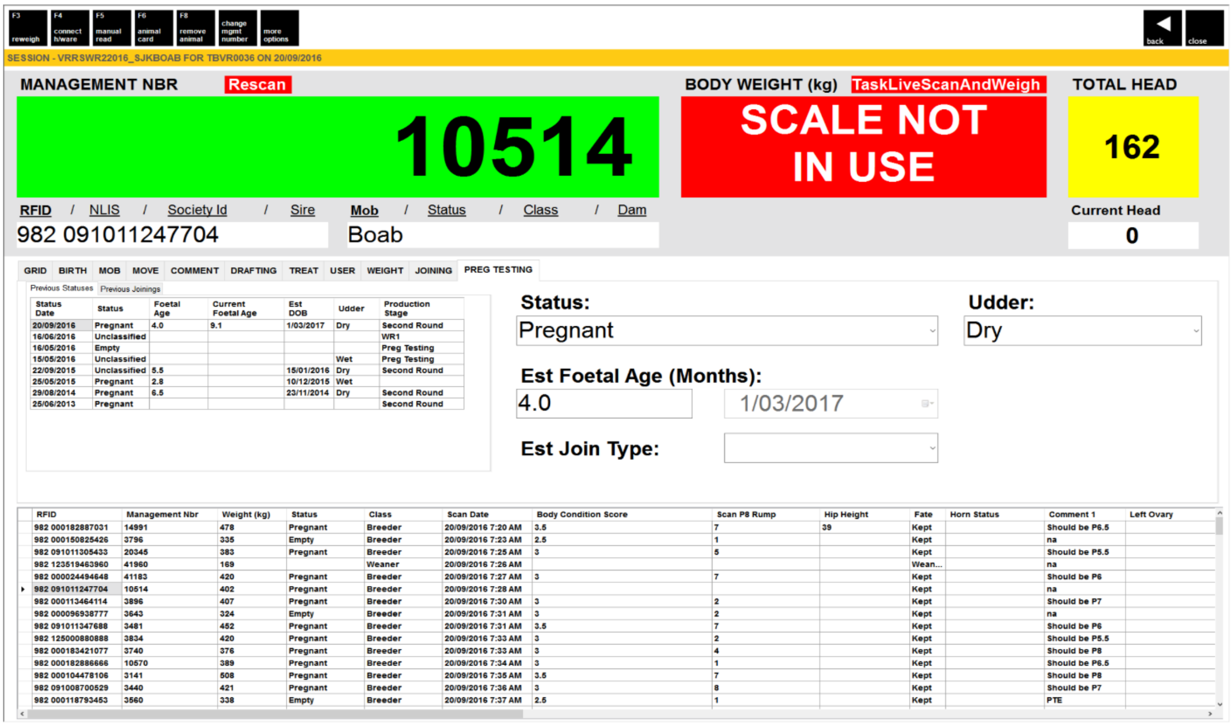


Fig. 15: The data collection screen.

4.9.2 4.9.2 Software

A number of individual animal data collection software programs, such as Kool Collect and Stockbook, offer the capacity to assign repetitive data, such as recording stages of pregnancy and levels of body condition, to their appropriate field by scanning a predetermined RFID tag. Multiple predetermined tags can be attached to a board that can be scanned with a wand to cue the entry of required data. However, the board can be cumbersome around a crush and there is a risk of miss-reading tags on the board with the wand.

The product 'Enterpad P120' (Fig. 16) available from Cedeq, a Canadian based company, offers the capability to program 120 different keys such that they can reproduce any series of keystrokes on a standard keyboard. Further, there are multiple versions of this product varying in their method of connectivity and how they communicate with different computer programs, such as being automatically recognised as a keyboard with pre-existing drivers installed with all software platforms.

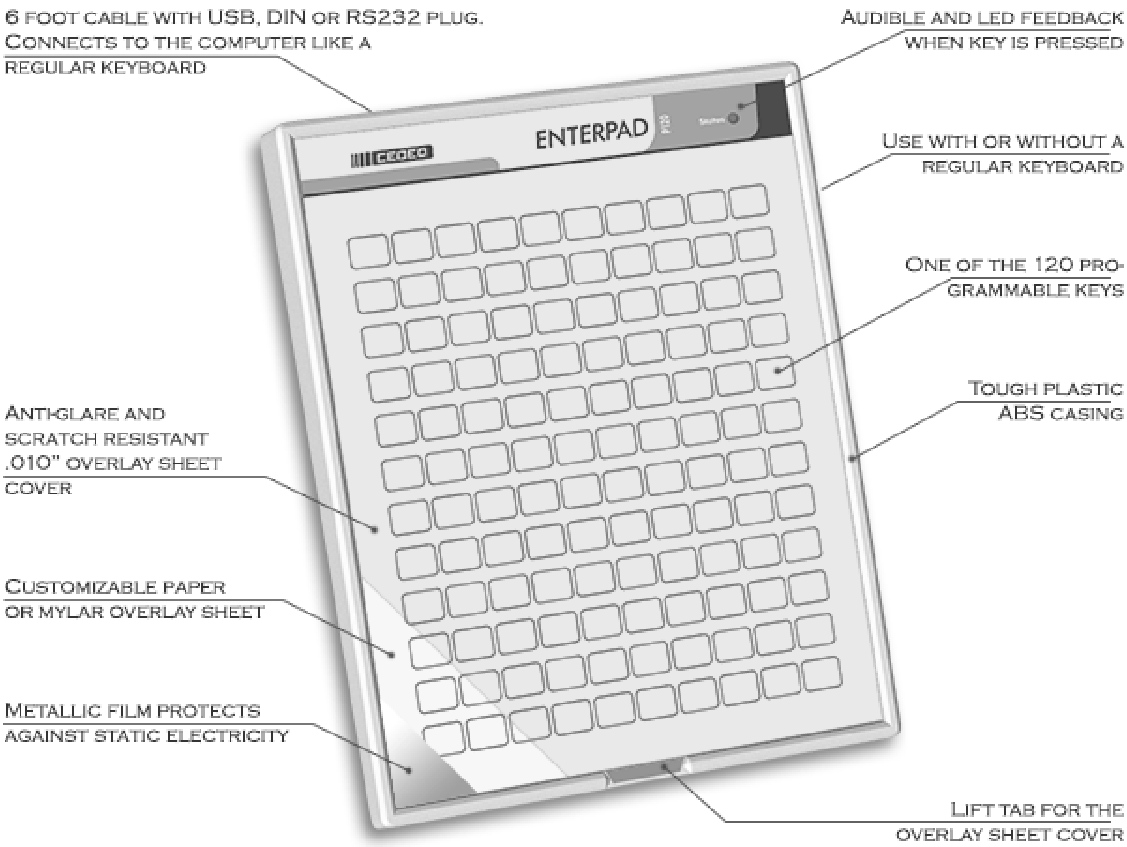


Fig. 16: Diagram of Cedeq's Enterpad P120.

This product was successfully programmed to simulate an auto record board by coding each of the 120 keys and resulted in an important improvement in the uniformity of data entry and the speed at which cattle could be processed. When commercially tested in excess of 1800 head of heifers could be enrolled using the KoolCollect data collection system when combined with the 'Enterpad', with both 'life-time' and 'muster' data being simultaneously recorded.

The ability to remotely identify cow-calf pairs within extensively managed situations offers the ability to address a number of new research questions as it provides the ability to ascribe the kg of calf weaned on an individual cow basis where the calf can tagged prior to weaning. An in-built feature within the KoolCollect system provides the capability to identify which calf belongs to an individual cow using RFID scanning frequency and combinations. The application of 'PedigreeScan' to the sheep industry has resulted in success rates of up to 97% accuracy in assignment of ewe-lamb pairs. To assess the practical application of this technology, a mob of 300 cows with calves at foot are currently being monitored near Katherine in the NT with calves expected to be weaned in May 2017. After installation, in excess of 50% of the mob was scanned within the first four days. However, an identified limitation is the proportion of the mob that are not regularly being scanned at either watering or supplement delivery points. No data is currently available on the accuracy with which calves have been matched to cows.

4.10 Evaluation of practical application of remote monitoring technology for calf wastage research

The 12-month evaluation enabled assessment of the performance of the RLMS during both a full wet and dry season. Also, because prior to the period of evaluation there had been a great deal of work put into troubleshooting and fine tuning the operation of the RLMS studied it was considered that it was operating near optimally. Therefore, the project team felt very confident that their evaluation of the system was fair. The major strengths and weaknesses for potential calf wastage intervention research were as follows:

4.10.1 Strengths

- Once trained to the RLMS cows move quietly over the dynamic weighing system offering the potential opportunity to capture potential video image data to define body condition, udder development and presence or absence of an accompanying calf.
- A system has been developed to enable remote video checking of the operation of the RLMS which facilitates timely intervention when problems are detected.
- The auto-supplement delivery system developed by the UNE research team to operate as part of the RLMS could enable accurate in-paddock assessment of the impact of a number of nutritional supplement interventions without the confounding effect of differences between paddocks.
- RLMS derived data for each satellite pass event can be automatically stored on removable USBs in the RLMS in case the satellite connection is temporarily lost for more than 24hrs.
- In the RLMS studied >80% of the data capture was able to be used to calculate predicted walk-over weights of cattle.
- Most cattle require one to three weeks of training to fully utilise the RLMS. The development of a remotely openable short-arm trap (Joe Miller pers. comm) has greatly facilitated this training. It consists of a short-arm trap with solar powered sealed hydraulic units to remotely open or close the arms of the trap. Using telemetry, this trap can be operated via the USEE website or directly by accessing the IP address of the unit. Another innovation developed during the study was to change from a rubber matted floor in the auto-drafter unit, to a corrugated/cleated floor covered with several inches of local soil. This means that cattle do not need to become accustomed to a new surface but rather have continuity of a soil surface to walk through. Collectively these developments have enable the training of 97% of cattle to use the system in approximately a week.

4.10.2 Weaknesses

- A major potential weakness of using RLMS for calf wastage research, particularly in the northern forest, is that during the wet season some cattle may only irregularly come into water at the site where the RLMS is located, choosing instead to water from temporary creeks and waterholes. Unfortunately, many cows typically calve during the wet season. To be able to accurately assess the direct impact of many management interventions requires regular data capture to enable assessment of when a cow has likely calved and whether the calf has survived and is following the cow into water.
- Cattle must be trained to being 'trapped' using non-return spear traps to prevent them backing out of the RLMS units (via an entry trap) and to ensure when they leave the water/lick yard they do not walk back in (via an exit trap) without coming thorough the

RLMS unit. This requires staff with experience in the operation of spear traps. Also as some cattle will refuse to come through the RLMS there is a risk of cattle dying. Therefore, video surveillance of the RLMS is required to enable timely intervention.

- The current cost per watering point is high because of the required cattle trapping infrastructure and the cost per RLMS unit. The requirement for permanent infrastructure reduces the flexibility of application of both RLMS and associated selective auto-supplementation technology.
- RLMS data capture and associated selective auto-supplementation requires that all cattle are NLIS tagged. Although there is some evidence of improvements in tag retention tag loss continues to be a concern. To insure against data loss when NLIS tags are lost all cattle should also have a plastic ID tag inserted at the time of NLIS tag insertion.
- Currently all RLMS units upload weight and cattle ID data via the Inmarsat network if using satellite telemetry, or the Telstra network if using NextG. Satellite upload is the only way of transferring data in near real-time from many remote sites and is very expensive ($4-8/MB). For locations closer to mobile towers, a 3G or 4G connection offers the same service at much lower cost.
- Failure of data capture or data transmission continues to be a problem. Causes include position of the NLIS tag in the ear (anything other than centre of the centre third of the offside ear can affect reading), failure of data transfer to the satellite (overcome by USB installed in RLMS), battery failure (systems that monitor battery function can reduce this), and problems with internet transfer of data.
- Other problems that were identified during the study include untrained cattle entering the paddock, lack of alignment of weights of individual cattle weighed at different RLMS units within the same paddock, and problems with automatic drafting of calves as they have no NLIS tag.

4.11 Phase II calf wastage research proposal

4.11.1 Background of proposed research

Calf wastage has been identified as a major cause of income loss by beef producers in northern Australia and a high priority for research to identify solutions. McGowan *et al.* (2014) showed losses were greatest in the northern forest and northern downs where a quarter of heifer and cow mobs experienced calf wastage of greater than 19% and 15%, respectively. Calf wastage is a complex problem. Many different environmental-, property/herd management-, animal- and disease-level factors or causes are known to contribute to the problem. In Calf Wastage Phase 1 (B.GBP.0001) a list of management interventions likely to reduce the major causes of calf wastage was developed from the findings of a recent scientific review (Burns et al, 2010), and a PhD (McCosker, 2016) and scientific papers describing the causes and factors contributing to calf wastage. An expert opinion workshop was held to map out the proximate and more distal factors affecting calf wastage. From this, causal webs were developed to facilitate assessment of the impact of candidate management interventions. A basic economic model was then developed to estimate the impact of each intervention on beef breeding business profit. Nine researchers, eight agribusiness personnel and 22 beef business owners/managers representing all country types across northern Australia then applied this model to rank 23 management interventions. The five interventions ranked highest for immediate research were improved phosphorus supplementation, improved calf husbandry, reduced paddock size, enhancing mothering, and improved nutritional management of pregnant yearlings to reduce dystocia. Implementation of each of these management interventions was predicted to improve business profitability. The proposed Phase 2 research will evaluate the impact of at least three of these interventions in commercial breeding herds experiencing chronically high calf wastage.

4.11.2 Brief project design and methods

The major project research question is 'What commercially-viable interventions can consistently keep calf wastage below achievable thresholds'?

Project outline. To investigate this, the project team's RD&A personnel are well credentialed, having led and participated in research programs/projects such as Beef CRC, Bull Power, Cash Cow and Calf Wastage Phase 1 (B.GBP.0001). Critically, the six beef producers who were the members of the Industry Reference Group in Calf Wastage Phase 1 have agreed to continue as members of the Phase 2 project team. Sixteen northern beef businesses with chronically high calf wastage and prepared to provide 2-4 paddocks for intervention research will be identified to join the Phase 2 project to test interventions over 5 years through a range of seasonal and environmental conditions.

Testing interventions impact. Each collaborating business will elect to test one or two high priority interventions that may be effective in their specific situation, using prescribed guidelines and assistance from the research team. To maximise industry ownership, four producers will be employed on a part-time basis to support and mentor on-property research. Interventions will be allocated at the paddock level for single year periods (paddock-years) with participating producers contributing pairs of paddocks, which are similar in key features that do not form part of the intervention such as similar area, pasture quality, annual pasture yield, geography and distance to water. One paddock will receive the intervention and the other will be managed using current practice. It is estimated that 40 pairs of paddock-years will be required to detect a 5% reduction in calf wastage. Recommended management of major infectious diseases and predation will be practised at all sites. Detailed component studies using complementary funds (ACIAR) will be conducted to improve understanding of impact of interventions. The effect of interventions will be assessed using the incidence of calf wastage, other productivity measures, and a cost benefit analysis.

4.11.3 Outputs and impacts of proposed project

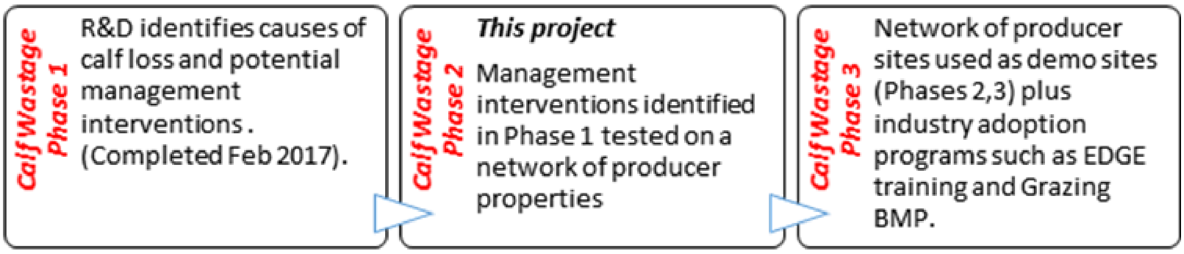
The primary project ***output*** will be ready-to-use evidence-based recommendations on application of selected management interventions to reduce calf wastage in northern beef herds. In addition, practical monitoring methods (eg, crush-side electronic data capture and analysis) will be developed to support informed decisions about which management should be implemented.

The expected ***outcome*** is that beef businesses experiencing high calf wastage will be able to reliably identify and apply appropriate management interventions to reduce losses by up to 5% units annually, translating into profit increases of at least $5 per adult equivalent in the herd.

Impact modelling has suggested a change in management that costs $15,000 to achieve a 5% unit reduction in calf wastage could increase annual live weight sales by 18 tonnes and increase EBIT by $19,000. This represents a potential annual return to northern Australia of $25M.

4.11.4 R&D Adoption - Extension pathways

The proposed project is the second phase in development of practical effective management interventions to reduce calf wastage in northern beef herds. It is envisaged that Calf Wastage Phase 3 will further develop the findings from Phase 2 via scaling up through establishment of an expanded producer network.



It is recognised that producers are often reluctant to implement new management strategies; however, an active producer reference group (established in B.GBP.0001) and at least four producers employed as part-time project officers in the proposed project will greatly help drive adoption of proven interventions.

The project will support a strong network of producers as the basis for a constant flow of information within and beyond the immediate network. An open project meeting for beef producers and beef consultants will be held annually in a changing regional setting. It is proposed that these meetings will be led by members of the producer reference group and will underpin a range of associated activities (eg, opportunistic participation in field days, newsletters, rural press, webinars) that will create awareness initially, leading to individual discussions to guide practice change. This will be enhanced by having active links with ReefPlan, Grazing BMP, Drought and other similar D&A projects.

5 Discussion

The reference group provided the project team with a wealth of practical experience in application of a range of management strategies in their own businesses, including control of dystocia in yearling mated heifers, sustainable grazing management, herd segregation, culling strategies to reduce calf wastage, and use of technologies such as walk-over-weighing and auto supplementation in extensively managed herds. This practical experience will be invaluable in the proposed evaluation of selected management strategies to reduce calf wastage and how the adoption of findings from this research should be managed.

The causal webs highlight the complexity of calf wastage, and provide strong support for the management interventions proposed in 4.3. 'Manage the feed-base' is supported by the identification of pasture quality, pasture availability, cow body condition score and phosphorus reserves as key leverage points. Improvement of each of these factors has the potential to have a lasting impact on the system i.e., reduce calf wastage though increased risk of dystocia due to foeto-pelvic disproportion should be monitored. 'Manage lactation' is supported by the identification of milk production (lactation) and calf vigour as key leverage points. Improvement of both of these factors has the potential to have a lasting impact on the system. 'Manage cattle health and stress' is supported by the identification of reducing the risk of a range of infectious diseases and development of immunity to these diseases as key leverage points. Improvement of each of these factors has the potential to have a lasting impact on the system. Additionally, in areas where predation is a concern, both predation and separation are key leverage points and minimising each has the potential to have a lasting impact on the system. Finally, the team recognised that these causal webs do not, and realistically cannot, incorporate all direct and indirect causes of calf wastage and associated linkages. However, they believe that key factors and associations are covered. Validation of the webs with other stakeholders would be useful.

The draft best practice recommendations for control of calf wastage commences with an outline of how producers should determine whether the calf wastage each of their breeding mobs is experiencing is at an acceptable level or needs to be investigated. Guidelines on how to conduct an investigation including how to conduct a post mortem examination of a dead calf are provided. In the absence of 'hard' evidence of the impact of each recommended control measure on the incidence of calf wastage and on business performance these measures must be considered by producers and advisors as guidelines only.

6 Conclusions/recommendations

The reviews conducted by the project team and external consultants have all clearly demonstrated the dearth of published evidence of the impact on calf wastage of various management interventions that could be employed by producers in northern Australia. A set of guidelines describing what producers could currently do to control calf wastage has been prepared. In addition, a survey tool has been developed to assess what producers are currently doing to manage calf wastage and to enable identification of appropriate management interventions that should be considered for implementation. The work conducted as part of Calf Wastage Phase I has enabled identification of the management interventions that both producers and researchers consider are the highest priority for systematic field evaluation. These have been incorporated into a fully-costed research proposal that has been submitted to MLA. In addition, a significant further analysis of data from the Beef CRC and Cash Cow projects has been conducted to improve our understanding of how to reduce calf wastage and how to measure the impact of management interventions on business performance.

7 Key messages

- There is a major lack of good quality evidence of the impact on the incidence of calf wastage and commercial business performance of most potential management interventions.
- A scientifically robust method has been developed to identify and prioritise for research potential management interventions to reduce calf wastage.
- The five interventions ranked highest for immediate research were improved phosphorus supplementation, improved calf husbandry, reduced paddock size, enhancing mothering, and improved nutritional management of pregnant yearlings to reduce dystocia. In addition, research into improved strategies to manage the impact of wild dogs was strongly recommended by the industry reference group.
- Because of the complexity of factors and causes of calf wastage in any given commercial situation, a systems based approach to researching the impact of specific management interventions must be used.

8 Bibliography

Behrendt K, Weeks P (2017) How are global and Australian beef producers performing? Global agri benchmark network results 2016. Market Information Report, Meat and Livestock Australia, Sydney.

Burns BM, Fordyce G, Holroyd RG (2010) A review of factors that impact on the capacity of beef cattle females to conceive, maintain a pregnancy and wean a calf - Implications for reproductive efficiency in northern Australia. *Animal Reproduction Science* **122**, 1-22.

Bunter K, Johnston D, Wolcott M and Fordyce G (2014). Factors associated with calf mortality in tropically adapted beef breeds managed in extensive Australian production system, Animal Production Science, 54

Fordyce G, McGowan MR, McCosker K, Burns BM (2014) Foetal and calf loss in extensively-managed beef cattle. In 'Proceedings of the 28th World Buiatrics Congress, Keynote lectures'. pp.94-100. (Cairns)

Fordyce G, Olchowy TWJ, Anderson A (2015) Hydration in non-suckling neonatal Brahman cross calves. *Australian Veterinary Journal* **93**, 214-220.

Lane J, Jubb T, Shepherd R, Webb-Ware J, Fordyce G (2015) Priority list of endemic diseases for the red meat industries. Project B.AHE.0010, Meat and Livestock Australia, Sydney, NSW.

Maani KE, Cavana RY (2007) "Systems Thinking, System Dynamics." Pearson Education: New Zealand.

McCosker K (2016) "Risk factors affecting the reproductive outcome of beef breeding herds in North Australia." PhD Thesis, The University of Queensland, Gatton Campus, Queensland.

McGowan MR, Fordyce G, Smith D, McCosker K (2016) Managing live weight production from beef breeding herds. In 'Proceedings of the 29th World Buiatrics Congress, Keynote lectures'. pp 87-90. (Dublin)

McGowan MR, McCosker K, Fordyce G, Smith D, O'Rourke PK, Perkins N, Barnes T, Marquet L, Morton J, Newsome T, Menzies D, Burns BM, Jephcott S (2014) North Australian beef fertility project: Cash Cow. Project B.NBP.0382, Meat and Livestock Australia, Sydney, NSW.

McMichael AJ (1999) Prisoners of the proximate: Loosening the constraints on epidemiology in an age of change. *American Journal of Epidemiology* **149,** 887-897.

O'Rourke PK, Entwistle KW, Arman C, Esdale CR, Burns BM, (1991) Fetal development and gestational changes in *Bos taurus* and *Bos indicus* genotypes in the tropics. *Theriogenology* **36**, 839-853.

Rwashana AS, Nakubulwa S, Nakakeeto-Kijjambu M, Adam T (2014). Advancing the application of systems thinking in health: understanding the dynamics of neonatal mortality in Uganda. *Health Research Policy and Systems* **12,** 36 (doi: 10.1186/1478-4505-12-36).

Steele F (2014) Multilevel Modelling of Repeated Measures Data. Stata Practical LEMMA VLE Module 15 [Online]. Available at: http://www.bristol.ac.uk/cmm/learning/course.html.

Acknowledgements

On behalf of the project team I would like to thank Dr Di Vankan for her wonderful help in compiling, editing, and formatting this report.

9 Appendices

N.B.: Appendices 1-7 are available from the author on request.