IMPROVEMENT OF THE REPRODUCTIVE PERFORMANCE OF VICTORIAN DAIRY HERDS

Review and recommendations carried out for the Gardiner Foundation

By

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DISCLAIMER

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Executive Summary

Reproductive performance in dairy cows continues to decline in Australia. The InCalf 2010 analysis commissioned by Dairy Australia identified declines in the 6-week in-calf, three-week submission rate and first-service conception rates whilst the 12-week not-in-calf and 21-week not-in-calf and overall not-in-calf rates continue to increase when compared to the original analysis from 2000.

All major dairying countries have experienced a similar decline and it has occurred across the full range of production systems (from pasture-based to total mixed ration systems) and per-cow productivity. The modern dairy cow is less fertile than her predecessors and it seems that selection pressure on milk production with insufficient consideration of fertility, has resulted in a cow that is capable of very high milk production, but in order to achieve this has redirected metabolic processes and functions away from other traits, one of which is reproductive efficiency.

Declining fertility of the cow is making it harder for seasonally-calving farms to retain a single, tight calving season. Farmers are losing the ability to choose the calving system for their herd. Many seasonally calving herds have or are shifting to split- and batch-calving systems and are using extended lactation and crossbreeding as ways of managing the problem. Effective seasonal milk pricing systems and good milk production by cows lactating beyond 305 days has limited the economic impact of these changes but the decline in fertility persists. Carryover cows also have declining fertility and this suggests that on its own, split-calving will not provide a stable system. Modelling of the decline suggests that if historical trends continue, the average lactation length for cows will reach 400 days by 2025. Insufficient artificially-bred replacements will be available to farmers from the major calving period before 2020 without resort to use of sexed semen. By 2030 insufficient replacements from both calving periods in split systems are predicted (again without resorting to use of sexed semen).

The long-term solution to the poor fertility that is associated with the typical high-producing cow, is to ensure that further selection for increased milk production is accompanied by increased genetic merit for fertility. The necessary steps have been implemented to re-weight the APR and genomics promises to help accelerate genetic progress. However, it will happen much faster if the quantity and quality of fertility data were improved. This will only occur if better systems for on-farm data capture are implemented. Restoring fertility levels of the Australian dairy herd to more acceptable levels through the genetic route will take many years and so it is imperative that other tools and approaches that can assist farmers to achieve acceptable fertility with the current genetic makeup of the herd are identified, researched, developed and extended to the industry.

Extensive reviews of the drivers of the declining fertility indicate that the high-producing cow has an aberrant metabolism. This high metabolic rate and preferential diversion of nutrients to the lactating udder in the average high-producing cow is compromising bodily homeorhetic functions. The uncoupling of the somatotropic axis with associated negative impact upon the gonadotropic axis further combined with metabolic disorders provide a cow with immune-suppression after calving, increased uterine infections, delayed restoration of ovulation after calving, decreased oestrus display duration and intensity, low circulating sex steroid levels, reduced conception rates and increased embryonic loss rates. Confounding these changes have been changes to the production

systems used by farmers – herd sizes have increased, increased feeding of concentrates and greater use of split calving have occurred, while at the same time there is concern that the relevant skill levels of farm workers have declined. This makes separating the cow-level drivers from the herd-level drivers (i.e. systems and management) difficult.

Comprehensive and integrated nutritional/metabolic studies are required to identify and map the complex metabolic and hormonal drivers of reproduction in the high-producing cow. These studies can potentially deliver a medium-term solution. It will take time for this research to identify, test and validate effective nutritional strategies to provide acceptable improvements to fertility in the high producing cow within the Australian pasture-based environment. The development of effective supplementation programs within a five to ten year horizon will bring significant benefit to the industry.

In the short term it will be necessary to revisit known (and identify any unknown) risk factors behind the decline in performance of key parameters of reproductive performance of seasonal herds – primarily the submission rate and AI conception rate. Many of these risk factors are already known, such as the interval from calving to mating start date. The long-term trend of increasing calving spread and later median calving date is impacting upon the likelihood of cows becoming pregnant early in the subsequent mating period. Other factors may also be contributing to this decline such as slower resumption of ovarian activity and increased incidence of anovulation in the period after calving and weaker and shorter heat displays in the modern cow. However, it is clear that many factors remain unknown, so it is important that comprehensive retrospective and prospective case-control studies be commissioned to identify the herd-level, management and nutritional factors that characterise the small proportion of the InCalf study herds that have maintained consistently high reproductive performance.

It will also be important that effective and integrated strategies for farms with sub-optimal reproductive performance be developed, to assist these farms restore and then maintain reasonable calving patterns. These strategies will require that an increased proportion of cows be successfully mated early in the mating period. For example, the overall effectiveness of synchrony programs may need to be re-assessed and to identify risk factors for failure in individual cows (e.g. low protein concentration in milk). The decline in AB conception rates has been dramatic. Again this is influenced by known risk factors (such as cow age, insufficient time since calving and poor AI technique) but may also be compounded by an increasing prevalence of early and late embryonic loss and increasingly delayed ovulation in cycling cows. Again, focused review of existing recommendations and tailored research may be required.

There is currently insufficient adviser activity. Too few are investigating, diagnosing and correcting poor reproductive performance in dairy herds. No InCalf adviser training courses have been undertaken for four years and the network of active advisers remains small. Many trained advisers are either not sufficiently interested in reproductive performance consultancy, are unable to identify economical ways of offering such a service, are not confident in their breadth and depth of skills to offer such a service or are daunted by the process of collecting, collating and analysing herd reproductive data from the fragmented data systems that are used across the industry. The lack of uptake of Fertility Focus Reports suggests that the awareness, skill levels and incentive for advisers to address reproductive problems are not there. The InCalf Program needs to re-invigorate and modify aspects of the extension material to reflect recent developments, actively build an effective hierarchical adviser network that has sufficient competence across the industry (culminating in a few individuals that can and readily undertake whole herd reproduction investigations), and focus research activities on investigating declining performance of the critical control points of the herd breeding program.

Recommendations

A summary of recommendations made throughout this report follows. In the body of the report, specific recommendations are shown in ***bold italics***, and the page numbers below indicate their location.

1. Cost-effective nutritional supplement programs that can improve herd reproductive performance are needed, together with practical strategies for monitoring herd nutritional and/or metabolic health in a grass-based production system. This will require research that:
    a. Identifies and quantifies the key relationships between nutrition and reproduction. It should focus on nutritional strategies and solutions applicable to the pasture-based system and should include consideration of genetic, metabolic, and endocrine interactions with nutrition. The aim is to develop a greater understanding of the pathways, interactions and time dependency between nutrition and reproduction.
    b. Identifies effective nutritional management programs that are able to limit body condition score (BCS) loss and negative energy balance (NEB) in cows with high genetic merit for milk production. This work effectively asks if dietary management can effectively be used to redirect nutrients away from milk production towards other essential processes (thereby preserving BCS and limiting NEB) in cows of high genetic merit for milk production. Effective metabolism-modifying diets should be investigated for their impact on endocrine pathways operating at the ovarian and uterine level.
    c. Compares the InCalf herds with high and consistent reproductive performance to herds that have experienced the typical decline in fertility over the past decade
    d. Investigates nutritional impacts upon early embryonic loss
    e. Leads to an understanding of the physiological mechanisms that cause the observed relationship between milk protein concentration and fertility.

    The resulting management programs that emerge from this work must be suited to a pasture-based grazed dairying system and should entail effective and consistent messages for managing the lactating cow in the transition period prior to mating. All activities should be coordinated with Dairy Australia's Feedbase and Grains2Milk projects.

Size of investment required:	*Large (individual components could be small-moderate)*
Potential impact:	*Large*
Likelihood of success:	*Moderate*
Time frame:	*5-10 years*
Priority:	*High-very high*
Pages:	*29, 33, 34, 36, 41, 54*

2. Apart from the need for effective nutritional strategies to ameliorate problems with low fertility, there is also a requirement to shorten the inter-calving interval (or more specifically, the calving to mating start date), potentially using synchrony and anoestrus cow treatments. The early mating of cows is not without risk - conception rates are lower and embryonic loss rates are higher. Practical strategies for shortening this period should be developed and promoted. Ideally, nutritional studies should specifically investigate the impact of any interventions on the calving-to-first-ovulation interval, the quality and strength of oestrus display, conception rates and embryonic loss. The interaction between various synchrony interventions (such as prostaglandin) with recently-identified risk factors upon the ability to detect oestrus may provide greater insight into the drivers of efficacy of these reproductive interventions within individual herds. Therefore research into EEL/LEL should continue and risk factors (e.g. low milk protein concentration) should be better defined and – if possible – the probability distribution for EEL/LEL at various intervals from calving to mating be mapped. This information may assist farmers and advisers use strategic nutritional and hormonal synchrony programs more effectively. The expected range of results and implications from use of systems to promote early mating of cows need to be elucidated and clearly presented to the industry.

   Size of investment required: *Moderate*
   Potential impact: *Moderate*
   Likelihood of success: *Moderate-high*
   Time frame: *2-5 years*
   Priority: *High*
   Pages: *41, 55*

3. Strategies for getting better quality fertility records into the ADHIS database are of paramount importance. More comprehensive data will not only facilitate faster rates of genetic improvement but also provide a more accurate assessment of fertility on a national basis. Ongoing collaboration between NHIA, ADHIS, the Dairy Futures CRC, and Dairy Australia to scope and develop better systems is essential. Having an effective central consolidated data system along the lines of that already proposed would be a distinct advantage but the challenges faced, both logistical and financial, are daunting. It is important that all stakeholders be included in these developments, including companies providing in-line farm sensing systems and farm- and herd-centre software providers, along with relevant IT and data management expertise. The work will require understanding the range and type of data collection opportunities in farm, the drivers for recording of data at farm, centre and industry level, mapping data flow pathways and describing data supply chains (and bottlenecks), and ideally, the development, management and administration of a centralised database (with associated data privacy, access and user privileges).

   Size of investment required: *Moderate to Large (depending on scope)*
   Potential impact: *Large*
   Likelihood of success: *Moderate*
   Time frame: *2-10 years*
   Priority: *Very high*
   Pages: *31, 42, 46*

4. Research to improve the reliability and timeliness of fertility ABVs, which is currently under way, should be given high priority. This would be greatly facilitated by the development of an integrated data system (as discussed in the previous recommendation) but is not solely reliant on it. The medium term goal is to obtain a large number of quality phenotypic (fertility) records, but in the meantime, methods should be implemented to make full use of data that are already available and to possibly develop interim fertility ABVs for all imported semen.
   Size of investment required: *Small-moderate*
   Potential impact: *Low-moderate*
   Likelihood of success: *High*
   Time frame: *1-2 years*
   Priority: *Very high*
   Pages: *35*

5. Effective, clear and consistent extension material is needed to allow farmers to assess the benefits and implications of crossbreeding programs within their herds.
   Size of investment required: *Small*
   Potential impact: *Low-moderate*
   Likelihood of success: *High*
   Time frame: *1-2 years*
   Priority: *Medium*
   Page: *39*

6. A decision support aid should be developed and assessed to estimate the projected lifetime value of a cow. It should incorporate genetics, production and recent fertility performance information (e.g. calving period). Such a tool could provide effective guidance for farmers as to the lifetime impacts of keeping a late calving cow, moving her to the next mating period or selling her. To be effective, this tool will need to developed, refined and then workshopped with industry to maximise its usefulness, coverage, ease of use and ensure its acceptance by farmers.
   Size of investment required: *Small*
   Potential impact: *Low-moderate*
   Likelihood of success: *High*
   Time frame: *1-2 years*
   Priority: *Medium*
   Page: *39*

7. InCalf Adviser training workshops should restart. Currently, too few advisers are actively working with clients to diagnose and correct herd reproductive problems. The number of *active and effective* advisers needs to increase throughout the industry, by increasing the awareness, interest and knowledge of existing public and private sector farmer advisory networks. This may require review of the current training material and systems and the development of new approaches and material. Developing greater understanding of the current motivations and drivers of 'inactive' advisers is recommended. This may identify specific requirements for the development of tailored refresher courses and material that can meet the needs of this group.

Adviser-focused material that can guide the systematic investigation of problem herds will most likely be required (as recommended by recent InCalf reviews). This would include material describing a standardised approach to investigating a herd problem and sections on collection and collation of data from various sources and recommended analyses using both stand-alone herd software programs as well as spreadsheets/statistical programs. It could extend to basic data collection, cleaning and processing with examples from the varied data sources used within the industry to capture reproductive data.

Size of investment required: *Moderate*
Potential impact: *Moderate*
Likelihood of success: *Moderate*
Time frame: *1-2 years*
Priority: *High*
Pages: *41, 44*

8. An industry-wide investigation into the decline in herd testing is needed, assuming it is not part of Recommendation 3. It should include (but not be limited to): a status assessment of the herd testing industry; identifying the drivers and barriers to herd testing by farmers; identifying analyses and information flows that may increase the worth of herd testing data to farmers; a SWOT analysis of disruptive technologies that may impact upon the industry-level; development of an industry plan to increase the proportion of herds and cows that provide herd-test data captured by the central proofing system (ADHIS).

Size of investment required: *Small*
Potential impact: *High (if it leads to changes)*
Likelihood of success: *Moderate*
Time frame: *1-2 years*
Priority: *Very high*
Page: *53*

9. Further investigation of the impact of timing of AI with respect to ovulation should be undertaken as part of wider-ranging studies to identify the causes of declining AI conception rates. Factors of interest include: DIY AI technician variability, lower semen fertility/survivability, changes to (and identifying risk factors for changes to) the distribution of onset-of-oestrus-to-ovulation times in cows, poorer oocyte health, increased embryonic loss, sub-optimal uterine and endocrine environment and suboptimal AI technique.

Size of investment required: *Small-moderate*
Potential impact: *Moderate*
Likelihood of success: *High*
Time frame: *2-3 years*
Priority: *Very high*
Page: *59*

10. Up-to-date, effective, tailored and comprehensive AI teaching resources should be developed, supported by a sufficient number of skilled (and possibly accredited) trainers, equipped to deliver AI refresher courses in all the major dairy regions each season.
    Size of investment required: *Small*
    Potential impact: *Moderate*
    Likelihood of success: *High*
    Time frame: *2-3 years*
    Priority: *High*
    Page: *59*

11. A reproduction advisory group should be formed to assist in the prioritisation, coordination and review of activities aimed at reversing the decline in cow fertility. It should include representatives of all relevant stakeholder groups and take responsibility for developing a clear, consistent and coordinated industry response to the problem that meets short-, medium- and long-term objectives and works within resource constraints as efficiently as possible.
    Size of investment required: *Small*
    Potential impact: *Moderate*
    Likelihood of success: *High*
    Time frame: *Immediate*
    Priority: *High*
    Page: *44*

Background

Dairy farmers are in the business of producing milk and surplus livestock, both of which rely heavily on herd fertility. The intensity and timing of these product streams differ from farm to farm, but traditionally, dairy farmers choose the production system that best matches their environment (climatic and economic), skill set and resources, and personal circumstances.

Fertility is an innate characteristic of the dairy cow. It can be regarded as being at an acceptable level when farmers can get their cows in calf soon after their mating start date. A dairy farmer needs to be able to effectively manage reproduction of the herd in order to:

1. Initiate lactation in cows
2. Ensure replacement animals are produced
3. Control the production system that they wish to employ.

There is abundant evidence that fertility is declining in the modern dairy cow, but the reasons are not simple: fertility is recognised as a multi-factorial trait with genetic, nutritional, environmental and managerial components interacting in a complex network[1].

The typical Australian dairy production system is changing. It has traditionally been pasture-based, operating within four broad climatic regions (cool temperate, Mediterranean, inland irrigation and subtropical regions)[2]. The pasture-based system revolves around effective grazing by cows with the broad objective of matching the seasonal supply of pasture and other forages with the energy demand of the herd. The key way for farmers to control the energy demand of their herd is through controlling the timing of onset (and end) of lactation for the milking herd. This in turn requires the farmer to be able to effectively control the herd's reproduction cycle.

An increasing proportion of Australian dairy farms are using purchased feeds to supplement pasture and to even-out the peaks and troughs of supply from home-grown and grazed feeds. The spectrum of production systems within Australia is extending from the wholly pasture-based system towards the feeding of partial mixed rations (PMR) or total mixed rations (TMR), such that there are now five recognised farming systems based on feeding practice[3]:

1. Pasture + other forages + <1.0 tonne grain/concentrate per cow (fed in bail);
2. Pasture + other forages + >1.0 tonne grain/concentrate per cow (fed in bail);
3. Pasture + Partial Mixed Ration (PMR) ± grain/concentrate (fed in bail);
4. Hybrid: Pasture + PMR + grain/concentrate per cow (fed in bail) at various times;
5. TMR.

[1] Walsh SW, Williams EJ, Evans ACO (2011). *A review of the causes of poor fertility in high milk producing dairy cows*. Animal Reproduction Science **123:** 127-138

[2] DMF Committee (2010). *Dairy Moving Forward: Research, Development and Extension Priorities for the Australian Dairy Industry*

[3] DMF (2009). *The Dairy Moving Forward: A national Research, Development and Extension strategy report*

The Australian industry continues to consolidate. Whilst national cow numbers have decreased by approximately 25% over the past ten years (decreasing from 2.1 million to 1.6 million), the number of dairy farms has almost halved in this time (decreasing from 12,900 to 7,500) with herd sizes increasing from an average of 167 to 213 cows. Annual per cow production has increased from 5,000 litres to 5,500 over the same period. The typical Australian dairy farm now milks more cows, has higher production per cow, employs more labour (but has more cows per labour unit) and operates at a higher stocking rate. These trends are continuing. Dairy farmers operate in a fully deregulated market with milk pricing systems driven by supply and demand – with strong seasonal pricing by many processors. And farms have experienced extreme climatic conditions during the past decade. This increasing seasonal volatility will continue if predictions about the impact of global warming on the major dairying regions prove to be correct.

A key premise of economics is the concept of choice. Economic theory provides the framework and the tools for making optimal choices about the allocation of scarce resources to satisfy wants and needs. This fundamentally becomes a decision about how the factors of production (pasture, cows, labour, purchased feed, etc.) are to be allocated to optimise 'profit' (finances, milk, surplus stock, lifestyle). Whilst farmers may differ in their view of the optimal system and production level, the key tool at their disposal is choice. With dairy cattle systems, one of the most fundamental choices that the farmer can make is when to get the cow pregnant.

The fertility of the Australian dairy herd has been steadily declining for more than two decades. The InCalf project measured herd fertility in seasonal-calving systems on two separate occasions – around 2000 and again in 2009. Whilst these two separate analyses were restricted to a small (and different) sample of herds, on each occasion the parameters used to measure reproductive performance of the herds were essentially identical. A summary of the key reproductive parameters from both analyses (2000 and 2009), demonstrates the ongoing downwards trend (Table **1**).

Table 1. Fertility statistics in 2000 and 2009

Parameter	**2000**[4]	**2009**[5]
6-week in-calf rate	63%	50%
21-week in-calf rate	91%	78%
Not-in-calf rate	9%	20%
3-week submission rate	77%	72%
First AI conception rate	49%	38%

This ongoing decline in dairy cow fertility within the Australian system is eroding the power of dairy farmers to choose their preferred production system and is forcing many into alternative production systems.

[4] Dairy Research and Development Corporation (2000). *The InCalf Project: Progress Report (seasonal, split and batch calving)* September 2000
[5] Dairy Australia (2011). *InCalf Fertility Data Project 2011*

The trends of increasing per-cow production and declining fertility seen in Australia have been reported in most dairy countries, including the USA, Netherlands, Ireland and New Zealand[6]. Average annual production of the cow within these countries varies greatly (USA: 11,000 kg, Netherlands: 8,000 kg, Ireland: 6,000 kg, and New Zealand: 3,800 kg)[7]. The predominant production system deployed in New Zealand resembles feeding system 1 and 2 (as described above), whereas the typical Europe and North American systems more resemble feeding systems 4 and 5. North America, Europe and New Zealand are all large suppliers of dairy genetics into the Australian system. These observations suggest that simply changing the production systems in use within the Australian industry will not halt the decline in fertility.

Thus herd fertility has declined across the complete spectrum of production systems and can be seen across the range of production levels and within all the major breeds of dairy cow throughout the world industry. This widespread and consistent pattern leaves little doubt that the decline is essentially occurring at the cow level. It may be further compounded (or partly ameliorated) by certain production systems and management approaches, but it seems clear that the modern dairy cow is intrinsically less fertile than her forebears.

Management implications of declining fertility

The seasonal calving system that predominates within the Victorian (and Australian) dairy industry is premised upon sufficient cows becoming pregnant within a condensed mating period, so that they calve at the appropriate time to match pasture supply with herd demand. This 'ideal' calving period is 8 weeks but can typically extend to 12 weeks or more (especially if calving induction is not used). This system requires the herd to maintain an average 365-day inter-calving interval.

The InCalf Fertility Data Project (2011) found that in 2009, there was a median submission rate of 72%, first service conception rate of 38%, six-week in-calf rate of 50% and a 12-week not-in-calf rate of 31% among the seasonal/split calving herds included in the study. On average, less than 1/3rd of the herd became pregnant after the first round of AI and approximately 1/3rd of the herd remained empty after 12 weeks. These results imply that most seasonally-calving farms will not be able to maintain a strictly seasonal calving system without the use of calving induction and/or heavy culling with increased herd replacements (cow purchases and/or use of sexed semen). The number of home-bred replacement animals (born to AI) each year is also declining in these herds. This both increases the average cost of a replacement animal and reduces the size of the replacement pool of heifers. Fewer replacements limit the farmer's ability to cull and replace poorer performers within the herd and therefore the rate of genetic gain within a herd is reduced.

Some farmers are responding to the downward trend in AI pregnancy rate by reducing their use of AI and increasing their use of bulls. Many buy dairy-breed bulls (typically with limited genetic

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[6] Walsh SW, Williams EJ, Evans ACO (2011). *A review of the causes of poor fertility in high milk producing dairy cows.* Animal Reproduction Science **123**:127-138.
[7] Dillon P et al. (2006). *Consequences of genetic selection for increased milk production in European seasonal pasture based systems of milk production*. Livestock Science **99:**141-158.

information) and keep heifers from these natural matings as herd replacements. ADHIS estimates that in terms of genetic merit, cows sired by natural service typically lag cows from AI bulls by about ten years; or are currently about 60 ASI units lower in Holsteins, 20 ASI units lower in Jerseys and 60 ASI units lower in Red Breeds[8]. Therefore these farmers have greatly compromised the genetic level of their herd and also their ability to choose sires with reliable breeding value information.

Fertile herds have higher proportions of productive animals (lactating and pregnant cows) and have a greater capacity to cull poorer performers each year than herds with lower fertility. Farmers with a fertile herd are more likely to continue using AI, thereby giving them continued access to top genetics, while retaining their capacity to select their best replacement heifers.

The ongoing decline in fertility has resulted in many farmers moving from seasonally-calving systems into split or even year-round calving systems. Fortunately for them, the seasonal milk pricing schemes employed by a number of processors has enabled many farmers to maintain milk income at satisfactory levels, despite moving to split calving systems. For many producers, this has eased the transition. The financial impact of moving away from strictly seasonal calving has been further ameliorated through better nutritional management, better information and ability to manage cows with extended lactations and increased production of home-grown forages (especially outside of peak growth periods). Economic analysis has indicated that the effective use of split-calving systems provides many farmers with an effective risk-management tool that can assist them to deal with the vagaries of season and price – by retaining more cows for the out-of-season herd when times and prices are good and by reducing the size of this herd during downturns or droughts[9].

However, the recent InCalf Fertility Data Project[5] demonstrated that split-calving and batch calving systems are also experiencing difficulty maintaining tight and sustainable calving periods, as a consequence of declining cow fertility. This is leading to increasing numbers of empty cows moving to the next mating/calving period each season. These farms must develop appropriate systems to deal with repeat non-pregnant or late cows as these animals have already changed calving seasons once before.

A detailed comparison of pure-bred Holstein-Friesian herds with herds using an effective crossbreeding program (Holstein-Friesian and Jersey) in a seasonal system[10], demonstrated that crossbred herds were more profitable than pure-bred Holstein-Friesian herds. The extra profit arose from:

1. Higher potential stocking rates of the (smaller) crossbred cows
2. Fewer herd replacement costs.

[8] Australian Dairy Herd Improvement Report 2010, p22: http://www.adhis.com.au/v2/downv2.nsf/(ContentByKey)/0af545034ac09bf7ca2576aa001bb67a/$file/australian%20dairy%20herd%20improvement%20report%202010.pdf?open

[9] B Malcolm (pers comm) October 2011

[10] Pyman MF, Malcolm W, Macmillan KL (2008). *Economic modeling of the comparative performance of Jersey x Holstein-Friesian crossbred cows in Victorian Holstein-Friesian herds*. Proceedings of the New Zealand Society of Animal Production 2008. **68**:84-87

The crossbred cows had longer-survival than the Holstein-Friesian and fewer replacements were required to maintain herd numbers. In summary, more of the crossbred herd was lactating and pregnant, and fewer annual replacements were required, compared to the Friesian herd. In that study, depreciation losses were greater in the Holstein-Friesian herd. However, the InCalf Fertility Data Project[5] also demonstrated that over the past decade, all breeds (including crossbreds) experienced similar declines in fertility to the Holstein-Friesian, albeit at a slower rate.

Collectively, these observations suggest that split calving systems and/or changing to a crossbreeding system will delay, but not halt, the loss of choice that farmers have in controlling their production system. Declines in cow fertility are occurring in split, batch-mating and year-round calving systems and are present within the major dairy breeds (and crossbreds).

The modern dairy cow is less fertile than her forebears.

Economic value of fertility compared with other traits of importance

In a detailed study of the traits affecting dairy cow profitability in Australia, Pryce *et al.* (2010)[11] calculated the economic value of a 1% increase in calving rate to be worth $3.02 per cow per year. The estimated value of unit changes in fertility and other traits were as shown in

Table ***2***.

Table 2. Economic values for dairy cow traits

Trait	Economic value ($)
Milk Yield (litres)	-0.05
Protein Yield (kg)	5.99
Fat Yield (kg)	1.49
Survival (%)	7.04
Fertility (%)	3.02
SCC (%)	0.26
Liveweight (kg)	-0.85
Milking Speed (1-5)	1.74
Temperament (1-5)	2.69

When expressed in terms of its phenotypic variability, fertility was valued at $139 per standard deviation, third in rank behind survival ($246) and protein yield ($144). However, as assessed in Australian dairy herds, fertility has a very low heritability of around 0.03 compared with around 0.30 for milk yield and its components. This means that even though fertility is relatively valuable, gains in total profit from selection will largely come from other traits, if the above values are assumed.

[11] Pryce, J., van der Werf, J. Haile-Mariam, M., Malcolm, B. Goddard, M. (2010). *A technical manual describing the Australian Profit Ranking (APR) index (Version 2).* December 2010

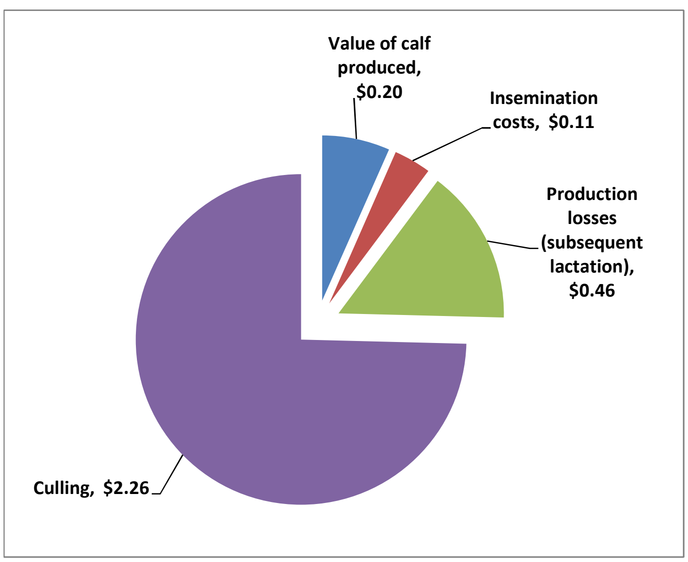
This economic value for fertility was derived by modelling a typical dairy cow herd using conventional methodology. Their economic model included published Australian values for the following variables:

- the current level of fertility
- the volume of milk produced
- the price of milk
- the cost of semen
- rearing costs
- cull cow costs
- semen costs and
- the value of the calf produced.

It accounted for the effect of delayed conception due to infertility on lactation length and cumulative milk yield in the subsequent lactation; a reduction in the number of calves sold; the cost of additional inseminations; and culling costs specifically related to fertility. A range of other variables were also taken into account including the cost of feed, the lactation curve and the herd's vital statistics.

Figure 1 shows that the greatest contribution to the value of increased fertility came from a reduction in costs associated with early culling (74% of the value), with smaller contributions from having more cows calving earlier in the following season (15%), extra value of the resulting calf (7%) and a reduction in insemination costs (4%).

Figure 1. Components of the economic value of cow fertility (Pryce et al. 2010)



An investigation of farmer concerns, conducted for Dairy Australia and published in 2007[12], indicated that fertility was seen as critically important and it was felt that the trait had historically received

[12] Paine M and Alexander K (2007) *Farmer decision making for the selection of genetics in Australian herds*. A report prepared by the University of Melbourne for Dairy Australia.

insufficient emphasis by bull breeders. This was supported by a recent collation of opinions of dairy farmers and advisers conducted by InCalf[13]. The majority of farmers providing opinions were concerned about the genetic trend towards higher milk production at the expense of other essential traits for a sustainable industry. A key trait of concern was the (perceived) decline in fertility of the genetics that are offered for sale. The Pryce report made the following comment on increasing the economic value assigned to fertility (box):

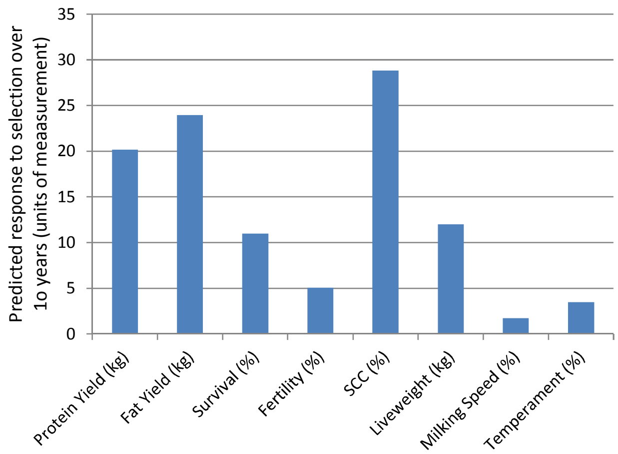
> Farmer perception is likely to be that infertility costs them more as they tend to lose their better cows and because these appear to be otherwise healthy, that this is more wasteful than cows culled for other reasons. The higher value of a cull due to infertility as opposed to another category of culling is not captured in the economic value for survival. Therefore, including culling as part of the economic value of fertility is warranted to satisfy some of the non-market value of genetic improvement of fertility. Furthermore, some of the recursive effects of infertility are not captured in the economic value, such as the shorter interval between calving and planned start of mating (in seasonal calving herds); induced calving to try and bring the calving date forward and carrying cows over to the next mating groups, which would incur more mating costs and yield losses. However, while there may be good reasons to increase the economic value of fertility further, these would be arbitrary rather than based on economics.

In other words, there may be some justification for increasing the value assigned to fertility, taking account of considerations that were not captured in their economic model.

After assessing the consequences on other traits of increasing fertility's economic weighting and finding the net effect to be relatively minor, the index coefficient assigned to fertility in the revised APR was increased three-fold, compared with the estimated economic optimum. It was predicted that using the new APR, fertility could be expected to increase by about 0.5% per year, or 5% over ten years (Figure **2**):

Figure 2. Expected trait changes over 10 years in a typical bull breeding enterprise, if selections are made using current APR weightings

[13] InCalf (2010), *Industry issues around herd fertility.*



This compares with a 28% reduction in somatic cell count, a 24kg increase in fat yield, a 20kg increase in protein yield and an 11% increase in survival.

Evidence of fertility decline – Australia

InCalf Fertility Data Project 2011

The InCalf program was initiated in 1996 by Dairy Australia (formerly Dairy Research and Development Corporation), after it was established that 70% of the variation in reproductive efficiency between farms was due to herd management issues for which there were known effective management strategies[14]. The InCalf Fertility Data Project 2011 aimed to find out if herd reproductive performance has changed over the past ten years, and to explore some possible herd and cow factors involved. The study involved collaboration with four veterinary practices which had complete reproductive records, including early pregnancy test results, for the same herds over a number of years. Records from 74 herds were included in the investigation, covering 180,000 lactations from 1997 to 2010. Of the 74 study herds, 30 had suitable data from 2000 to allow an assessment of the change in reproductive performance over the 10 years from 2000 to 2009. All herds analysed had early pregnancy testing data available (within 17 weeks of start of mating with non-pregnant cows retested at the end of mating). A summary of the results for the 2009 season is provided in Table **3**.

Table 3. Median fertility parameters for herds sampled in 2009.

Parameter	Median performance
6-week in-calf rate	50%
12-week not-in-calf rate	31%
Not-in-calf rate	20%
3-week submission rate	72%
First-service conception rate	38%
Two-period not-in-calf rate	8%
6-week in-calf rate (for second	55%

[14] http://www.dairyaustralia.com.au/Levy-investment/Improve-margins-and-growth/Farm-margin-improvement/Animal-performance/InCalf.aspx

mating period post partum)

There was large variation between mating periods and between herds for all parameters listed in Table **3**.

Risk factors identified in the original InCalf analysis[15], which was carried out using data collected between 1996 and 1998, remained important in the current analysis. Calving-to-mating-start-date was a highly influential factor in determining 6-week in-calf rate. This, along with cow ABV for daughter fertility and milk protein concentration, were linear (positive) predictors of 6-week in-calf rate and not-in-calf rates. Factors such as cow age, milk volume, fat yield, protein yield and solids yield all showed curvilinear relationships with these measures.

Breed was an important factor – in general, Holsteins had the poorest reproductive performance, Jerseys were intermediate, with crossbreds performing best. When the effects of protein concentration and yield were included in the statistical model, the differences between Holsteins and Jerseys were removed but crossbreds remained superior to both pure breeds. In other words, the superior performance of the crossbred was not associated with differences in milk production or milk composition.

Milk protein concentration was strongly associated with superior reproductive performance. This association remained when other milk production variables (such as volume, total protein yield, etc.) were accounted for; and the association was present across all breeds. This suggests that there are important metabolic pathways that influence both milk protein concentration and fertility, which are not fully understood at present. A summary of the decline in reproductive performance between 2000 and 2009, as found in the InCalf 2011 study, is provided in Table **4**.

Table 4. Linear changes in fertility parameters 2000-2009.

Parameter	**Annual change in performance***
6-week in-calf rate	-1.0%
12-week not-in-calf rate	1.1%
21-week not-in-calf rate	0.7%
Not-in-calf rate	0.6%
3-week submission rate	-0.6%
First-service conception rate	-0.7%

** from trend regression*

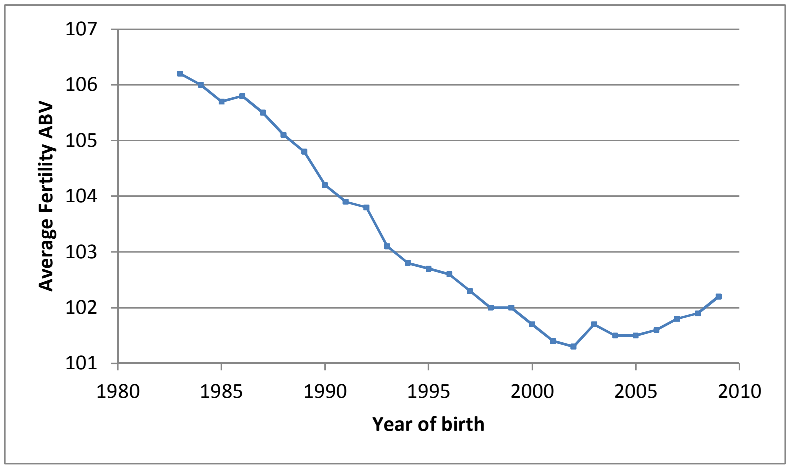
Despite the clear overall trends, there was large variation between herds within years. Variation between years was less – in general 6-week in-calf rates were reasonably repeatable between years within herd. Importantly, a few herds experienced no decline in reproductive performance across the decade.

[15] DRDC (2000) *The InCalf Project: Progress Reports No. 1 and No. 2.*

Genetic trends in Australian dairy cattle

The downwards genetic trend in fertility ABVs in the 20 years from 1983-2002 averaged about -0.28% per year for Holsteins (ADHIS unpublished). The decline appeared to reach its nadir in cows born in 2002 (Figure **3**), after which there is evidence of a slight improvement.

Figure 3. Genetic trends in fertility, for Holstein cows born in Australia 1983-2009



Notably, ADHIS introduced fertility ABVs in 2003, which happened to coincide with the reversal of the trend, whether by chance or otherwise. The genetic trend line refers to year of birth, so the mean genetic level in the national herd would lag the above figure by some years. According to Pryce et al. (2010), the average age to which a cow survives is 6.4 years (or 4.4 lactations), so the average genetic level for fertility probably only bottomed around 2008. It is unlikely that the genetic decline prior to that time could be attributed entirely to selection for productivity using the Australian Selection Index (ASI). Calculations indicate that if selection had been based on ASI alone and fertility was ignored altogether, the decline would only be about 0.1% pa. That suggests that importations of semen were probably exacerbating the downwards trend.

Other unpublished reports of changes in fertility

Discussions with veterinarians indicate that the decline in reproductive performance is general and in line with the results described in the Morton InCalf Fertility Data Project 2011 report. Western District and Gippsland veterinarians reported similar decreases in 6-week in-calf rates and increases in not-in-calf rates over the past decade from analysis of the mating data of their long-term clients.

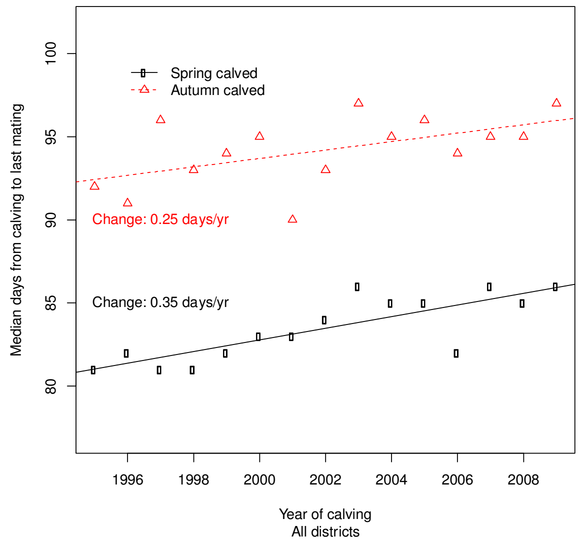
Veterinarians also reported that the animal husbandry skills of farm workers were generally declining, leading to less effective management of the herd's reproductive cycle (transition, calving, mating, etc.). In part this may be due to increasing herd sizes and a (perceived) lowering of the skill level of farm labour. Many feel that this is a major factor contributing to the reduction in herd reproductive performance. There has been a movement towards synchrony-based programs and use of fixed-time insemination programs as a means of reducing reliance on worker skills. Automating the detection of cows on heat is seen as a response to the reduction in labour quality and the increase in herd size. However this approach cannot be used to improve the detection of return services because the major synchrony tool available is prostaglandin which will cause abortion if accidentally administered to pregnant cows.

Veterinarians also mentioned that farmers no longer regard maintaining acceptable reproductive performance as imperative. This has arisen due to successful use of split calving systems and extended lactations. Motivating farmers to optimise herd reproductive performance when they have an established split-calving system is very difficult because the economic impact of moving a non-pregnant cow to the next mating period – for the first time – was not great. But, the likely long-term impact of using this practice for the majority of cows that fail to become pregnant each mating season is that individual cows will regularly (and repeatedly) change herds. The economic losses arising from these 'repeat offenders' can be difficult to visualise. Therefore unless a strict culling policy exists for these cows it is likely that the herd will gradually become less profitable as the average stage of lactation of the herd increases. Many farmers can miss this gradual loss profitability and reproductive efficiency and as a result they become less concerned about maintaining acceptable herd reproductive performance.

Analysis of insemination and calving data sourced from a large number of herds in the Western District, South Gippsland and the Macalister Irrigation District[16] indicates that the reproductive performance of both spring-calved and autumn-calved cows has declined over the past fifteen years. The median interval from calving to last recorded mating is an indicator of the rate which cows become pregnant again after calving. Most farmers aim for at least 50% of the herd to become pregnant to AI in order to produce sufficient AB replacements. Therefore this measure effectively looks at herd performance within the AB period (when heat detection is still actively undertaken). There has been a persistent yearly increase in this measure for both spring-calved and autumn-calved cows. This indicates that cows are taking longer each year to fall pregnant– see Figure **4.**

[16] Shephard RW (2011). Assessment of reproductive performance of a sample of HiCo herds (unpublished)

Figure 4. Median interval from calving to last recorded mating by season of calving and year.



Evidence of fertility decline - Rest of world

Declining dairy cow fertility in other countries is well-documented and we have not attempted to present an exhaustive account here. However, several reports are worth recounting because semen imports to Australia are significant, coming principally from USA, Canada, Europe and New Zealand[17].

- In a recent review of reproduction in high-producing dairy cows, Rodriguez-Martinez et al. (2008)[18] reported fertility declines in Holstein cattle between 1988 and 2006 of around 20% in Spain, Canada, UK and France, with lower declines of around 10-15% in Sweden and Ireland.

- In US dairy populations[19], the genetic trend in daughter pregnancy rate declined between 1960 and 1999 for all six breeds reported, ranging from about 3% in Milking Shorthorns to about 9% in Holsteins[20]; although most declines seemed to level off after about 1994. These changes were consistent with genetic parameters but only accounted for about 40% of phenotypic decline in days open, which in Holsteins increased over the same period from about 110 days to 140-155 days, depending on parity (greater in later parities).

- In New Zealand, Harris[21] presented national average statistics for the percentage of cows mated in the first 21 days and 42-day calving rate, which showed that the former was relatively stable

[17] National Herd Improvement Association of Australia Inc. – *Semen Market Survey 2010*

[18] Rodriguez-Martinez, H and 15 others (2008) *Reproductive Performance in High-producing Dairy Cows: Can We Sustain it Under Current Practice?* IVIS Reviews in Veterinary Medicine, I.V.I.S. (Ed.). International Veterinary Information Service, Ithaca NY (www.ivis.org), Last updated: 11-Dec-2008; R0108.1208

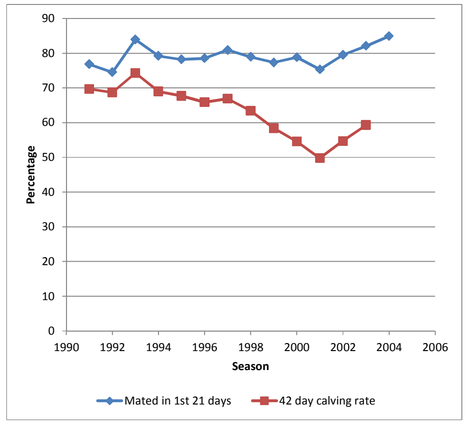
[19] P. M. VanRaden, A. H. Sanders, M. E. Tooker, R. H. Miller, H. D. Norman, M. T. Kuhn, and G. R. Wiggans (2004) *Development of a National Genetic Evaluation for Cow Fertility* J. Dairy Sci. 87:2285 http://ddr.nal.usda.gov/dspace/bitstream/10113/10275/1/IND43638175.pdf

[20] Expressed as double the changes in Predicted Transmitting Abilities

[21] Harris, B.L. (2005) *Multiple Trait Fertility Model for National Genetic Evaluation* LIC publication: http://www.aeu.org.nz/news/ACFDEA5.pdf

until about 2001, after which there was an indication of a slight increase (***Figure 5***), while the latter fell approximately 20% from 1999-2001, when it also began to increase.

Figure 5. National trends in New Zealand dairy data 1991-2004 (after Harris 2005).



These figures are averaged across breeds. Genetic trends for 42-day calving rate in Holstein-Friesians (HF), Jerseys (J) and HF x J were also shown over the same period. For HF, the average fell by about 0.6 genetic standard deviations (or about 5% in our estimation) between birth years 1990 and 1998, when the trend reversed, and about half of the loss had been regained by birth year 2003. A broadly similar genetic trend was seen in Jerseys, but with a flatter slope and later nadir; with HF x J intermediate.

Collectively, these studies show declining fertility levels in many countries over the past decades, both genetically and phenotypically. However, the phenotypic decline has been generally greater than could be explained by the genetic decline; and furthermore, there is evidence of a reversal in the genetic trends beginning some time between about 1995 and 2003, depending on the country. Arguably one of the more successful countries in addressing the problem has been Ireland, where there is general recognition that fertility is being restored: "The decline in the use of AI to breed replacement dairy stock has been halted and turned around. Recent trends in the genetic characteristics of bulls entering AI show a dramatic improvement in the key traits of production, fertility and robustness."[22]

Factors known to be important determinants of fertility

Interest in the causes of the decline in fertility in the high-producing cow has increased around the world. A primary focus on milk production in genetic selection programs last century has driven increased per cow production but this is also believed to have compromised fertility – especially in the Holstein. There is now more focus on individual traits of importance such as fertility within selection programs but many industries will be operating with a cow with sub-optimal fertility levels for a number of years to come.

[22] Irish Cattle Breeding Federation Annual Report 2010: http://www.icbf.com/publications/files/Annual_Report_2010.pdf

The impact of management changes including the trend towards larger herd sizes, more intensified nutritional management of herds, increased reliance on hired labour, do-it-yourself AI etc. have changed the operating environment for the cow. In many cases these management factors have exacerbated the fertility decline of the cow.

The key drivers of reproductive performance of the adult cow can be summarised as follows.[23,24,25]

Pre-partum and early post-partum factors

Body condition score (BCS) and negative energy balance (NEB)

- BCS is a gross measure of the nutritional and health status of the dairy cow. Cows with severe NEB after calving experience greater BCS loss in the post-partum period. The majority of dairy cows experience some BCS loss post-calving as nutrients are partitioned towards milk production.

- Cows that are in very low or very high BCS at calving or experience excessive loss of BCS post-calving typically have severe NEB. This is associated with: weaker oestrus, fewer ovulations, lower conception rates, increased calving-to-conception intervals, lower 6-week in-calf rates and increased pregnancy loss.

- Major alterations in carbohydrate and lipid metabolism occur post-partum following increased partitioning of nutrients to the udder. Growth Hormone (GH) is a principal coordinator of these processes and this drives liver production of Insulin-Like Growth Factor 1 (IGF-1). IGF-1 acts directly upon the ovary and indirectly via the hypothalamus (stimulating LH release) to promote follicle development and sex steroid production.

- High producing dairy cows are prone to excessive partitioning of carbohydrate to the mammary gland. This drives milk production but when excessive results in greater BCS loss and lower blood: glucose, insulin and IGF-1 levels. This effectively 'decouples' the somatotropic axis resulting in high GH but low (and non-responsive) IGF-1 concentrations. These cows produce smaller follicles, less oestradiol, experience more delayed ovulation/anovulation and ovulate weaker oocytes.

- There is evidence that 'gluconeogenic' diets (fed pre-mating) can reduce NEB, increase the (essential) glucose concentration and reduce the concentration of (cytotoxic) non-esterified fatty acids (NEFA) within follicular fluid resulting in healthier oocytes. This also stimulates the

[23] Leroy JLMR, Van Soom A, Goovaerts IGF, Bols PEJ. (2008) *Reduced Fertility in High-Yielding Dairy Cows: Are Oocyte and Embryo in Danger? Part I*. Reprod. Dom. Anim. **43**:612-622
[24] Leroy JLMR, Van Soom A, Goovaerts IGF, Bols PEJ. (2008) *Reduced Fertility in High-Yielding Dairy Cows: Are Oocyte and Embryo in Danger? Part II*. Reprod. Dom. Anim. **43**:623-632
[25] Walsh SW, Williams EJ, Evans ACO (2011*) A review of the causes of poor fertility in high milk producing dairy cows.* Animal Reproduction Science. **123**:127-138

resumption of normal endocrine signalling (somatropic axis) and the return of normal ovarian activity.

- Supplementing cows with specific lipid diets can assist restore the somatrotropic axis resulting in larger and healthier follicles, improve the phospholipid membrane integrity of oocytes, increase sex steroid production (esp. diets high in cholesterol) and reduce endometrial prostaglandin synthesis (esp. diets with polyunsaturated fats). Effective supplementation may yield healthier oocytes, stimulate more overt oestrus display, improve corpus luteal health and functionality and decrease embryonic loss rates.

- Diets high in rumen degradable protein (e.g. lush pasture) can result in increased levels of follicular fluid, urea and ammonia levels and these reduce the viability of the oocyte.

- Heat stress has been observed to compound the effects of excessive NEB on reproductive parameters. Heat stress is recognised as a significant factor impacting on cow health and welfare in many dairying districts of Australia.

- The dairy cow is immuno-compromised in the period commencing 2-weeks before calving to 4-weeks post calving (period of NEB).

- There is low awareness and understanding by farmers and advisers of the impact that an effective transition feeding program can have reproductive performance[13].

Metabolic disorders

- Metabolic disorders such as hypocalcaemia, hypomagnesaemia and ketosis further immuno-compromise the cow.

- Effective transition period nutritional strategies can control BCS loss, NEB and metabolic disorders with flow-on effects for subsequent fertility.

Uterine pathology and concomitant disease

- Highly immune compromised dairy cows – for example cows in severe NEB – are prone to increased levels of mastitis, metritis and other infections (e.g. foot abscess). These diseases markedly reduce the likelihood of cows becoming pregnant shortly after the start of mating.

- The endometrium in cows with metritis has increased production of luteolytic prostaglandins and this contributes to reduced conception rates and increased embryonic loss.

- Clinical disease reduces reproductive performance in affected cows dramatically.

- Resumption of normal ovarian activity is delayed in cows with peri-parturient disease.

Resumption of cyclicity

- Risk factors for delayed resumption of ovarian activity include age (heifers are at greater risk), number of days since calving, excessive BCS loss post calving, season and concurrent disease.

- Low BCS and excessive NEB result in delay and reduced frequency of pulsatile LH release with subsequent smaller follicles and less fertile ova. Delayed uterine involution, ovarian follicular activity and oestrus is common in pasture-based systems

Breeding season factors

Oestrus behaviour

- Oestrus behaviour is changing in the dairy cow. Heats are shorter with fewer mounts per heat. A key driver appears to be lower circulating levels of sex steroids (especially oestradiol) due to increased liver clearance rates rate and the production of smaller follicles and corpora lutea in cows associated with excessive NEB.

- Heat detection methods and effectiveness appear to be changing. Fewer farms use paddock detection. More visual aids such as heat-mount detectors are being used and automated systems such as pedometers are being deployed. The proportion of heats that are detected is decreasing and this may be associated with an increase in false positive diagnoses.

- The reduction in observed conception rates may be contributed to by an increase in the proportion of false positive heats detected and presented for AI. There are negative impacts of inseminating cows not on heat (false positive) – pregnant cows may abort.

Fertilisation failure

- Severe NEB impedes the growth of follicles – the concentration of NEFA within follicular fluid increases, glucose and IGF-1 decreases resulting in reduced oocyte quality and survivability post ovulation. Smaller follicles produce weaker ova with reduced fertilisation rates, slower blastocyst growth rates, reduced implantation rates and increased embryonic loss rates. Smaller follicles produce less oestradiol and become small corpora lutea which take longer to mature and produce less progesterone also reducing implantation rates.

- High producing cows have increased liver metabolism and this effectively reduces the half-life of circulating sex steroids effectively leaving them with low peak levels of oestradiol and progesterone throughout the cycle. These inadequate and imbalanced sex steroids levels and ratios reduce the window of fertilisation and can impair implantation.

- Recent Australian studies of the impact of timing of AI with respect to ovulation found that less than half of all inseminations occurred within the most fertile window of 0-16 hours before ovulation[26].

Embryo/foetal/neonatal mortality

- Severe NEB promotes the production of low quality oocytes. Severe NEB is more common in high-producing cows, which have lower levels of circulating steroids. These combine to produce delayed development in embryos.

- The first three cycles post partum of high producing dairy cows with severe NEB tend to have lower progesterone concentrations. This slows embryo development and provides inadequate progesterone priming of the endometrium. Implantation rates are lower and early embryonic loss (<24 days) rates are higher.

- Early embryonic loss (EEL) is contributed to by poor oocyte quality and failure of implantation as a result of inadequate progesterone and a hostile endometrial environment. Delayed development of the blastocyst can impair its ability to prevent luteolysis through inadequate production levels of interferon tau.

- EEL is increasing in incidence.

- Late embryonic loss (25-45 days) and foetal loss (>45 days) are less prevalent than above and primarily caused by infection and genetic abnormalities. However, endocrinological factors and management factors may also be contributing.

- Neonatal death due to dystocia and infection with agents such as E coli, salmonella, rotavirus contributes to reproductive wastage.

[26] Hockey CD et al. (2010) *Improved Prediction of Ovulation Time May Increase Pregnancy Rates to Artificial Insemination in Lactating Dairy Cattle*. Reprod. Dom. Animals. **45(**6):239-248 (doi: 10.1111/j.1439-0531.2009.01548.x)

Terms of Reference

TOR 1:	*Review current projects and programs that have the potential to improve herd reproductive performance through extension, newly emerging technology, genetics and focused fertility research so as to provide a scenario that integrates each of these aspects with their differing short to long-term horizons*

Dairy Moving Forward (DMF)

DMF is part of the National Primary Industries Research, Development and Extension Framework initiated by the Primary Industries Ministerial Council (PIMC) and is intended to be the co-ordinated and integrated pre-farm gate R,D&E strategy for the dairy industry[2].

The Animal Performance Program of DMF has identified four priority areas for RD&E:

Priority 1. Breeding herds that perform in Australian conditions

Priority 2. Improve capacity for genetic improvement through genomic and reproductive technologies

Priority 3. Overcome issues and practices which impact on cow productivity, health and welfare

Priority 4. Investigate novel approaches to improve farm productivity via animal performance

The relevance of these to dairy cow fertility can be summarised as follows:

The key objective of Priority 1 addresses the genetic supply chain so that suitable genetics for the Australian industry are available and accessible to farmers and herd managers, which encompasses information and systems to allow farmers to select genetics to meet their breeding objectives and to optimise herd reproductive performance.

Priority 2 is premised upon substantial improvements in the genetic selection of dairy cattle being achieved with use of genomic and other advanced reproductive technologies. Genomics are considered essential to provide sustainable ABVs in the future.

For Priority 3, the major themes that have relevance to dairy reproduction include heat stress, Countdown Downunder (national mastitis control program) and lameness control.

For Priority 4, the major aspects that may impact upon reproduction include maximising the benefits of automatic sensing systems and development of structures and systems for the effective automated capture and centralisation of on-farm data.

Dairy Australia

In the Dairy Australia RD&E portfolio, the **Animal Performance** and the **Feedbase** programs are expected to have greatest impact on dairy herd fertility.

Within the **Animal Performance** program the major projects of relevance that Dairy Australia fund or co-fund are discussed below.

InCalf are co-ordinating the development of an industry plan for fertility (currently in draft form) to coordinate work with the Animal Performance strategy objectives of DMF. This plan seeks to establish the current gaps in knowledge of current reproductive performance, and from within the key InCalf management areas of: transition management; bull management; heifer growth; heat detection and artificial insemination.

A recent survey of farmers and advisers was undertaken to complement the current analysis of reproductive performance[5]. The key issues identified by farmers and advisers were:

1. Body condition, nutrition and cow health – especially within the first 4-weeks of lactation and around joining and for heifers.
2. AI and natural mating – where heat detection was the major concern. Also noted were AI technique and bull management.
3. Farm systems choices – where genetics was the major issue listed. Also noted were calving systems, methods to manage high producing cows, and culling approaches.
4. The enabling environment – where people management was the major concern along with identifying issues pertaining to reproduction and the value of taking action to alter reproductive performance of the herd.

The InCalf working group has identified the following six priority areas of concern in reproduction:

1. Heat detection – this may be influenced by changes in cycle length, less overt signs of oestrus and these can be impacted by synchrony programs.
2. Artificial insemination – results may be influenced by the quality of semen used on farm and performance of technicians (especially across synchrony days).
3. Calving pattern – the importance of early pregnancy testing to assist with management decisions (induction, culling etc.) was listed.
4. Heifer rearing – the extending heifer calving pattern and the information obtained from production ratios (comparison to adult cows).
5. Body condition score and nutrition – including BCS loss, impact of transition feeding and nutritional management from calving through mating and the interpretation of milk protein concentration and fertility correlation were the primary concerns.
6. Bull management – more effective management of and use of sufficient bulls to meet herd bull power requirements was tabled as a potential issue.

Precision Farming is charged with developing farming solutions for Australia in the face of limited land, labour and water resources. This includes work in the fields of home-grown forages, automated milking systems and application of automated sensing systems to farm management.

Within the **Feedbase** program, work is focusing on development of a feed database on a regional basis that contains effective and accessible, developing improved feeding systems (that provide improved feed use efficiency), improved sub-tropical, temperate and cool-region forages.

Grains2Milk is a program to assist farmers adapt to a changing seasonal conditions, unstable pasture and water resources and increased grain feeding by managing feeding decisions. The quantity, quality, price, timing of use and utilisation of farm feed sources (including home grown and purchased) determine the profitability of dairy farms and the health of the cows. This includes information and guidelines on buying feed; fact sheets and information on how markets work, buying and feeding strategies; feed conversion theory, targets and strategies; feed budgeting and use of nutritional models; and options for efficient feeding of cows.

A key collaboration between Grains2Milk and InCalf is the development of effective transition cow management information and extension material. This has led to the recent publication: *Transition Cow Management: A review for nutritional professionals, veterinarians and advisers* by Drs Peter Degaris and Ian Lean. Recent workshops of the key issues in dairy herd fertility demonstrated that few farmers associate effective transition feeding programs with reproductive benefits and they appear unfamiliar with the transition period starts 4-6 weeks prior to dry off.

The benefits from effective transition period programs appear significant and this should be a priority area for further collaborative work*. It requires the key issues to be identified and researched, done in concert with developing and delivering effective extension material and strategies that reach to the Australian dairy farming community.*

Dairy Futures CRC

The Dairy Futures CRC aims to deliver research-based productivity gains in areas such as the development of genomically-informed breeding values (including new ABVs for valuable and desired traits), new approaches to producing and delivering sexed semen to the industry, and use of molecular breeding technologies to produce better, more productive, efficient and resilient temperate forages.

Sub-Program 2.3 of the CRC ("Trait improvement for fertility and lactation persistence") specifically addresses fertility with a stated aim to "Deliver practical genetic tools to improve fertility in the national herd". Relevant projects are:

Project 2.1.1 Optimal breeding scheme design under genomic selection

Project 2.1.4 Improving Herd Fertility Phenotypes for the Australian Dairy Herd Improvement Scheme

Project 2.2.1 10,000 Holstein Cows genomes project

Project 2.3.1 Reducing infertility and improving lactation persistence

Project 2.3.2 Genomic selection for lactation persistence (PhD project)

Project 2.3.3 Investigation of fertility by contrasting maiden heifer fertility with cow fertility (PhD project)

Project 2.3.4 Genomic analysis of herds under investigation by the InCalf project

It can be seen that the CRC's activities are well-integrated with ADHIS and InCalf. The sub-program has recently been externally reviewed[27] and as pointed out in that review, reliable genomic predictions are highly dependent upon effective systems to capture phenotypic data. Reviewers pointed to a "dearth of information in the current ADHIS system", with the consequence that ABVs for fertility have low reliability. This is illustrated in Figure **10** (page 50), which shows how many of the bulls that rank highly on APR have insufficiently reliable fertility ABVs to reach the reporting threshold. The sub-program's reviewers endorsed a genomic approach to resolving the problem, and recommended that ensuring better quality phenotypes should be a major focus. The reviewers expressed reservations about the value of major investment in the development of sophisticated phenotypes, because the over-riding need is to obtain conventional, reliable data on large numbers of animals in order to develop genomic predictions – an opinion that we share. Development of the genomic technology itself, which is happening in other parts of the CRC, was not covered by the review, but we note that the scientists developing the technology are world leaders in the field.

The reviewers noted that "While *fertility of the lactating cow* is the target, a key issue was to consider the case as to whether or not to include *heifer fertility* and *persistence of lactation* within the objective. We agree that these traits are appropriate components of the target." We are not convinced that heifer fertility is a major contributing factor to low herd fertility – the problem is largely one of the producing cow – but it does make sense to consider expression of fertility across the entire age spectrum.

ADHIS

ADHIS provides independent calculation of Australian Breeding Values (ABVs) – including genomic breeding values (ABV(g)). ADHIS also manages the breeding indexes known as the Australian Selection Index (ASI) and Australian Profit Ranking (APR) and issues publications such as the Good Bulls Guide, and web tools such as Displayabull and Selectabull.

A key priority for ADHIS is to improve data capture, coverage and further standardise the data that is received from various providers – a point raised in the previous section. The industry coverage of ADHIS data has been declining and it often relies on incomplete and potentially biased data for generating fertility ABVs. Work is under way to develop methods for improving the analytical models (e.g. Haile-Mariam 2011), but the weak link remains the quality of the data.

The lack of a proper database is also of concern and this leaves ADHIS overly reliant on the technical skills of a small number of IT and analytical experts. ADHIS is working closely with Dairy Australia and the Dairy Futures CRC to develop central, consolidated and effective data systems. These systems require the drivers of data capture and data flows to be better understood, improved approaches to delivering meaningful information from effective analysis of data to farmers and various service provider and at all levels from farm through herd improvement centres to ADHIS. Integral to this process will be the capture of necessary additional data to improve individual ABVs – including ABV(g)s and assist with analysis of herd health and productivity.

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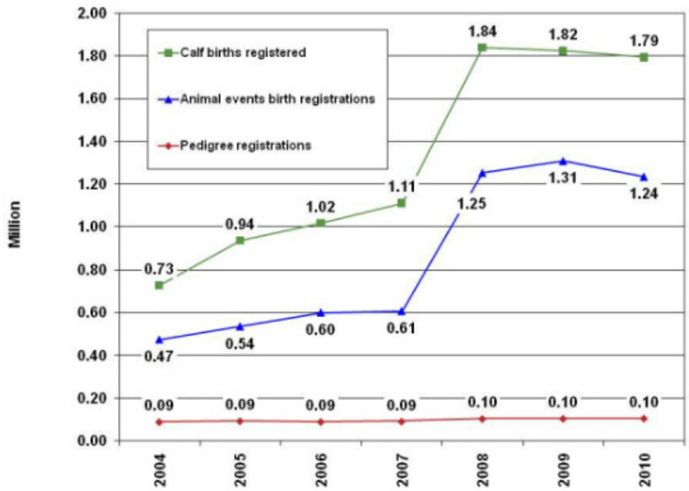
[27] *Review of Dairy Futures CRC Subprogram 2.3: Trait improvement for fertility and lactation persistence*. Prepared for Dr David Nation, Dairy Futures CRC by Peter Fennessy & Terry Hughes 21 July 2011

A major contributor to the turn-around in fertility in Irish dairy herds has been the introduction of a centralised data repository, which is claimed to capture some 90% of industry data[28] (See ***Figure 6***). This underpins the national genetic evaluation system and adds great power to genomic predictions.

Figure 6. The impact of a national dairy database on the quantity of dairy fertility data (green and blue lines) now available compared with traditional records in seedstock herds (red line)[28]



We support ongoing collaboration between ADHIS, Dairy Futures, and Dairy Australia to identify and develop an effective central consolidated data system. *The greater involvement of organisations such NHIA, companies providing in-line farm sensing systems and farm- and herd centre- software providers along with relevant IT and data management expertise is encouraged.*

Department of Primary Industries, Victoria (DPIV)

DPIV and Dairy Australia signed a Memorandum of Understanding in 2005 to provide a predictable funding base. In general, R,D&E investment decisions in DPIV are driven by four strategic outcomes[29]:

1. increasing productivity and net value
2. growing market access
3. sustaining the natural resource base
4. protecting and enhancing community resources.

DPIV's dairy priorities for 2011-12 are summarized below[30] :

[28] Source: B. Wickham (2011). "*How Ireland is Capturing the Benefits of Genomic Selection in its Cattle Population".* Presentation to Sir Mark Oliphant Livestock Genomics Conference, May 2011 http://www.mediavisionz.com.au/genomics/2011/110503-p10/index.htm

[29] Harris D. (2011). Victoria's dairy industry: An economic history of recent developments. Report prepared for the Department of Primary Industries, Victoria and Dairy Australia Ltd

[30] http://www.dpi.vic.gov.au/agriculture/dairy/dpi-services-to-dairy-farmers/services-to-dairy-farmers

Productivity

- Dairy Futures CRC – increasing the value of pastures and dairy cattle using advanced technology and genomics.
- Breeding for Performance – workshop programs conducted in conjunction with the Australian Dairy Herd Improvement Scheme (ADHIS).
- Flexible Irrigated Forage Systems – developing guidelines to help irrigation farmers select, grow and utilize forages more effectively and efficiently.
- Flexible Feeding Systems - examining the role of partial mixed-ration feeding systems.

Market and business development

- FutureDairy is a R,D&E project investigating technology and feed innovations for the dairy industry.
- Support for key extension programs such as Pasture Consumption Calculator, CowTime, Countdown Downunder and InCalf.
- Dairy Industry Farm Monitor Project – capture, analysis and interpretation of farm economic and productivity data.
- Providing extension material, information, and training for private service providers in farm management guidelines and decision-support tools related to irrigated and dryland dairy systems.

Biosecurity preparedness

- Manage disease surveillance and emergency animal disease preparedness, product integrity and traceability programs.
- Control threats from invasive plant and animal species through integrated communication, surveillance and compliance programs.

Natural resource management

- Programs supporting improved land and water management to reduce the environmental impact of dairying including
- Accounting for Nutrients on Australian Dairy Farms project - the development of nationally agreed frameworks for nutrient accounting for the dairy industry.
- Climate variability and seasonal risk information research – to support and inform the dairy industry of climate change scenarios and impacts.
- Design of lower-greenhouse-gas-emitting dairy production systems – through increased production efficiency, new forage and feeding combinations and improved animal and on-farm nitrogen management.
- Advice on and regulation of production animal welfare, including demonstration of approaches that improve dairy cattle welfare outcomes.

The preferred investment model is co-investment from industry proportional to the expected magnitude of the benefit expected from the investment. Many of the projects listed above are collaborations that are co-funded by Dairy Australia and the Gardiner Foundation.

The Flexible Feeding Systems group is investigating ways to improve pasture-based systems through better feeding of supplements. Effective supplementation systems may assist the modern dairy cow more effectively manage metabolic processes such as fertility whilst lactating.

Sydney University

Sydney University (in collaboration with the University of Queensland and SBSCibus) are proposing the establishment of a Chair in Dairy Science, with the primary objective of researching the decline in dairy cow fertility. The proposed work program will attempt to identify: superior genetics for the Australian and international dairy industry; risk factors for delayed ovulation and suppressed oestrus signs in dairy cows; environmental and nutritional 'amplifiers' of performance for dairy cows within a predominately pasture-based environment (GxE interactions) and the identification of effective nutritional strategies for management of the high-producing pasture-based dairy cow. This proposed research program will be closely integrated with international research programs in dairy cow fertility.

We commend this initiative and believe it warrants industry support. *The evidence suggests that the modern high producing dairy cow has metabolic, endocrine and nutritional imbalances. Identifying the key metabolic and endocrine pathways and relationships in order to develop effective – primarily nutritional – solutions must be the primary approach to working with the current genotype.*

Adelaide University

The Early Development Group within the Research Centre for Reproductive Health at the University of Adelaide (A/Prof Jeremy Thompson) is studying embryo health and factors associated with embryonic death in the high producing Holstein-Friesian dairy cow. We believe that the effectiveness of this program, at least as it relates to the dairy industry, may be enhanced if it was integrated, or at least co-ordinated, with R&D taking place in other dairy research organisations. Such integration is in fact one of the primary purposes for national industry RD&E plans such as Dairy Moving Forward.

Melbourne University

There is no dedicated program of research directed at dairy reproduction; rather, projects are undertaken on an opportunistic basis, depending on post-graduate availability and interest. There are several joint appointments with DPIV, notably Profs Goddard and Malcolm, who help ensure that any such activities are complementary to those taking place in DPIV.

Dr Tim Bowden has recently completed and submitted a study titled "A comparative study of the performance of New Zealand Friesian cross Holstein-Friesian cows in Victorian commercial dairy herds" as part of a Masters degree. This was a Gardiner Foundation funded project.

Dr Rebecca Dickinson – a Rural Dairy Veterinary Residents based at Warrnambool Veterinary Clinic is conducting a study investigating cow body weight and condition scores and their associations with dairy cow production and fertility on a local commercial farm. This work was funded by Dairy Australia, Gardiner Foundation and WestVic RDP.

TOR 2:	*Identify recommendations from the recent InCalf Review commissioned by Dairy Australia and conducted by Dr John Morton that justify consideration for research funding such as elucidating the nature of the strong positive association between milk protein concentration and reproductive performance on a within herd basis.*

The InCalf Report essentially has nine major recommendations. They are discussed in turn:

Research is required to identify reasons for different rates of decline (including why some herds had no decline), to prevent further decline.

We strongly support this recommendation. As we have indicated in our introduction, declining fertility levels undermine the sustainability of seasonal calving systems and may force farmers to change to split or year-round calving. While the economic consequences of this are not entirely clear, it certainly removes an element of flexibility and may be accompanied by a reduction in genetic progress. Strategies such as changing the calving system or moving to crossbreds may help ameliorate any adverse consequences of declining fertility, but unless we gain a better understanding of the causes for the decline, it is likely to continue, creating further problems. It is noteworthy from the InCalf report that some herds did not decline in fertility over the study period. This suggests to us that a detailed study of these herds is likely to be informative.

We suggest a series of case-control studies comparing the InCalf herds with high and consistent reproductive performance to herds that have experienced the typical decline in fertility over the past decade be supported. *Comparison of these high performing herds with 'typical' decline herds is likely to be more informative than comparison with herds from the lowest quartile of reproductive performance as the primary objective is to identify the cause of the industry-level decline. The InCalf study has consistently identified risk factor variables from the (limited) set of variables recorded within NatSCAN and veterinary databases. What is clear is that this set of variables is incomplete and unable to identify all of the major factors behind the decline. It is imperative that these other currently unrecorded factors that are contributing to the decline be identified as soon as practicable.*

It is expected that new explanatory variables will include herd nutritional and management practices and also management quality measures (these may be difficult to define). Therefore a working group consisting primarily of the participants (especially veterinarians) that assisted with the 2009 InCalf analysis should meet to discuss, identify, define and develop non-NatSCAN variables that may be useful predictors of the decline in herd reproductive performance. These variables should then be tested using a small-scale retrospective case-control (previous year only due to limits of farmer recall) study of the target farms. The primary objective will be to determine completeness of the variable set, the effectiveness of any surrogate variables as indicators of performance and to identify potential key variables for future studies.

Information from the analysis of the retrospective case-control study should be used to refine and adapt the variables to be recorded from a prospective case-control study using the same farms. An effective prospective case-control study should identify sufficient risk factors to explain the majority of the variation in reproductive decline (should this decline continue unabated into the current decade). Strong focus on examination of the artificial insemination period is suggested as the decline in conception rate appears pivotal in the decline in herd reproductive performance.

As a priority, potential reasons for errors causing low NatSCAN reproductive performance estimates should be investigated, and steps taken to prevent these.

NatSCAN is the national fertility statistics report for dairy cattle, which utilises the national dataset stored on the ADHIS database. It allows the fertility performance of the Australian population including classification by region, herd size, production level and many other variables. The recommendation arose because of a strong suspicion that many of the records pointing to extremely poor reproductive performance in NatSCAN, were likely to be a consequence of errors in data presented to Fertility Focus (i.e. incomplete, incorrectly formatted etc.), but this cannot be ascertained with certainty. There appears to be strong centre biases in data recording with centres varying in the proportion of captured records for individual fields such as pregnancy test results, heats and matings etc. Results from the corresponding periods based on service and re-calving data (as opposed to early pregnancy diagnoses) appeared to be more plausible.

Clearly, inconsistencies like this in the national database are a concern, particularly if they lead to unreliable information for traits of industry importance and compromise the results of ADHIS analyses.

Consequently, we agree that resolving the reasons for these inconsistencies should be undertaken. *This needs to be considered in light of the preference to move towards a central integrated database that is currently under a feasibility assessment by Dairy Australia and Harris Park.*

Nutritional strategies that enhance reproductive performance in high-producing cows should be clarified/identified.

It is apparent that while there has been a negative genetic trend in fertility over the past several decades, it has not been sufficient to account for the phenotypic decline. Other factors are clearly important, particularly our ability to provide the cow with a nutritional regime that enables her to withstand the metabolic stress associated with high levels of milk production and/or balance milk production with effective control of BCS and NEB in the period from calving to peak milk production.

Greater understanding of the interaction between milk production, cow physiological processes, ovarian function and embryo development has occurred in recent years. Whilst most of this work has focused on the high-producing Holstein cow, it seems clear that the metabolic and endocrinological pathways that have been identified demonstrate binding links between the nutritional, management and farm environment and the milk production, body condition score (BCS) and negative energy balance (NEB) response of the modern dairy cow. It is the nature of this response that determines the timing and quality of ovarian activity and the reproductive health of the cow.

There is strong evidence that severe NEB causes an uncoupling of the somatotropic axis resulting in high growth hormone (GH), low insulin-like growth factor (IGF-1), low glucose and high non-esterified fatty acid (NEFA) concentrations in blood and follicular fluid[31,32,33]. Low IGF-1 directly inhibits follicle and oocyte development at the ovarian level and indirectly by reducing the pulsatile release of luteinizing hormone (LH) by the pituitary. Low glucose levels and high NEFA concentration in follicular fluid result in production of less viable oocytes. Smaller follicles produce less sex steroids resulting in weaker oestrus displays, late/absent LH spikes (resulting in delayed/failed ovulation), delayed development and maturation of the corpus luteum post ovulation resulting in lower circulating progesterone levels in the period immediately following ovulation with subsequent increased failure of implantation and early embryo loss.

Supplementation studies[32] have shown positive effects of gluconeogenic diets on NEB and follicle/oocyte health when fed pre-mating and a positive effect of a high lipid diet (of appropriate lipid composition) fed during mating on oocyte health and viability and on endometrial health.

We recommend that studies are undertaken to identify effective nutritional management programs that are able to limit body condition score (BCS) loss and negative energy balance (NEB) in cows with high genetic merit for milk production. *This work asks if dietary management can effectively be used to redirect nutrients away from milk production towards other essential processes (thereby preserving BCS and limiting NEB) in cows of high genetic merit for milk production. Effective metabolism-modifying diets should be investigated for their impact on endocrine pathways operating at the ovarian and uterine level. Studies should extend to investigating impact on early embryonic loss. The development of nutritional supplementation strategies that can be effectively applied within grazing systems should be a key objective of this research.*

The metabolic and endocrine pathways that occur in cows with high milk production, severe NEB and excessive loss of BCS after calving appear to also impair ovarian function. These relationships may also be driving the observed relationship between milk protein concentration and fertility.

We recommend that studies to determine the causal mechanisms underlying the observed relationship between milk protein concentration and fertility be undertaken. *The mapping of the metabolic and hormonal pathways linking low milk protein concentration with lowered fertility will be important to ensure that effective strategies to increase milk protein will also assist correct the underlying metabolic and hormonal factors that produce the decline in fertility. The use of genomics to identify risk markers for cows and sires with low protein concentration and reduced fertility is recommended.*

[31] Walsh SW, Williams EJ, Evans ACO (2011) A review of the causes of poor fertility in high milk producing dairy cows. Animal Reproduction Science. 123;127-138

[32] Leroy JLMR, Van Soom A, Goovaerts IGF, Bols PEJ. (2008) *Reduced Fertility in High-Yielding Dairy Cows: Are Oocyte and Embryo in Danger? Part I.* Reprod. Dom. Anim. **43**:612-622

[33] Leroy JLMR, Van Soom A, Goovaerts IGF, Bols PEJ. (2008) *Reduced Fertility in High-Yielding Dairy Cows: Are Oocyte and Embryo in Danger? Part II*. Reprod. Dom. Anim. **43**:623-632

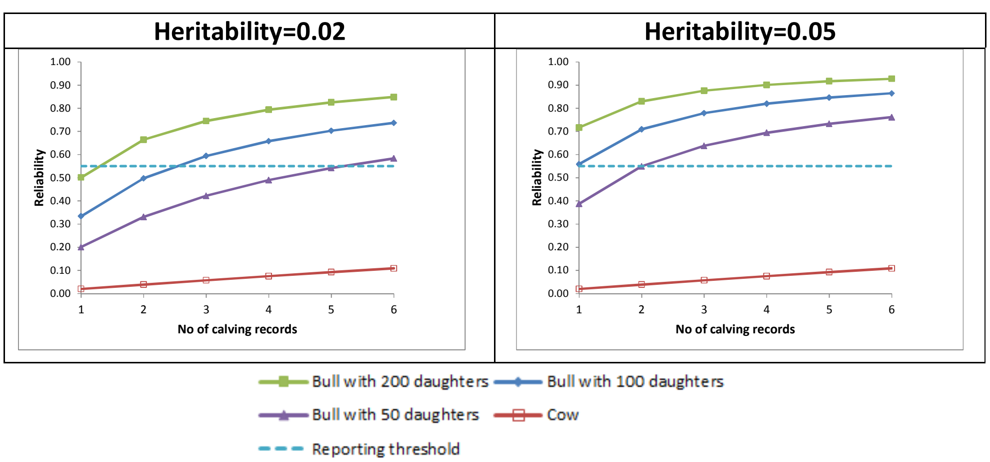
The ABV for daughter fertility is a key genetic measure and current research to improve the accuracy and timeliness of this ABV is strongly supported. There is a need for an extension package to help herd managers assess the benefits and implications of cross-breeding in a range of farming systems.

We also strongly support research to improve the accuracy and timeliness of fertility ABVs. *The InCalf report provided strong evidence that fertility ABVs are working.*

Unfortunately however, many of the bulls that currently rank highest on APR do not have Australian fertility ABVs available, as is illustrated later in Figure **10.** In fact only about a quarter of the Holstein bulls in the current Good Bulls Guide[47] have ABVs available for fertility, largely because their reliabilities have not reached the reporting threshold. Fertility is heritable but the quality of fertility records submitted to ADHIS is such that its heritability is very low; meaning that many daughter records are required before the reporting threshold of 55% reliability can be achieved. Improving the reliability of fertility ABVs can be achieved in a variety of ways:

1. Having access to better quality records has the effect of increasing the heritability, as demonstrated recently by Moser[34], who showed that having complete information on calving interval increased the trait's heritability from around 0.02 to 0.05. Figure **7** illustrates that when the heritability is 0.02, bulls with one calving record from 200 daughters will not achieve the reporting threshold for fertility – at least two calving records per daughter are needed. However, when the heritability is 0.05, a single calving record from 100 daughters (or alternatively two calving records from 50 daughters) is sufficient to achieve the threshold.

Figure 7. Effect of heritability on the number of calving records required to achieve the ADHIS reporting threshold for fertility, for varying numbers of daughter records (bulls, upper 3 curves) or own records (cows, lower curves)



[34] *"Improving the accuracy of genomic selection for fertility"* Presentation for review of Dairy Futures CRC sub-program 2.3, July 2011

2. Including additional information on correlated traits in the genetic prediction model also increases the reliability of predictions for fertility. For example, Haile-Mariam[35] recently showed, using a limited subset of ADHIS data, that joint analyses of calving interval with other traits such as milk yield, survival and lactation length effectively doubled the heritability of calving interval compared with a single trait analyses.

3. As pointed out later on page 49, genomic information can be, and is being, used to augment progeny test information to increase the reliability of fertility ABVs.

4. A process is available whereby international ABVs can be derived by Interbull for bulls with overseas proofs, denoted ABV(i). Interbull currently produces fertility breeding values for 18 countries[36], but not for Australia. Further work is necessary before fertility ABV(i) can be produced routinely for Australia, but there may be an argument for publishing trial fertility ABVs for Australia[37] based on overseas information. USDA, for example, provides tables for converting overseas breeding values to US PTAs for bulls that don't have the required Interbull estimates available[38]. Similar conversion tables could be used to provide trial fertility ABVs to Australian dairy farmers, based on the best information currently available.

5. We also acknowledge the need for an extension package to help farmers assess the benefits and implications of crossbreeding. Heterosis for fertility in dairy cows has been adequately demonstrated e.g. in New Zealand, compared with the mean of the parental purebreds, Holstein-Friesian x Jersey crosses had about 3% more mated at 21 days and 2% more calved in the first 42 days[21]. The survey of Victorian dairy farmers by Watson[39] in 2004 found that whilst there was a reasonable understanding of the pros and cons of a crossbred herd, the majority of respondents felt that more information was needed to assist in decision-making. Crossbreeding can potentially have wide-ranging consequences on-farm, affecting, as noted by Malcolm and Grainger[40]:
   - Conversion of farm energy supply to particular quantity and quality of saleable product
   - Choice of farm system
   - Herd reproduction performance
   - Animal health
   - Herd age structure and dynamics

In a benefit-cost study that considered such variables, these authors concluded that some Victorian dairy farm systems currently operating as Holstein-Friesian systems there is likely to be some advantage in changing to Holstein-Friesian x Jersey crossbred dairy systems. They concluded that:

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[35] Haile-Mariam (2011) *Comparison of reproductive performance of cows based on "well-recorded" data and ADHIS data.* Unpublished paper presented to the ADHIS Genetic Committee, March 2011.

[36] http://www-interbull.slu.se/Female_fert/framesida-fert.htm

[37] BREEDPLAN, the national genetic evaluation system for beef cattle, releases trial EBVs for traits still under development but are provided to breeders under a "user beware" caveat., generally because they are in demand. e.g. http://breedplan.une.edu.au/tips/Understanding%20Trial%20Structural%20Soundness%20EBVs.pdf

[38] http://aipl.arsusda.gov/reference/ib/convinfo.html

[39] *"A comparative study of the productivity, selected health parameters and reproductive performance of Holstein Friesian x Jersey crossbred cows in Victorian pasture based seasonal calving herds"*: Dairy Farmer Survey Conducted for NHIA, July 2004

[40] NHIA report (2004): *Benefit Cost Study of Increased Holstein-Friesian Jersey Crossbred Dairying in Victoria* http://www.nhia.org.au/files/Ben_cost_altering_breed_comp.pdf

"there certainly seems to be sufficient (promise) in the idea of HFxJ dairying to warrant further rigorous, and thorough, investigation."

We support the recommendation for development of effective, clear and consistent extension material for farmers to allow them to assess the benefits and implications of crossbreeding programs within their herds.

However, as pointed out by Rodriguez-Martinez (2008)[18] for example, it is important to recognise that cross-breeding is not *per se* genetic improvement and that genetic selection is still needed within the breeds used; unless of course the cross is fixed, such as has been done with the Kiwi-Cross in New Zealand[21].

An extension tool is required to help herd managers explore various culling strategies; this tool should incorporate effects on herd age structure and calving pattern, and consequent effects on herd reproductive performance and profitability.

Farmers need information and structured systems to help them decide the most appropriate management pathway for cows within their herd. They are faced with decisions about culling and retention based on information such as the age of the cow, stage of lactation, pregnancy status and the cow's production level.

The correct decision is not always obvious, as it impacted by many factors. The value of an individual cow at any point in time can be estimated from her expected lifetime income and lifetime costs. Her ability to produce milk and provide replacement calves will depend upon her age, her pregnancy status (and expected calving time) and production potential (genetic merit). A cow pregnant early in the mating season can be expected to produce more milk and is more likely to become pregnant again and to calve early in the subsequent calving season (i.e. have greater survival) than a cow that does not meet these criteria. Her lifetime profitability will be greater and therefore her current value is greater than empty or late cows, or cows undergoing extended lactation as they shift from one calving period to the next. Decisions to retain but move non-pregnant or late cows to the next mating period in split calving systems will result in a change to her income and cost and survival profile.

Systems based upon determining the projected lifetime value of the cow given genetic, production and recent fertility performance may assist farmers make rational decisions on retention and culling of cows that do not have optimal fertility. ***We therefore recommend that approaches such as this are researched and refined and workshopped with industry to assess their usefulness, coverage, ease of use and acceptance by farmers and industry.***

Most of the required transition probabilities have been or can be derived from the InCalf data and industry databases (such as herd recording centre databases). The effectiveness of such an approach will require careful research, development and extension to ensure that there is an adequate balance between the complex economic concepts and calculations that drive the process and ensuring the process is understood, accepted by and readily used by farmers. However, the benefits are likely to be worthwhile and consequently we support this recommendation.

The estimated effects of increased ABV for fertility on 6-week in-calf rates are greater than theoretically expected, possibly due to some form of bias. Further investigations could explore potential causes of this.

The method used in this report for estimating the cows' expected fertility ABVs was calculated 2/3 ABV_{Sire} + 1/3 ABV_{MGS}, where is the ABV_{Sire} of the cow's sire and ABV_{MGS} is the ABV of the cow's maternal grand-sire. An unbiased estimate, if the maternal grand-dam's (MGD) ABV was also known would be ½ ABV_{Sire} + ¼ ABV_{MGS} + ¼ ABV_{MGD}. However, estimated breeding values for cows have a very low reliability and are generally not computed, hence the simplification. The discrepancy caused by the approximation is 1/6 ABV_{Sire} + 1/12 ABV_{MGS} - ¼ ABV_{MGD}. This amount would need to be subtracted from the ABVs used in the report to make them equal to their true expectation. If we hypothesize a negative genetic trend over time, then on average, the fertility ABVs for both grand-parents in the equation would be greater than the ABV for the sire. Thus the correction factor would be slightly negative, which means that the estimated ABVs used in the report may be a little smaller than they should be (i.e. they may need to have a negative amount subtracted from them, or a small amount added). However, that should not affect the issue of differences being greater across ABV categories than expected, because there is no obvious reason to believe that the correction factor should be greater at one end of the scale than the other.

One could speculate that farmers who were concerned about fertility and purchased semen with higher ABVs for fertility, might also implement management strategies that are also aimed at improving fertility. However, herd effects were fitted to the analytical model so if there were herd-level biases of this nature, they should have been removed in the analysis.

Consequently, it does appear from this report that the differences in cow fertility due to their ancestors' ABVs are greater than would be predicted from the genetic model. When this happens, it can be an indication that the heritability assumed in the genetic model is too low and should be increased. However, analyses of data sets similar to that used in this report have produced heritability estimates of the same order as that assumed in ADHIS, e.g. Moser (2011)[34]. There are plans to estimate heritabilities from the InCalf data set used in this report (Haile-Mariam, *pers comm*) and the results may help shed some light on the reason for the large effect found in this analysis. However, it should be recognised that not many bulls have reliable ABVs for fertility now (shown later in Figure **10**), so it is likely that the ABVs computed for the cows had very high standard errors. Therefore a possible explanation for the apparent anomaly is one of sampling error, rather than some kind of bias. Even though the computed ABVs may actually have been slightly biased, this should not have affected the regression of offspring performance on ancestral ABV to any great degree.

As herd managers are usually primarily interested in herd performance, these results [refers to early calving, protein concentration and fertility ABV] could be a useful support for extension messages.

The study found that in-calf rates were higher in mating periods with higher percentages of cows that calved in the first 6 weeks, herds with higher average milk protein concentrations and higher average 305-day milk solids. In contrast, no consistent associations were found between fertility and herd average ABVs for milk volume, fat or protein yield, or for herd size. We agree that these results do help identify the circumstances under which herd fertility is likely to be higher. However, the associations do not provide a practical solution for herd managers who are faced with low fertility in their cows. Consequently, it isn't obvious to us that these results can provide support for extension messages unless they are accompanied by clear guidelines on how the required performance levels can be achieved. Without detailed understanding of the relationship between milk protein concentration in milk and fertility (and by implication, the effectiveness of various management and nutritional approaches to increasing milk protein concentration on fertility) it will be difficult to use this information to guide and direct management.

We recommend that any extension material and messages based upon the relationship between milk protein concentration and fertility be restricted to describing low protein concentration as a risk factor for low fertility (e.g. as a risk factor for low oestrus detection rate) until the true underlying causal associations have been clearly defined. *Nutritional approaches to increasing milk protein concentration may not be effective at increasing cow fertility if the milk concentration association with fertility is shown primarily to be a confounder.*

The importance of increasing calving to mating start date intervals to improve herd reproductive performance should be a key focus of extension programs. Practical strategies to do this without use of calving induction should be promoted.

Without resorting to calving induction, the only effective way to increase the interval from the calving to mating start date (in the future) is to mate late-calving cows as soon as practicable after calving. Reproductive interventions using progesterone releasing devices, GnRH and prostaglandin combinations can allow all treated cows to be submitted for AI within 10 days of initiation of treatment. However these systems are not perfect. The proportion of cows responding to prostaglandin with oestrus displays is variable[41]. These treatments, if effective, may provide increased risk of early embryonic loss (EEL) / late embryonic loss (LEL) rates in cows with abnormal ovarian, uterine and endocrine environments. A key consequence arising from EEL/LEL is delayed return to service arising (in part) from partial signalling of implantation by the embryo before loss. This partial signalling can prevent the cow from future oestrus displays in the false belief that she is pregnant. The end result is further delay to resumption of cycling activity and increased risk remaining empty at the end of the mating period or of extending the inter-calving interval beyond 365 days in an already late cow.

Systems to manage known risk factors for implantation failure and EEL/LEL (such as NEB) will be essential to ensure acceptable results. We agree that reducing the calving to mating start date interval is critically important and that practical strategies for doing this should be promoted. ***Therefore we recommend that research into EEL/LEL continue and that risk factors (e.g. low milk protein concentration) be better defined and – if possible – the probability distribution for EEL/LEL***

[41] Macmillan KL (2010). *Recent Advances in the Synchronization of Estrus and Ovulation Dairy Cows*. J. Reprod. Dev. **56**(Suppl.):S42-S47

at various intervals from calving to mating be mapped. *This information may assist farmers and advisers use strategic hormonal synchrony programs more effectively. The expected range of results and implications from use of systems to promote early mating of cows need to be elucidated and clearly presented to the industry.*

The decline in fertility should be monitored and if it continues, research instituted to identify major causes of this decline, to inform future research and extension.

Given the importance of fertility in herd management and long-term productivity, it is essential that such trends are monitored. However, as pointed out earlier, this requires a reliable source of data and the current NatSCAN dataset appears to have deficiencies that should be rectified. The InCalf report suggests that a detailed prospective monitoring project may be a useful approach and section 0 of this report indicates some aspects that we consider are worth exploring.

TOR 3: Review and recommend structures that encourage stakeholder engagement and strategies in the Australian dairy industry that facilitate improved herd reproductive performance (such as considering the re-establishment of a National InCalf Management Committee, possibly having similarities to the National Mastitis Management Committee or to the board of the Flexible Dairy Systems Program)

The Australian InCalf project has been recognised as an excellent national model for monitoring, analysing and correcting deficiencies within dairy herds[42]. However, the analysis and interpretation of herd reproductive data leading to effective interventions to improve herd reproductive performance has not progressed at the desirable rate within the industry. To date approximately 300 advisers and 300 farmers have completed the respective adviser training and farmer training courses (and no adviser course has been run in the past four years). Many advisers who completed the course were also not directly in a position to work with commercial farms and assist them with their reproductive programs (e.g. milk factory field reps, drug company technical staff, etc.) and no adviser courses have been run in the past four years. There has been a lack of industry coverage and loss of momentum in building the adviser network. We have a sense that this apparent loss of InCalf's momentum and effectiveness may be partly attributed to incomplete engagement with the entire range of stakeholders in dairy reproduction. Consequently, it could benefit from an industry steering committee, which would include representatives from organisations such as herd test centres, private semen importers and sellers, the wider research community, etc.

In the same vein, a 2007 review of the InCalf program by Dairy Australia (unpublished) suggested that the science that underpins InCalf was not effectively penetrating at adviser and farmer levels. The many inter-dependencies within the reproductive cycle was also perceived as a barrier for both farmers and advisers in the development of farm-level programs for improving reproduction; many advisers did not feel competent or comfortable advising farmers in areas outside their direct area of expertise. The complicated and time-dependent nature of the reproductive cycle may also contribute to difficulties in starting effective herd reproductive management programs.

Effective intervention is typically preceded by timely data analysis of historical herd performance. Variations between herds in the completeness of reproductive data sets and the wide range of herd data repositories (paper systems, various software systems, etc.) used often makes the first step – collection and collation of herd reproductive data an off-putting step for the adviser. Many advisers also had difficulty in visualising effective ways of incorporating herd reproductive consultancy services into their business. This should be contrasted with information-based services that a large number of New Zealand dairy veterinary practices provide to their clients. The InfoVet™ system[43] collates relevant farm-level data from a wide range of sources (milk factory, herd recording centre, veterinary centre) and this information is available on-line for analysis and examination by farm consultants, advisers and veterinarians (including on farm). New Zealand veterinarians are increasingly using InfoVet™ in a pro-active manner to monitor herd performance in mastitis, milk

[42] Lucy MC (2001). *Reproductive Loss in High-Producing Dairy Cattle: Where Will It End?* J. Dairy Sci. 84:1277-1293
[43] http://www.infovet.co.nz

quality and reproduction. A key quoted feature of this system is the centralisation of data thereby preventing the need to 'chase down bits of paper at critical times'[43].

Herd Fertility Focus reports – a standardised and automated report on herd fertility performance available from many data processing centres and farm software systems – is under-utilised by both farmers and advisers. Few farmers and advisers routinely request these reports suggesting that just providing information to farmers is not enough. An active network of competent advisers is required to assist farmers both recognise problems within their herds and to take (and monitor) corrective action.

The current thinking by the InCalf team is that the dairy industry needs approximately 30 active and complete 'power' advisers who are highly skilled at analysing, diagnosing, intervening and monitoring herd reproductive performance. These super-advisers would typically be highly experienced veterinarians. Other advisers should be encouraged to provide relevant advice from within their sphere of expertise. For this group, focused material is required that is directed and relevant to the target audiences. For example, stock and station agents should be made familiar with the concept of bull power (hence *Bulls: Power up!* resource was developed).

We support these initiatives and make the following specific recommendations:

1. ***Adviser workshops should restart.*** *The population of capable and active advisers must be increased throughout the industry. This should include attempts to engage inactive advisers by specifically identifying and addressing their requirements. This may require the development of refresher courses as new material and knowledge is integrated into the existing knowledge base (e.g. transition feeding, selecting for fertility, genomics)*

2. ***Adviser-focused material that can guide the systematic investigation of problem herds will be required (as recommended by recent InCalf reviews).*** *This should include material describing a standardised approach to investigating a herd problem and sections on collection and collation of data from various sources and recommended analyses using both stand-alone herd software programs as well as spreadsheets/statistical programs. This could extend to basic data collection, cleaning and processing with examples from the varied data sources used within the industry to capture reproductive data.*

Dairy reproduction is complex. There are many stakeholders operating from the level of the individual farm through to whole of industry – each with their own imperatives, planning horizons, restrictions and objectives. ***We recommend the formation of an active Industry Advisory Group to meet regularly to assist in the prioritisation, coordination and review of activities aimed at reversing the decline in cow fertility.*** This group must represent all relevant stakeholders and take responsibility for developing a clear, consistent and coordinated industry response that can meet short-, medium- and long-term objectives and work within resource constraints as efficiently as possible.

TOR 4:	*Review current and alternative methods for measuring or estimating herd reproductive performance that may not rely on pregnancy testing (e.g. herd calving pattern; daughter calving rate) and that could be used in seasonal calving and split-calving herds as well as for deriving sire ABV's for fertility*

As a minimum, three pieces of information are needed to assess a cow's fertility:

a) Whether or not she was mated/inseminated
b) Whether she subsequently began lactating; and
c) If she isn't recorded as having lactated, whether she was diagnosed as being pregnant or not.

ADHIS analyses for fertility are based on calving interval (CI). Six-week in-calf rate is the fertility measure recommended in Australia by the In-calf Project (DRDC, 2000) and it is the trait included in the breeding objective (APR). However, data on six-week In-calf rate are not readily available and the proportion of cows with any pregnancy test data in the current ADHIS database is only about 2% (Haile-Mariam, unpublished); even though it is thought that usable pregnancy test data (i.e. early pregnancy tests with follow-up for non-pregnant cows) actually exists in some form for approximately half the herds and cows in the industry.

At present, most records entering the ADHIS database are incomplete. Nulliparous cows that are mated but fail to subsequently calve, will only enter the database if they are retained and conceive successfully in a subsequent mating season. If they are culled, or are retained and remain barren, they will generally not have a CI record. Similarly, there will be ambiguity for older cows that failed to calve to a particular mating, unless she conceives successfully at a subsequent mating, in which case her previous failure can be inferred. If however she is culled on the basis of pregnancy diagnosis, this inference cannot be drawn. In this instance, her CI record will only be correct if the results of pregnancy testing or reasons for culling are supplied. There may be an increasing trend to withhold high producing cows from mating until they have been calved for a sufficiently long period (i.e. beyond the traditional herd mating start date). These cows will have a semi-artificial increase to the CI and this may affect certain bull ABVs.

A recent study has shown that cows that are not pregnant 6 weeks after the start of the mating period, are twice likely to be culled and not have a CI record, than an average cow (Haile-Mariam, unpublished). The study was based on about 4600 cows, each with a single record, and from 22 relatively well-recorded herds, both seasonal and split-calving. Analyses showed that using censored (incomplete) data resulted in the heritability of fertility being lower than when complete records were available. This was discussed earlier in section 1 (the study by Moser[34] used the same data set). The study also found that changing the definition of fertility from interval traits (such as calving to first service and CI) to submission rate or in-calf rate did not have any advantage in terms genetic variance or heritability. Joint analysis of CI with other traits such as milk yield, survival and lactation length increased the heritability of CI as compared to a single trait analyses and this approach shows some promise.

Although it possible to make inferences about a cow's reproductive performance from indirect measures such as persistence of lactation or longevity, we cannot escape the conclusion that for estimating sire AVBs for fertility, what is required is direct information on daughters' mating date and subsequent calving status. Farmers (and possibly their consulting veterinarians) will have this information but much of it is not reaching the ADHIS database. Ireland (albeit in a more intensive production environment and with regulatory requirements imposed upon it) has made massive improvements on the quality and quantity of reproductive data that is centrally stored and accessible for genetic and genomic evaluation – see earlier discussion on page 31 and ***Figure 6***. A dramatic increase in data collection in that country has been largely facilitated by the use of interactive data loggers by farmers, AI technicians and veterinarians. As pointed out by Fennessy and Hughes[27], recording of AI information on hand-held devices has enabled:

- Analyses of insemination and pregnancy data to help identify early predictors of lifetime fertility.
- Development of inbreeding and lethal gene checks with feedback in the field
- Provision of sire advice to farmers
- Provision of fertility management reports for farmers

Australia would clearly benefit by adopting a similar system, particularly in the context of declining participation in herd testing and veterinary records not finding their way into the ADHIS database. This, in fact, was one of four options identified in a recent review of current and potential future data arrangements in the Australian dairy industry, commissioned by a NHIA Dairy Industry Working Group[44]. ***We recommend that the various options be costed and that subject to a favourable cost-benefit analysis, work initiated to develop an appropriate working system.***

[44] National Herd Improvement Association Dairy Industry Data Working Group - *Report for NHIA Dairy Industry Data Project* Final Report July 2010

TOR 5:	*Identify likely outcomes on herd productivity, calving patterns and replacement rates if average herd reproductive performance as shown in the recent InCalf Review does not improve significantly by 2021*

Maas et al. (2009)[45] modelled the UK herd and estimated that the current trend would lead the national dairy herd to be unsustainable due to increasing calving intervals and reduced fertility in as few as 10 years. A similar modelling exercise has not been conducted in Australia, but the likely outcome is reasonably obvious: simple extrapolation of the trends shown in Table 1 and Table 4 suggest the following seasonal herd parameters would exist in 2020 and 2030 should the decline continue unabated (

Table 5). By approximately 2025, the spring-mated herd would cease to become viable, with as many empty cows as pregnant cows after 12 weeks of mating. This is clearly incompatible with the primary objective of the seasonal system – the calving of cows to match seasonal pasture supply – thereby questioning the logic of persisting with such practices.

Table 5: Seasonal herd fertility decline projection trend (based on InCalf analyses to 2000 and to 2009[5])

Parameter	Trend (p.a.)	2000*	2009*	2020#	2030#
6-week in-calf rate	-1.00%	53%	49%	34%	24%
12-week not-in-calf rate	1.10%	27%	34%	58%	70%
21-week not-in-calf rate	0.70%	15%	21%	30%	37%
Not-in-calf rate	0.60%	14%	18%	27%	32%
3-week submission rate	-0.60%	68%	71%	59%	53%
First-service conception rate	-0.70%	44%	38%	31%	25%

** - Actual performance (from InCalf analyses). # - Projected performance from trend regression*

Key implications from these projections are:

1. The ability of the seasonal herd to produce sufficient replacement heifers (calves born within the first 6-weeks of the mating period) is seriously compromised. Given usual targets of 25% replacements born each mating period this has already become difficult to achieve with AI using unsexed semen. By 2020 only 17% artificially bred (AB) replacements may be achieved by 6-weeks into calving (without use of sexed semen). This trend may force farmers to keep heifer calves from the second mating period as replacements. Assuming the long-term average 6-week in-calf rate for the second mating period is 55% the maximum herd AB replacement rate can be estimated by the formula: Replacements = 0.5 * (6-week in-calf rate + 0.55 * not-in-calf rate). This estimates the maximum herd AB replacement rates of 29.5%, 24.4%, and 20.8% for 2009, 2020 and 2030 respectively. Reduction in the AB replacement rate below 25% is likely within the next ten years without improvements in herd baseline fertility or increased use sexed semen. A

[45] James A. Maas, Philip C. Garnsworthy, Anthony P.F. Flint (2009) *Modelling responses to nutritional, endocrine and genetic strategies to increase fertility in the UK dairy herd,* The Veterinary Journal **180**(3):356-362

potentially more serious consequence of the declining replacement rate is the increased retention of calves from natural matings to meet shortfalls.

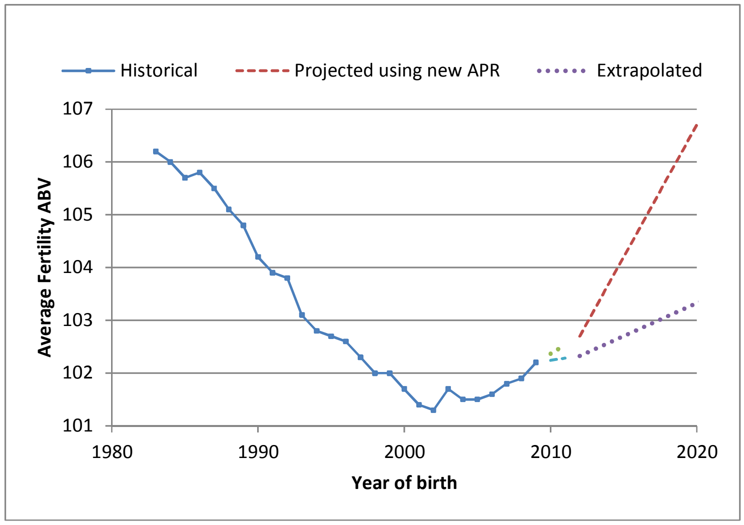
2. The average lactation length will continue to increase. This is estimated to increase to approximately 340, 390, and 410 days for 2009, 2020 and 2030 respectively. As the average lactation length extends beyond 305 days (assuming a 60 day dry period) the ability to match herd lactation energy demand to pasture growth becomes more difficult. Examining the ratio of highest to lowest herd monthly feed demand across a year provides a measure of the changes to the pattern of milking herd feed demand over time. This ratio was estimated at 1.48 for 2009, declining to 1.37 in 2020 and 1.33 in 2040 indicating a clear decline in seasonal milking herd demand. The continual movement of this ratio towards unity may influence many farmers to move away from seasonal calving systems.

Expected genetic trend in fertility

If gains in fertility of 0.5% pa as predicted by Pryce et al. (2010) could be realised, fertility ABVs for bulls in 2020 could be restored to levels seen around 1980 ("Projected" in Figure **8**). However, such gains are unlikely to be achieved in practice unless there are other changes. Collectively, the trait gains illustrated in Figure **2** sum to an annual gain of $23.09 per cow. This compares with an estimated annual gain of $23.52 per cow with the previous APR coefficients, which had different trait emphases. Goddard (2005)[46] indicated that the actual APR gain was about $6 per year, which is a little over one quarter of the theoretical potential. If this "selection efficiency" continued into the future and gains were distributed across the traits in proportion to their contribution to the index, the potential figure of 5% over ten years calculated by Pryce et al. (2010) would decline to something more like 1.25%, which would result in the lower trend ("Extrapolated") portrayed in Figure **8***.*

Figure 8. Past and possible future genetic trends in fertility, if selection is based either solely on APR (projected) or using historical selection efficiency (extrapolated).

[46] Goddard, M.E. *R&D plan for dairy cattle genetic improvement* Final Report DAV11989. July 2005, Dairy Australia 2005

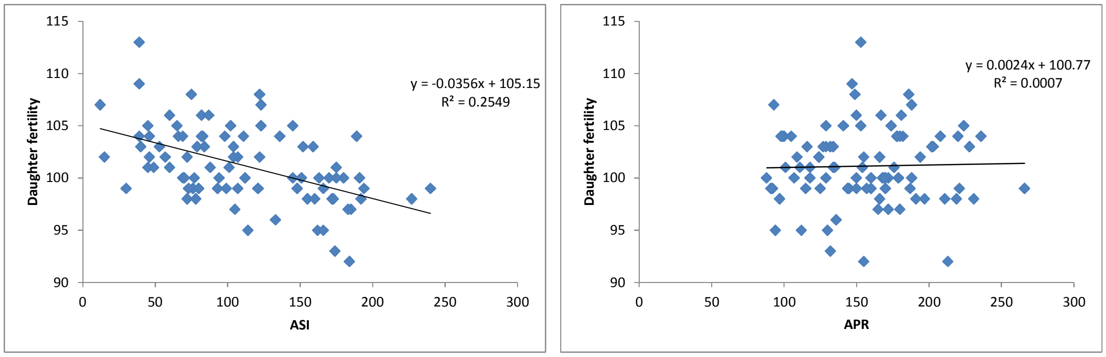


However, this is an over-simplification because it really only applies to a herd that is sitting on the current average and the owner is making informed, within-herd decisions about bull selections. In practice, semen buyers can take advantage of across-herd variation in fertility as well. Unfortunately, however, fertility ABVs are not available for all bulls listed in the Good Bulls Guide published by ADHIS. For example in the August 2011 edition, there are 337 Holstein bulls listed, but only 91 of them have Australian fertility ABVs available[47]. (Notably, 25 of the 91 managed to reach the required reliability for fertility because they had genomic information available.)

It is relevant to examine the relationship between production and fertility in these 91 bulls, as the distributions capture both within- and across-herd genetic variation. The left plot in Figure **9** shows that if bulls are chosen purely on ASI, which only accounts for milk, protein and fat, then those with lower fertility will tend to rank more highly. However, if they are chosen on the current APR, then there is a very slight tendency for higher fertility bulls to be identified (right plot in Figure **9**). Certainly there appear to be high-ranking bulls on APR with above-average fertility ABVs. This indicates that across-herd relationships are not dissimilar to within-herd relationships. It also indicates that farmers could achieve a genetic boost in the fertility of their herd by selecting bulls that rate highly for APR <u>and</u> rate highly for fertility.

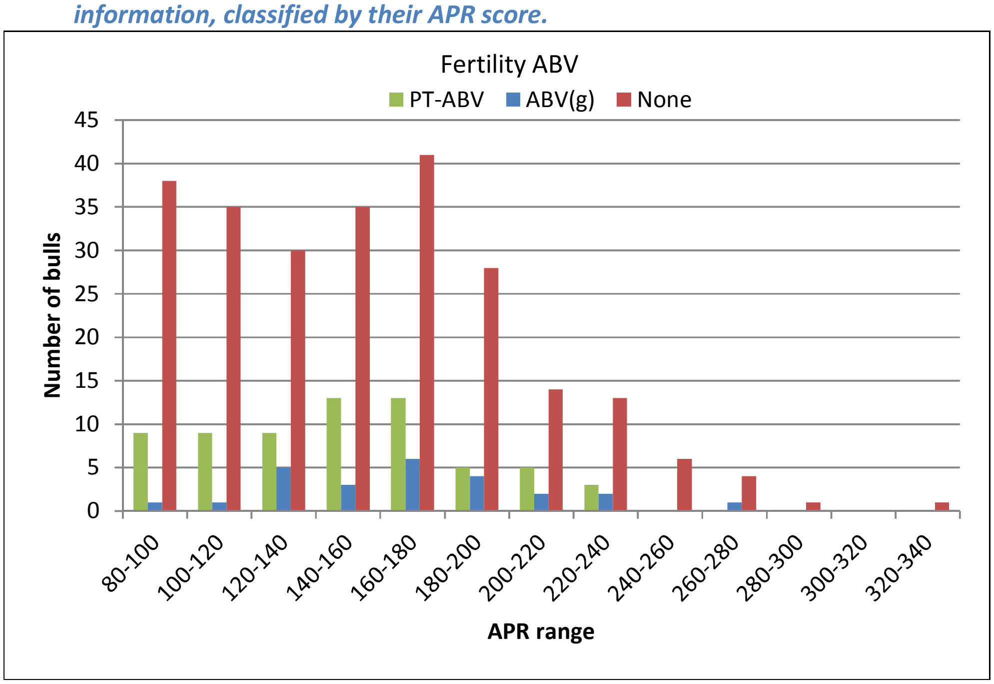
Figure 9. Scatter plots showing relationships between fertility ABVs for Holstein bulls with ASI (left plot) and APR (right plot).

[47] http://www.adhis.com.au/v2/downv2.nsf/0/00b965958e84c1e6ca257906002e9f9c?open Downloadable file GBG_Hol.xls



Unfortunately, however, there are many bulls with high APRs that do not have a fertility ABV. These can be clearly seen in Figure **10**.

Figure 10. Frequency histograms of Holstein bulls with either no fertility ABV, with a fertility ABV derived from progeny tests, or with a fertility ABV augmented by genomic information, classified by their APR score.



Thus many of the most highly-ranked Holstein bulls, based on APR, do not have fertility information available, or at least not sufficiently reliable information to warrant reporting. Figure **9** suggests that some of these could have quite low breeding values for fertility and therefore represent a potential risk. The great majority (84%) of bulls with no fertility ABVs have international proofs and are not proven in Australia.

In summary, the following conclusions can be drawn about the prospective genetic level of fertility in the national dairy herd at the end of this decade:

- If bull breeders selected their bulls using the current APR, then genetic levels for cow fertility in their herds could be restored to levels approximating those of 1980 (about 5% above the current level)

- However, not all selection pressure has applied simply to APR and unless there is a change in philosophy, realised gains in fertility will only be about one quarter of what is achievable using conventional technology.
- Nevertheless, the range in fertility ABVs indicates that many farmers could probably achieve a relatively rapid lift in their herd's genetic level for fertility now, by simply identifying bulls with the right combination of APR and fertility ABV.
- Genetic gains in fertility are likely to be grossly sub-optimal unless there is an effort to increase the reliability of fertility ABVs. This is necessary if the majority of bulls are to have their fertility ABVs published.
- Genomic technology has the potential to a) help more bulls attain the reporting threshold for fertility; and b) increase rates of genetic gain in fertility.
- Although the above discussion has drawn on information available for Holsteins, similar conclusions are likely to apply to other breeds.

Further recommendations

Improved phenotype recording

This relates to an earlier recommendation on options for improved data collection (page 46). The proportion of herds undertaking herd recording is declining. Fewer than 50% of farms and cows are currently herd recorded. Anecdotal evidence suggests that somatic cell count information is the primary reason for most farmers continuing to herd test – this also implies that the majority of herd testing farmers are either not aware of or not using the range of information available from herd test reports. The use of Teatseal™ is rapidly increasing throughout the industry. Teatseal ™ is an intramammary preparation that is used at dry off. Once inside the teat the formulation provides an effective physical barrier at the teat canal thereby reducing new infections throughout the dry period[48] until the material is ejected from the teat shortly after calving. This is a preventive that is used as a blanket herd treatment that reduces the risk of infections in the dry period and reduces the incidence of new infections in the subsequent lactation[49]. Teatseal™ has reduced the bulk milk somatic cell count (BMCC) and the incidence of mastitis within many herds. This combined with the recommended usage as a blanket treatment is further reducing the incentive of farmers to continue herd testing[50]; the industry is highly exposed to major reductions in the proportion of herds and cows that are herd tested.

This also suggests that should cost-effective alternative methods of measuring cow somatic cell count (e.g. in-line metering) be developed then this may result in the loss of a significant proportion of current herd testing farms with associated loss of cow phenotypic information obtained from herd testing (volume, components etc.). The herd recording industry is vulnerable to the impact of a disruptive technology such as in-line sensing (eg Seonsortec's YieldSense™ and CellSense™ systems,

[48] Woolford MW et al. (1998). *The prophylactic effect of a teat sealer on bovine mastitis during the dry period and the following lactation*. NZ Vet. J. **46**:12-19
[49] Runciman DJ, Malmo J, Deighton M (2010). *The use of an internal teat sealant in combination with cloxacilling dry cow therapy for the prevention of clinical and subclinical mastitis in seasonal calving dairy cows*. J. Dairy Sci. **93**:4582-4581
[50] Brightling P (pers. comm.)

De Laval's Herd Navigator^{TM} system and GEA's Sensoric^{TM} system). Automated systems offer farmers opportunity to automatically record essential management information in a more efficient and less disruptive manner compared to traditional flask-based herd testing. Many farmers at HiCo have stated that without ability to conduct herd testing from a single milking (a facility recently made available from use of TruTest electronic milk meters with appropriate conversion equations that use bulk milk tank volumes and components on the day of testing to estimate cow 24-hour production) then they would withdraw from herd testing. Many farmers use little of the potential information provided from herd testing – most remain focused on individual cow somatic cell count (ICCC) information.

Importantly, data captured by automated sensing systems are typically analysed on-farm using proprietary software and the farmer has no requirement (or incentive) to forward the data to the herd improvement centre (ADHIS system) for processing. This is potentially a source of significant loss of phenotype production data from the proofing system.

Herd improvement centres are under increasing financial pressure from other service providers (especially private semen sellers). Herd testing centres and organisations have insufficient resources to analyse, research and predict/pre-empt changes in the herd recording space. Before dairy deregulation in 2,000 dairy licence fees were diverted into RD&E activities around herd recording (DIF Fund) managed by NHIA. After deregulation this licence money was directed elsewhere (Dairy Food Safety Authority) representing the annual loss of up to $500,000 annually from focused research, development and extension on herd testing. This loss of industry-level funding has reduced the ability of the industry to evolve to the changing herd testing environment.

The fragmented, under-resourced and increasingly competitive Australian herd testing industry has limited capacity to develop more cost-effective and sustainable herd testing offerings or to predict and adapt to the future. The industry does not have sufficient resources to investigate: farmer drivers for herd testing (or not herd testing), levels of awareness by farmers of the range of information that can be derived from herd test data, new reports, information and ways to provide this information to farmers from analysis of their herd test data. They are also unable to develop effective alternate ways of capturing herd test data – such as pro-active implementation of automated recording systems or fostering of collaborations with automatic sensing system companies.

There is significant risk of loss of a large number of herd testing farms and/or herd testing data from the ADHIS system. At some stage this loss of coverage of herd test data collection may impact on the national industry through an inability to provide bull proofs in sufficient time and with sufficient reliability. Examination of the Good Bulls Guide suggests that approximately 75% of the premier bulls that are marketed and 75% of semen sales are from bulls originating outside of Australia. The combined effect of a increased use of overseas germplasm with a reduction in herd testing, exposes the Australian industry to inability to develop local proofs for overseas bulls as well as reduced capacity to progeny-test Australian bulls. Genomics also requires the collection of a large volume of high-quality phenotypic data from a reference population, on an on-going basis.

We recommend that co-ordinated investment into investigating the decline in herd testing. This will include (but not be limited to): a status assessment of the herd testing industry; identifying the drivers and barriers to herd testing by farmers; identifying analyses and information flows that may increase the worth of herd testing data to farmers; a SWOT analysis of disruptive technologies that may impact upon the industry-level; development of an industry plan to increase the proportion of herds and cows that provide herd-test data captured by the central proofing system (ADHIS).

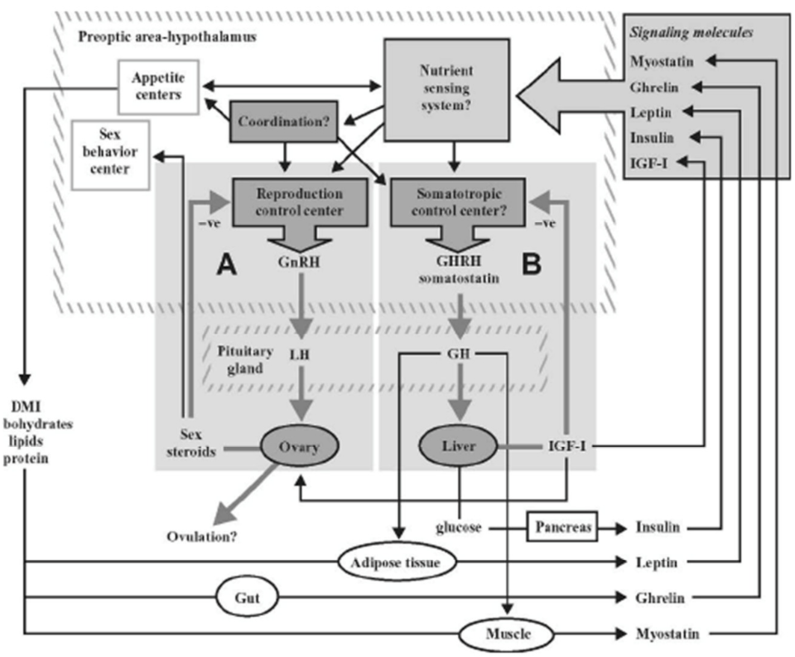
Nutritional aspects

Timeliness of nutritional intervention

Recent reviews on the causes of infertility and the role of nutrition on influencing fertility of high producing dairy cows have indicated that the timing of nutrient delivery may be more important than originally thought[51,52]. There is increasing understanding of the complex interactions between genetics, nutrition, endocrinological and metabolic pathways that operate through the central (but inter-related) somatotropic and gonadatropic axis (see

Figure 11)[52].

Figure 11. Map of the feedback-regulated systems that control the reproductive axis (shaded - A) and somatotropic axis (shaded – B) and their interaction with nutritional and metabolic pathways with focus on the reproductive process[52]



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[51] Walsh SW, Williams EJ, Evans ACO (2011) *A review of the causes of poor fertility in high milk producing dairy cows.* Animal Reproduction Science. **123**:127-138

[52] Chagas LM et.al. (2007) *New Perspectives on the Roles of Nutrition and Metabolic Priorities in the Subfertility of High-Producing Dairy Cows.* J. Dairy Sci. **90**:4022-4032

We recommend that focused studies to identify and quantify the key relationships between nutrition and reproduction be supported. This work should focus on nutritional strategies and solutions applicable to the pasture-based system and should include consideration of genetic, metabolic, and endocrine interactions with nutrition. The key outcomes should be: greater understanding of the pathways, interactions and time dependency between nutrition and reproduction; identification of effective strategies for monitoring herd nutritional and/or metabolic health; and development of effective and economical nutritional supplement programs that can improve herd reproductive performance and are suitable for deployment within a pasture-based grazed dairying system. Inherent in this work will be the development of effective and consistent transition cow messages. This work should be coordinated with the Grains2Milk project in this area.

Management aspects

Heat detection efficiency

Submission rates are declining as shown by the recent InCalf analysis. This could be contributed to by: more cows calving later; prolonged calving-to-first-ovulation intervals in cows; reduced oestrus signs and displays by ovulating cows; and decreased detection of oestrus signs in ovulating cows by farm workers.

The recent InCalf analysis indicated that the crude mean calving to mating start date has not changed significantly over the intervening decade between the two major InCalf analyses – thereby suggesting that changes to the proportion of late calving cows within herds is not the cause of the decline. The three-week submission rate for early-calved, mature cows (cows that should be cycling by mating start date) has also essentially remained unchanged over this time (approximately 80% submission rate since 2000). This also suggests that the performance of farm workers in detecting cycling cows showing signs of oestrus has not deteriorated appreciably over this time.

The specificity of oestrus detection has been demonstrated to be historically high[53]. The first InCalf analysis (2000) demonstrated that few false positive cows are submitted on the majority herds. However, there may now be greater tendency for farmers to submit cows of uncertain status for service in light of declining submission rates. The artificial insemination of false positive oestrus detection cows that are already pregnant can result in high rates of pregnancy loss[54].

The only remaining explanations for the observed decline include reduced strength of oestrus display by ovulating cows and/or prolongation of the calving-to-first-ovulation interval by cows. There is a significant body of literature suggesting that both these changes are occurring.[6,23,24,52]

Australian work[55] suggests that cows with higher dry matter intake, higher ratio of plasma glucose to 3-hydroxybutyrate, lower blood urea nitrogen concentrations, higher plasma cholesterol, lower milk

[53] Morton J (2004) *Determinants of reproductive performance of dairy cows in commercial herds in Australia.* PhD Thesis. University of Melbourne (accessed 11 Nov 2011: http://repository.unimelb.edu.au/10187/1503)
[54] Hockey CD, Morton JM. (2010). *Use of a stochastic simulation model to assess effects of diagnostic specificity of systems for detecting ovulating cows on herd reproductive performance in year-round calving dairy herds*. Anim. Reprod. Sci. (2010), doi:10.1016/j.anireprosci.2010.08.009
[55] Westwood CT, Lean IJ, Garvin JK (2002). *Factors Influencing Fertility of Holstein Dairy Cows: A Multivariate Description*. J. Dairy Sci. **85**:3225-3237

production and were of lower genetic merit were more likely to show signs of oestrus at the first ovulation after calving. These variables explained approximately 50% of the variation in the model. Examination of the factors that influence the risk of overt oestrus display for the second ovulation after calving identified that interval from calving to second ovulation, body weight of the cow at calving, herd prevalence of ovulation during the week of ovulation, feeding of a high density diet and longer luteal phases in the cycle before the second ovulation were positively associated with oestrus display at the second ovulation – although this model explained less of the total variation (36%) then the model for oestrus display at first ovulation. Effective uterine production of prostaglandin requires prior progesterone priming of the endometrium. This priming stimulates the production of oxytocin receptors in the endometrium and this enables the endometrium to respond to pulsatile release of oxytocin by the corpus luteum by the production and release of prostaglandin into the local circulation[56]. This mechanism is involved in the programmed luteolysis in non-pregnant cows. Cows with inadequate progesterone priming are prone to silent oestrus display at ovulation. High producing cows have lower levels of circulating progesterone and therefore may not have sufficient endometrial priming and reduced overt oestrus.

A recent study identified four cow-level risk factors for non-detection of ovulating cows within seasonal herds[57]. These were low milk protein concentration, short interval from calving to mating start date, a history of being carried over from one mating period the next, and cows affected by post-partum vaginal discharge. Interestingly, milk yield was not a strong predictor. These risk factors are consistent with known and putative risk factors described in Section 1.5 and above and suggest that changes to the metabolic, somatropic and endocrine system in the modern cow are driving the reduction in detection efficiency for ovulation.

We recommend that any integrated nutritional intervention study specifically investigate the impact of the interventions on the calving-to-first-ovulation interval, the quality and strength of oestrus display, and the effectiveness of heat detection where feasible. The interaction between various synchrony interventions (such as prostaglandin) with these recently identified risk factors upon the risk of detection in oestrus may be warranted as this may provide greater insight into expected efficacy of these interventions within individual herds.

AI conception rates

The decline in first service AI conception rates is of major concern to the industry. Whilst there may be cow factors associated with the decline in CR the original InCalf study found wide variation in conception rates between AI technicians – especially do-it-yourself (DIY) AI technicians. Recent Australian studies of the impact of timing of AI with respect to ovulation found less than half of all inseminations occurred within the most fertile window of 0-16 hours before ovulation[26]. These results have been mirrored elsewhere[58,59]. This recent Australian work also described the onset-of-

[56] Macmillan KL – pers comm
[57] Chaplin SJ, Morton JM pers comm
[58] Saacke RG (2008). *Insemination factors related to timed AI in cattle*. Theriogenology **70**:479-484
[59] Dransfield et al. (1998).*Timing of Insemination for Dairy Cows Identified in Estrus by a Radiotelemtric Estrus Detection System*. J. Dairy Sci. **81**:1874-1882

oestrus-to-ovulation interval distribution as 33 ± 14 hours [60]. This is notably different to the distribution described by Walker of 28 ± 5 hours[61]. The trend towards later and more varied ovulation times is compatible with endocrine changes in high producing cows[23,24].

Earlier work found that the effect of timing of insemination (comparing once-daily to twice-daily AI) on pregnancy rate was only of concern when semen from low fertility bulls was used. Differences in conception rates of 5% between average and low fertility sires were observed when early oestrus inseminations were analysed[62].

These recent Australian observations were therefore modelled to quantify the gain (if any) from moving from once-daily to twice-daily inseminations on farms and to examine the impact (if any) of changes to the onset-of-oestrus-to-ovulation distribution. A stochastic simulation model was programmed in R (version 2.13.2)[63]. Model assumptions, details and output are presented in Appendix 2.

Model results indicate that the difference in average conception rates between once-daily and twice-daily AI are not substantial (3% maximum) under the observed changes in the onset-of-oestrus-to-ovulation distribution. The difference between AI approaches was less than 3% for both onset-of-oestrus-to-ovulation distributions of 33 ± 14 hours (Hockey) and 28 ± 5 hours (Walker). The slight reduction in average conception rate between once-daily and twice-daily inseminations was due to a reduction in conception rate in cows that come into heat during the night and are first detected at morning milking and inseminated later that morning (once daily AI).

However, there were significant differences in conception rates – for both once-daily and twice-daily regimes – between an onset-of-oestrus-to-ovulation distribution of 33 ± 14 hours (Hockey) and one of 28 ± 5 hours (Walker). This suggests that (potential) changes to the onset-of-oestrus-to-ovulation interval distribution are strongly influencing conception rates under current AI practices. A reduction in conception rate of 6.0% for herds with an average conception rate of 40) and a reduction of 7.5% for herds with an average conception rate of 50% was present when the onset-of-oestrus-to-ovulation was 33 ± 14 hours (Hockey) compared to 28 ± 5 hours (Walker).

Further examination indicated that increases to the mean time from onset of oestrus to ovulation was resulting in a modest decrease in conception rates – again with greatest impact in once-daily AI systems. Of greater concern was that the increased variability of the onset-of-oestrus-to-ovulation distribution was driving a generalised and marked decline in conception rates for both once-daily and twice-daily AI practices (i.e. standard deviation of 14 hours versus 5 hours).

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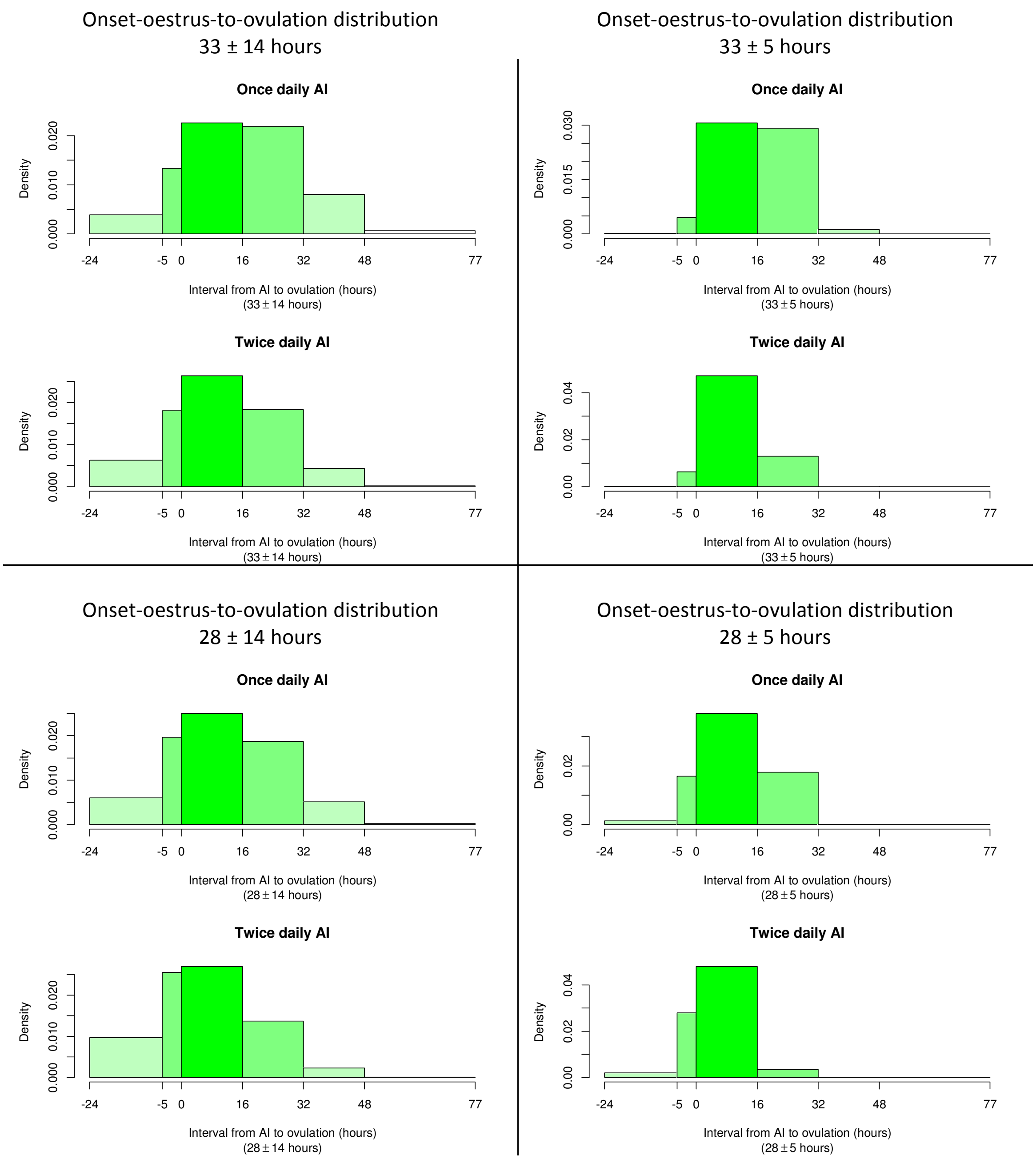
[60] Hockey CD, Morton JM, Norman ST, McGowan MR. (2010). *Evaluation of a neck mounted 2-hourly activity meter system for detecting cows about to ovulate in two paddock-absed Australian dairy herds.* Reprod. Domest. Anim. **45**:107-117.
[61] Walker WL, Nebel RL, McHilliard ML (1996). *Time of Ovulation Relative to Mounting Activity in Dairy Cattle*. J. Dairy Sci. **79**:1555-1561
[62] Macmillan KL, Watson JD (1975) *Fertility differences between groups of sires relative to the stage of oestrus at the time of insemination*. Animal Prod. **21**:243-249
[63] R Development Core Team (2011). *R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.* ISBN 3-900051-07-0. URL http://www.R-Project.org/

A summary of the impact of changes to the onset-of-oestrus-to-ovulation distribution is presented in ***Figure 12***. This provides example output from four model runs (using different means and standard deviations) and estimates of the proportion of inseminations within each time category (as described by Hockey) for once-daily and twice-daily AI. It should be noted that AI in the interval 0-16 hours before ovulation had approximately twice the conception rate of the windows either side of this interval.

Figure 12. **Histogram of inseminations within interval categories for time of onset of oestrus to ovulation across different mean and standard deviation values for this distribution and comparing once-daily to twice-daily AI. The distribution as observed by Hockey is presented in the top left quadrant and the distribution as described by Walker is in the bottom right quadrant.**



The changes to the somatotropic and gonadotropic axes and the endocrine and metabolic changes that occur in the high producing dairy cow after calving variously described in preceding sections may also be resulting in delayed ovulation. High producing cows have smaller and less endocrinologically active follicles and this can result in a delay to follicle maturation and ovulation.[23,24] This delay may be resulting in declining AI conception rates in affected herds – especially those herds using once-daily AI.

We recommend that further investigation of these observations be undertaken as part of wider ranging studies to identify the causes of reducing farm AI conception rates. Factors of interest in future studies may include: DIY AI technician variability, lower semen fertility/survivability, changes to (and identifying risk factors for changes to) the distribution of onset-of-oestrus-to-ovulation times in cows, poorer oocyte health, increased embryonic loss, sub-optimal uterine and endocrine environment and suboptimal AI technique.

Discussions with NHIA indicate that there is significant requirement for refresher courses for technicians across topics such as semen handling and preparation, insemination technique, basic cow physiology, heat detection (including inseminating false positive cows). Pilot studies have indicated that many DIY technicians have sub-optimal knowledge and technique to operate optimally. Existing teaching material and manuals are in excess of 30 years old and require updating[64].

We also recommend that modern, effective and tailored teaching resources are developed and that sufficient skilled trainers exist and are equipped to deliver AI refresher courses in all the major dairy regions each season.

Closing summary

Dairy cow fertility is declining and current performance is impacting upon the ability of Australian dairy farmers to select the production system that they prefer. The long-term focus on breeding for production, with insufficient emphasis on maintaining fertility, has contributed to the decline. The predominant feeding systems used by farmers are compounding the problem.

The best long-term solution to the decline in cow fertility is to breed for improved fertility. It will take a number of years to restore fertility to acceptable levels, and more immediate solutions are needed to help manage the problem. Accordingly, we have identified research priorities with long, medium and short-term objectives.

The long-term objective is to improve the genetic merit for fertility in the national dairy herd. Work should focus on improving the quality of information used in genetic evaluation to achieve greater selection accuracy, particularly at early ages using genomic selection.

Medium-term objectives are aimed at identifying and describing any practical management and nutritional practices (if any) that can limit dysfunction of the metabolism of high-producing cows. Effective metabolism interventions – if identified – may preserve other key physiological processes

[64] Carol Millar, NHIA – pers comm

such as reproduction and therefore provide for better performance. The medium-term objective is therefore to identify ways for farmers to operate effectively with the current genotype.

The short-term objectives are to improve the awareness and performance of farmers in controlling the many known risk factors for poor reproductive performance – such as increasing the calving to mating start date, preventing metabolic and peri-parturient disease and ensuring good AI technique. These objectives are therefore to re-assess, re-invigorate and re-focus the key messages from the InCalf program.

Appendix 1 - Abbreviations and acronyms

Abbreviation / Acronym	Definition
AB	Artificial breeding / artificially bred
ABV	Australian Breeding Value
ABV(g)	Genomic-based Australian Breeding Value
ABV(i)	Interbull-based Australian Breeding Value
ADHIS	Australian Dairy Herd Improvement Scheme
AI	Artificial insemination
APR	Australian Profit Ranking
ASI	Australian Selection Index
BCS	Body condition score
CI	Calving interval
CR	Conception rate
CRC	Cooperative Research Centre
DA	Dairy Australia
DIY	Do-it-yourself
DMF	Dairy Moving Forward
DPIV	Department of Primary Industries, Victoria
DRDC	Dairy Research and Development Corporation
EEL	Early embryonic loss
GA	Genetics Australia
GH	Growth Hormone
GnRH	Gonadotropin releasing hormone
GxE	Genetics by environment interaction
HF	Holstein-Friesian
HiCo	Herd Improvement Cooperative Australia Ltd
ICCC	Individual cow cell somatic count
IGF-1	Insulin-like growth factor 1
J	Jersey
LEL	Late embryonic loss
LH	Luteinising hormone
ME	Metabolisable energy
MGD	Maternal grand dam
MGS	Maternal grand sire
MJ	Megajoules
NatSCAN	National dairy fertility dataset – a subset of the ADHIS database
NEB	Negative energy balance
NEFA	Non-esterified fatty acid
NHIA	National Herd Improvement Association of Australia
PIMC	Primary Industries Ministerial Council
PMR	Partial mixed ration
PTA	Predicted transmitting ability
R,D&E	Research, development and extension
RDP	Regional Development Program
SWOT	Strengths, weaknesses, opportunities, threats
TMR	Total mixed ration
TOR	Term(s) of Reference
USDA	United States Department of Agriculture

Appendix 2

Assumptions behind modelled outcomes for predicted unhalted decline in dairy herd reproductive performance through 2020 and 2030

The assumptions behind the modelled estimate are as follows. Cows with an average intercalving interval of 365 days will spend on average 305 days lactating and 60 days dry each year. Therefore approximately 83% of a year is spent lactating and the average duration of lactation will be 305 days. Similarly, a cow pregnant in the second 6-week period of mating will have an average of 386 days between calving events providing an average lactation length of 326 days and thus spend an average of 84% of a year lactating. Cows pregnant from week 12 to week 21 of mating will have an average intercalving interval of 438 days with typical lactation length of 378 days and will lactate for approximately 86% of a year.

Cows that are carried over will spend an extra 6 months lactating (182 days) before drying off than if they became pregnant in the first six-week period of the initial mating period. If approximately 55% of these become pregnant by 6-weeks into the second mating period this extends to an extra 21 days or a total of 305 + 203 = 508 days of lactation. Therefore approximately 88% of a year is spent lactating. Given that only 8-10% of cows are typically empty after two consecutive mating periods in herds that use split mating systems then we can assume the remainder of carryover cows that become pregnant do so in the second 6-week period of this mating. This yields average estimates of lactation length of 529 days and 89% of the year spent lactating. Cows empty after two mating periods will typically have a 16-month (486 days) lactation before culling and effectively lactate for 100% of the year.

We have assumed that over the long term the proportion of cows in the second calving period herd is approximately the same as the not-in-calf proportion after the first mating period.

The changes to herd feed demand are based upon the following: constant cow maintenance requirements of 60 megajoules (MJ) of metabolisable energy (ME) per day; each litre of milk requires approximately 5.0 MJ of dietary ME to produce; and cows peaked in production at an average of 30 litres milk per day in the month immediately following calving. Lactation declined at 9% per month until cows averaged 15 litres per day in the 10th month of lactation. This production was held constant for cows with extended lactation (up to 16 month of lactation).

Appendix 3

Description of the stochastic model examining the impact of potential changes to the optimal window of insemination relative to the time of insemination and changes to the onset-of-oestrus-to-ovulation interval distribution.

A stochastic simulation model was programmed in R (version 2.13.2)[65] using the following assumptions: onset of oestrus occurred randomly throughout a 24-hour daily cycle, oestrus was modelled as 12 ± 4 hours, oestrus is detected at milking (start times set at 5 AM and 3 PM); AI occurred at 10 AM (1x daily) or at 10 AM and 6 PM (2x daily); and the interval from onset-of-oestrus-to-ovulation was modelled as 33 ± 14 hours[60]. As this was notably different to the distribution described by Walker of 28 ± 5 hours[66], the model was then re-run using the Walker distribution in order to assess the impact of changes in the interval from onset-of-oestrus-to-ovulation upon results. Finally to assess the impact of the change in the mean interval from onset of oestrus to ovulation (33 versus 28 hours) whilst controlling for the increased standard deviation of ovulation time observed by Hockey et al. (14 hours versus 5 hours) the model was rerun using 33 ± 5 hours to define the onset-of-oestrus-to-ovulation distribution (thereby combining the mean result of Hockey with the standard deviation observed by Walker).

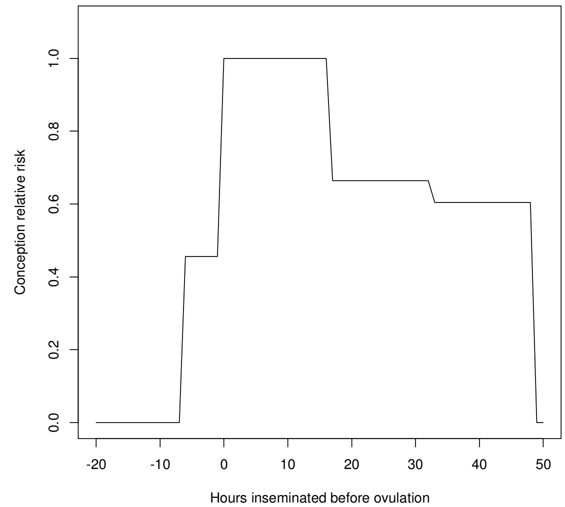
No ovulations were allowed to occur within 5 hours of the onset of standing oestrus – the onset-of-oestrus-to-ovulation distribution was resampled on these occurrences until an interval of 5 hours or greater was selected. Each simulation run modelled 10,000 cows.

Because conception rates varied substantially between the two study farms the relative risk of conception (as opposed to actual conception rates) were modelled. A relative risk of 1.0 indicates the maximum conception rate for that farm (AI within the interval 0-16 hours before ovulation) is expected for the modelled insemination. This relative risk distribution is presented in ***Figure 13***.

[65] R Development Core Team (2011). *R: A language and environment for statistical computing. R Foundation for Statistical Computing*, Vienna, Austria. ISBN 3-900051-07-0. URL http://www.R-Project.org/

[66] Walker WL, Nebel RL, McHilliard ML (1996). *Time of Ovulation Relative to Mounting Activity in Dairy Cattle*. J. Dairy Sci. **79**:1555-1561

Figure 13. Relative risk of conception versus interval from insemination to ovulation (hours before ovulation). From Hockey at al.[26]



The estimated relative risk of conception for cows entering oestrus at each hour of the day (with lowess smoother lines of best fit between adjoining times) comparing once-daily with twice-daily AI from an example output from a 10,000 cow simulation is presented in ***Figure 14***. This model output assumes the distribution of times from onset of oestrus to ovulation is 33 ± 14 hours (Hockey results[26]). The histogram of actual intervals from AI to ovulation for this example model output is presented in ***Figure 15***.

Figure 14. Conception rate relative risk by time of onset of oestrus comparing 1x with 2x daily AI (modelled distribution of onset oestrus to ovulation: 33 ± 14 hours)

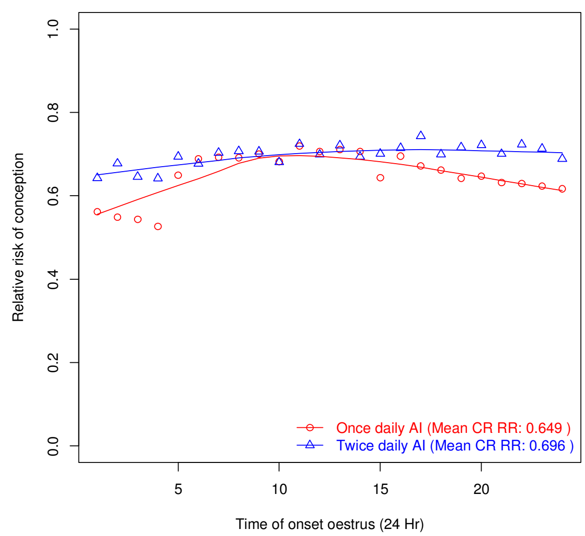
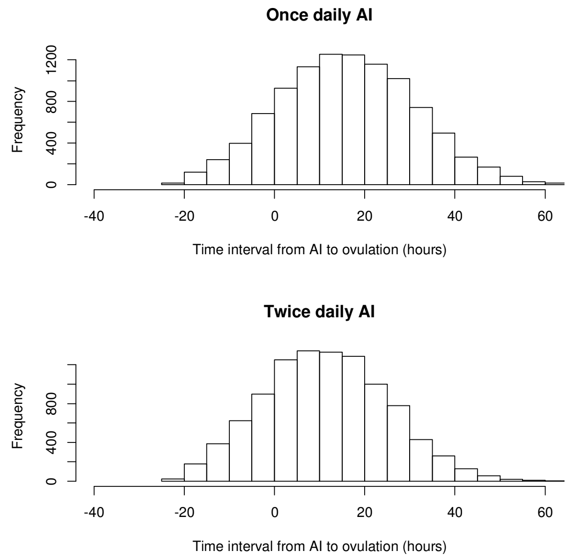


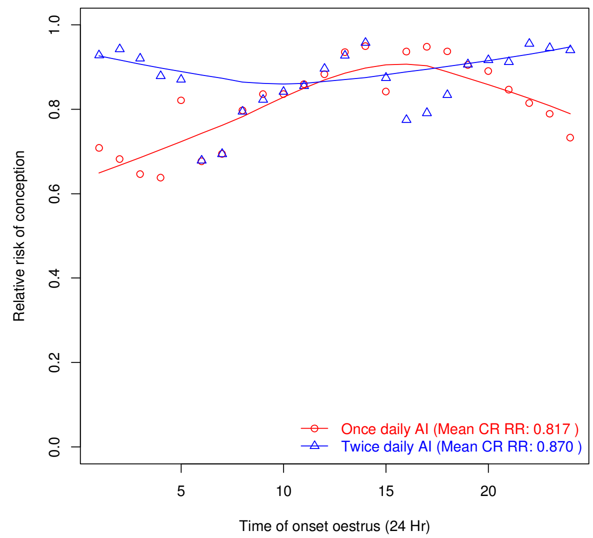
Figure 15. Histograms of interval from AI to ovulation comparing 1x (top) with 2x (bottom) daily AI (modelled distribution of onset oestrus to ovulation: 33 ± 14 hours)



The histogram of intervals from AI to ovulation indicates that approximately 1/3rd of inseminations occurred within the optimal window of 0-16 hours before ovulation thereby mirroring the observations of Hockey el al and giving confidence in model performance. For a herd with 50.0% conception rate for cows inseminated in the interval 0-16 hours before ovulation the average farm conception rate would be 32.5% for once-daily AI and 34.8% for twice-daily AI.

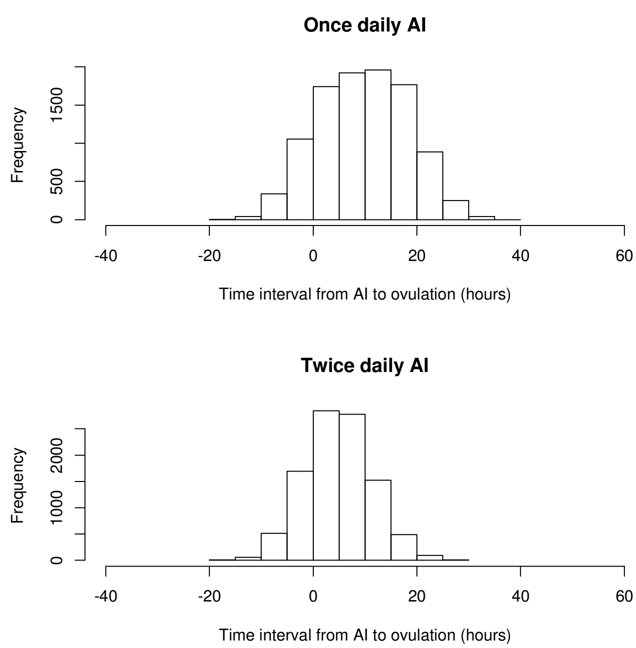
The estimated relative risk of conception for cows entering oestrus at each hour of the day (with lowess smoother lines of best fit between adjoining times) comparing once-daily with twice-daily AI from an example output from a 10,000 cow simulation is presented ***Figure 16*** and the histogram of the of actual intervals from AI to ovulation is presented in ***Figure 17.*** This model assumes the distribution of times from onset of oestrus to ovulation is 28 ± 5 hours (Walker results[61]).

Figure 16. Conception rate relative risk by time of onset of oestrus comparing 1x with 2x daily AI (modelled distribution of onset oestrus to ovulation: 28 ± 5 hours)



For a herd with 50.0% conception rate for cows inseminated in the interval 0-16 hours before ovulation the average farm conception rate would be 40.9% for once-daily AI and 43.5% for twice-daily AI.

Figure 17. Histogram of interval from AI to ovulation comparing 1x with 2x daily AI (modelled distribution of onset oestrus to ovulation: 28 ± 5 hours)



The following observations and comparisons are relevant: the difference in performance between once-daily and twice-daily AI within models is not great. Both models provided a relative risk difference between once-daily and twice daily AI of approximately 0.05 to 0.06. This equates to a conception rate difference of <3% for farms with an average conception rate of 40% (0.05 x 40.0% =

2.0%). Most of this reduction in conception rate occurs in cows that come into heat during the night and are first detected at morning milking. The optimal time for a cow to come into oestrus is between morning and afternoon milking.

However, there appear to be significant differences in the relative risk of conception between models. This suggests that (potential) changes to the onset-of-oestrus-to-ovulation interval distribution are strongly influencing conception rates under current AI practices. The differences between the two models suggests that the increase in the onset-of-oestrus-to-ovulation interval from 28 ± 5 hours (Walker et al.) to 33 ± 14 hours (Hockey et al.) results in an approximate risk reduction in conception of 0.15 for both once-daily and twice-daily AI. This is equivalent to a 6.0% reduction in conception rate for herds with an average conception rate of 40% and a reduction of 7.5% for herds with an average conception rate of 50%. Approximately 50% of inseminations would occur within the optimal 0-16 hour window under once a day insemination with this figure increasing to approximately 60% of all inseminations with twice daily AI.

Results from the model using 33 ± 5 hours to define the onset-of-oestrus-to-ovulation distribution are presented ***Figure 18*** and ***Figure 19.***

Figure 18. Conception rate relative risk by time of onset of oestrus comparing 1x (top) with 2x (bottom) daily AI (modelled distribution of onset oestrus to ovulation: 33 ± 5 hours)

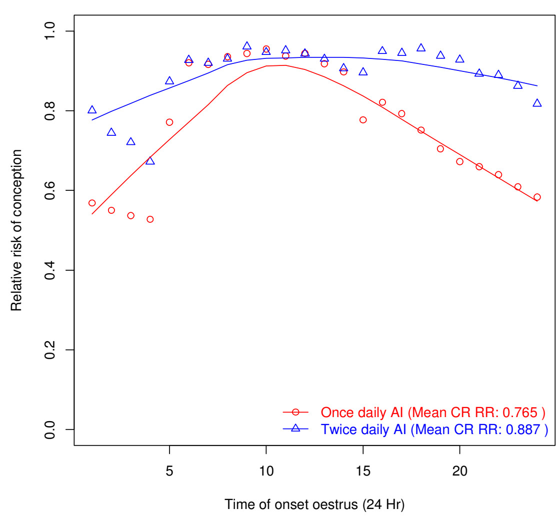
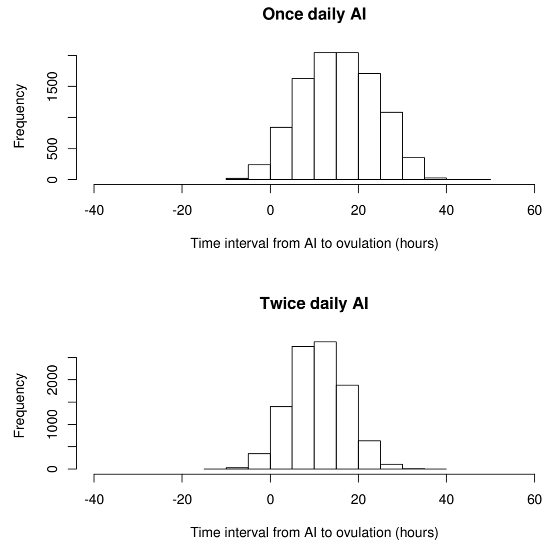


Figure 19. ***Histogram of interval from AI to ovulation comparing 1x (top) with 2x (bottom) daily AI (modelled distribution of onset oestrus to ovulation: 33 ± 5 hours)***



This final model indicates that there is a clear economically valuable risk difference between once-daily and twice-daily insemination of approximately 0.12 – equating to a conception rate loss of nearly 5% for a herd utilising once-daily versus twice-daily AI and with an average conception rate of 40%. This final (theoretical) simulation implies that any delay in the mean time from onset of oestrus to ovulation will have a more serious impact upon conception rates in once-daily AI than twice-daily AI herds. This arises because once-daily AI herds now inseminate more cows too early – more than 16 hours before ovulation and the majority of these first come into oestrus during the night. The increase in the standard deviation of the onset-of-oestrus-to-ovulation distribution is seriously impacting once-daily and twice-daily farms – fewer cows now receive AI within the optimal 0-16 hour window as a result of the greater variation in ovulation times.

Appendix 4

List of contacts

The following people were consulted during the preparation of this report. We wish to thank them for their patience and guidance, and in some instances, their willingness to supply confidential or unpublished information to assist us in our task. We also apologise for any inadvertent omissions or misinterpretations of the facts and opinions provided to us.

Person	Organisation
Daniel Abernethy	ADHIS
Peter Amer	AbacusBio (NZ)
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Mick Blake	Dairy Australia
Pauline Brightling	Harris Park
Rohan Butler	Holsteins Australia
John Craven	Harris Park Group (InCalf)
Mick Daly	HiCo, Maffra
Peter Fennessy	AbacusBio (NZ)
Mekonnen Haile-Mariam	DPIV
Joanne Hakim	AgVet Projects
Ben Hayes	Dairy Futures CRC / DPIV
Jonathon Hill	University of Queensland
Michael Holland	University of Qld/CSIRO Livestock Industries
Nick Hooper	Dairy Farmer, Nambrok
Anne Hope	Harris Park Group (InCalf)
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Bill Jessep	Dairy Farmer, Tinamba
Ian Lean	SBSCibus / University of Sydney
Michael Lee	HiCo, Maffra
Bill Malcolm	Univ of Melbourne / DPIV
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Tony Urek	Total Livestock Genetics
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