Pilot System for Routine Collation of Non Return Data for Bulls

Final Report to

Genetics Australia
and
NHIA

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Executive Summary

The aim of this project is to develop a pilot system to routinely monitor the non-return rate (NRR) of AI bulls. To achieve this the following steps were carried out:

- insemination data were collected from herd recording centres and stored in a specially prepared ADHIS database
- a statistical analysis of the data was carried out to estimate the effect of factors affecting NRR and to predict the future NRR of individual bulls and inseminators.

Seven herd recording centres supplied data to ADHIS on mating records to both natural and AI matings covering in all, almost 900,000 matings. These were married with ADHIS data and subjected to a filtering process which classified matings as success, failure or unknown. Further filtering resulted in a set of data of approximately 500,000 matings for which a result (success or failure) was held to be known.

Herd, year, days since last calving, month of mating, insemination number, cow age, cow and bull breed affect NRR. After allowing for these effects, there is still significant variation in NRR among bulls and inseminators. Bull effects are highly repeatable across years but inseminator effects are only moderately repeatable. Predicted future NRR for bulls vary from approximately 8% below to 8% above average and for inseminators from 5% below to 5% above average.

NRR data are notoriously unreliable. We have attempted to check the validity of the data and conclude that the predicted bull NRRs are probably reliable but much of the current research effort was needed to eliminate anomalies from the analysis. With further research the combination of insemination data and the existing ADHIS database will be a powerful tool for investigating cow fertility and producing genetic evaluations for the fertility of a bull's daughters.

Recommendations

- ADHIS be encouraged to extend its services to include calculation of predicted NRR for bulls and possibly inseminators.
- NHIA, GA, VIAS and ADHIS consider how this should be done to maximize benefit to the dairy industry. The recommendations or options decided upon by these organisations should then be canvassed with the wider industry. That is, discussions should be held with AI centres, herd recording centres and semen suppliers and ADHIS with a view to establishing protocols for release of the NRR predictions for use in fertility improvement.
- Further research should be carried out on the fertility of dairy cows using the enlarged ADHIS database to develop methods of obtaining unbiased estimates from the database and to study the genetic and non-genetic factors affecting fertility.

Introduction

Farmers and scientists have long been interested in herd fertility and how to improve it, especially in herds practicing seasonal production. Holmes and McClintock, (1993) reported significant variation among bulls (also referred to as the service sire) in calving rates after AI programs. However calving rates are biased because many non-pregnant cows are culled and are reported too late to be of much use in detecting less fertile bulls. A means of using non-return rates, if reported and analysed quickly, would deliver the information almost a year earlier and would therefore be more useful.

The purpose of the project, funded by the National Herd Improvement Association, managed by Genetics Australia and carried out by VIAS, was to develop a pilot system to routinely monitor the non return rates (NRR) of AI bulls. As part of the current project ADHIS has received data on matings from seven major herd recording centres comprising approximately 230,000 mating records each year. Most of these are AI matings. Historical data back to 1994 were received from the same centres. The most desirable outcome would be that the pilot system is taken over by ADHIS and performed by them as part of their service to the industry. However before this can happen the data must be of sufficient quality to produce valid results, it must be stored in ADHIS's database, an appropriate statistical method of analysis must be available and the industry must agree on how the results are to be used.

Non return rates are not always reliable indicators of pregnancy rates so we need to assess the quality of the data and perhaps restrict the analysis to a more reliable subset. Some herd recording centres already calculate NRR for bulls but these are typically raw averages. More accurate NRR can be obtained by pooling the data from many centres and by carrying out a statistical analysis which allows for other factors affecting conception such as herd and season. Inseminators also vary in their success rate and a by-product of the analysis could be predictions of the NRR achieved by different inseminators. Therefore the aims of the project were:

Objectives

Overall

- To develop a pilot system to routinely monitor the NRR of AI bulls.

Specifically

- To derive a set of ADHIS-compatible rules to filter incorrect or otherwise unusable data and to derive sensible criteria for mating success and failure and hence non-return to service.
- To derive a suitable statistical model accounting for all fixed effects and all identifiable random effects.
- To estimate variance parameters for these random effects.
- To derive predicted effects for each of the major random effects (bulls and inseminators) based on the above parameters.

- To test the validity of the data and the predictions of bull and inseminator effects by comparing different sub-sets of the data.
- To put in place a routine system of collecting mating data, storing it in the ADHIS database and calculating bull and inseminator effects on fertility.

Methods

Data sources

Data were supplied by seven herd recording centres: CHIS, Colac, Maffra, Northern Herd, South Gippsland, Timboon and Yarram. In all, 885,889 mating records were used, 823,690 of which were inseminations of bulls registered with NASIS and 62,199 were natural matings. Nearly all of the records were for cows in Victorian herds (97%), with data also supplied for cows in Tasmania (1.7%), New South Wales (0.9%) and Queensland (0.4%).

In future, it is anticipated that data will be available from Dairy Express for New South Wales and Queensland, HISCOL in South Australia and for herd recording centres employing the AUSHERD software system in Victoria. HISWA in Western Australia or TDIA in Tasmania do not collect mating data.

Data Selection

Nearly all of the matings were recorded over the six-year period from 1994 to 1999. A small number of matings (2%) were recorded between 1986 and 1993 but, as the number of records for any given year was very small, these data were not included. Mating records with an invalid herd ID, cow national ID, mating date or mating code were excluded.

ADHIS database

ADHIS uses its suite of software to maintain and update a master database of herd recording data. This software was extended to allow mating data to be included and integrated with other components of the database. For the purposes of this project, a copy of the master database was created containing only herds for which mating data had been supplied. All cows in these herds were included even if no mating data were supplied. The copy was created from the April 1999 database that has been used in calculating the ABVs to be released in July. This database also included the list of bulls registered with NASIS up to April 1999. The mating data supplied by the seven testing centres were added to the copy of the master database.

Extraction of data for analysis

Data required for the analysis of bull fertility were extracted and collated from the specially prepared copy of the ADHIS database. Each herd in the database was processed in turn. The length of time over which AI was used in the herd within a given mating season was used to classify the herd as seasonal or non-seasonal. Herds in which AI was used for a continuous period of 90 days or less were classified as seasonal.

A mating year was defined as commencing after April and ending before March of the following year. Since very few cows in seasonal herds are mated in March and April (less than 0.2%), this definition of the mating year minimised the risk that two cows in the same herd, mated in adjacent months, would be allocated to different mating years. It also means that cows mated in the same mating period should calve in the same calendar year.

In seasonal herds, the interval over which AI was used was determined separately for heifers and adult cows. This allowed for different mating strategies for these two age groups.

For seasonal herds, the result of each artificial insemination was classified as follows:

> **Failure -** a subsequent AI or natural service was recorded for the cow.
>
> **Don't Know -** the service happened less than 25 days from the last known AI date for cows of a given age group in the herd. In this case, there is insufficient time to know if the cow returned to oestrus.
>
> **Success -** the service happened more than 25 days from the last known AI date for cows of a given age class in the herd and no repeat AI or natural service was recorded for the cow during the mating period.

For non-seasonal herds, the result of each artificial insemination was classified as follows:

> **Failure -** a subsequent AI or natural service was recorded for the cow in the mating year.
>
> **Success -** no repeat AI or natural service was recorded for the cow in the mating year.

Other derived data for each mating record included:

- the number of days from successful mating to calving (calculated as a check),
- the number of days from the preceding calving to mating (for lactating cows),
- the number of days from the start of the mating period to mating,
- the number of days from mating to the end of the mating period,
- mating result based on a 25-day non-return and
- the number of days from mating to subsequent return.

Table 1 The full list of data fields extracted

Field Name	Description
Bull number	Sequential number for bulls included in the analysis
Bull national ID	
Mating result	Success = 2, Failure = 1, Don't Know = 0
Mating number	Mating number within mating season
Inseminator	3-7 character code
Breed of bull	ADHIS four character breed code (e.g. JJJJ)
Breed of cow	ADHIS four character breed code (e.g. JJJJ)
Herd	Herd sequence number
Year	Year in which mating occurred (April to March)
Month	Month number in which mating occurred
Age	Age in years at time of mating
Parity	Lactation number
Days from last calving	Number of days from the calving that preceded the mating
Calving confirmed	Number of days from mating to the subsequent calving
DPC code	Code for data processing centre that supplied data
Cow's Sire Number	ADHIS sequence number for the sire of the cow
Cow's Sire ID	
Cow's National ID	
Mating Code	Professional = 1, DIY = 2, Natural = 3 or 4
Seasonality of herd	Non seasonal = 0, Seasonal = 1
Age class	Heifer = 0, Adult = 1
Mating result (25)	25-day non-return (Success = 2, Failure = 1, Don't Know = 0)
Time to failure	Number of days from insemination to subsequent return

Table 2 Summary statistics for the data extracted for analysis:

Mating Season	Number of Matings		
	NASIS	Natural	Total
1994	75,165	742	75,907
1995	139,953	8,258	148,211
1996	187,902	13,410	201,312
1997	213,442	19,266	232,708
1998	207,175	20,517	227,692
All	**823,637**	**62,193**	**885,830**

Total number of herds with mating records:	1,950
Total number of cows with mating records:	>250,000
Average number of NASIS bulls used per herd:	12.6
Total number of NASIS bulls used in 1998:	1,752

Data sub-sets used

Data were further reduced to remove unknown mating results (68% remained), mating numbers greater than 4 in seasonal herds, ages greater than 12, parity greater than 12 and days since calving less than 15 or greater than 150 (55% of records remained). Matings less than

25 days before the end of mating were also removed to eliminate one source of bias (48% remained). Several data sub-sets were analysed to ensure that biases were identified:

- All matings from non-seasonal herds (146,623 records): the full non-seasonal data set
- 1st inseminations from the full non-seasonal data set (102,809 records)
- All matings from seasonal herds (249,951 records): the full seasonal data set
- 1st inseminations from the full seasonal data set(224,843 records)
- All adult matings from seasonal herds, inseminated by professional inseminators (184,609 records): the restricted data set
- 1st inseminations from the restricted data set (167,982 records)

Statistical Model

The following model was fitted by restricted maximum likelihood (ASREML):

Mating result (0 or 1) = Overall mean +	
Fixed effects:	Cow age + Mating number * + Month of mating
	+ Bull breed + Cow breed + Mating code**
	+ Days from last calving fitted either as 15 ten-day groups or as a linear regression (with random spline)
	+ Linear regression on days to the end of mating (with random spline) #
	+ Herd.year
Random effects:	+ Bull ID + Bull ID x Year
	+ Inseminator + Inseminator x Year
	+ Cubic spline on days from last calving fitted with the linear regression
	+ Cubic spline on days to the end of mating fitted with the linear regression #

* The mating number variable dropped out where only first inseminations were analysed.

** Professional, DIY or natural service

Not fitted in the non-seasonal data set.

Results

Validating NRR against calving data

To provide a measure of confidence in the data classification rules, **Figure 1** below shows the distribution of the number of days from a mating classified as a success, to the following calving.

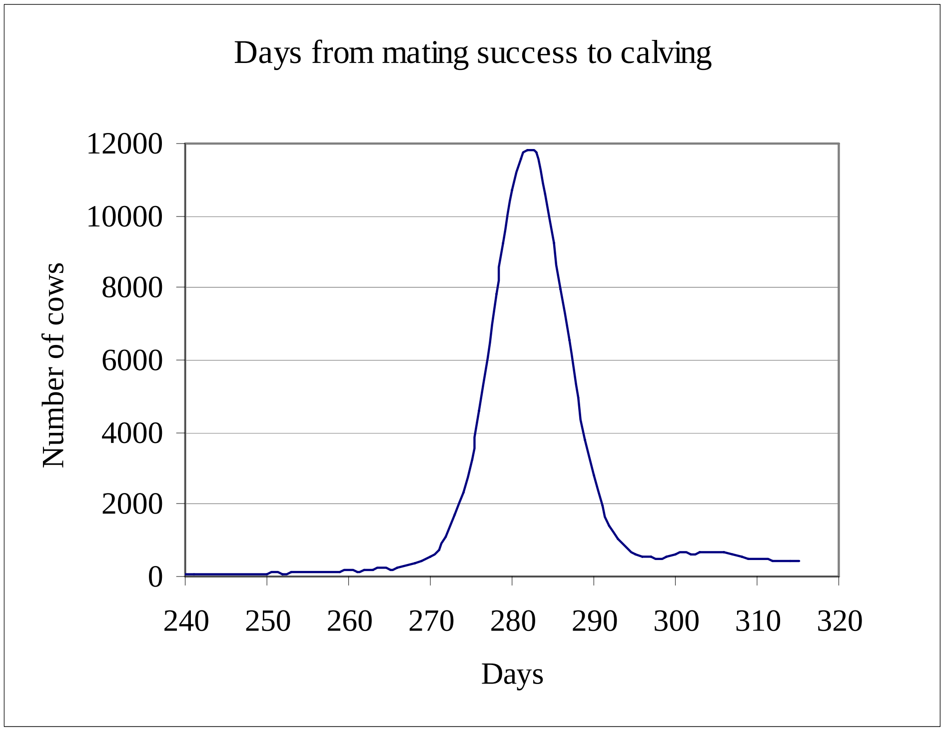


Figure 1 Distribution of gestation length following successful insemination.

This shows that the great majority of cows which remain in the herd, calve approximately 282 days after a successful insemination. The spread around 282 days is consistent with the reported standard deviation of gestation length of 4.5days (Macmillan and Curnow, 1976). Thus most inseminations classified as a 'success' appear to lead to pregnancy and calving. It is possible that cows that don't conceive are culled but if many cows were incorrectly classified as successful inseminations, a proportion of them would conceive to a subsequent insemination and appear in Figure 1 as a small peak around 303 or 324 days.

Time required to observe return to service

We classified the results of a mating as unknown if there were less than 25 days from insemination to the end of the mating period in a seasonal herd (assuming that few returns to service would be recorded after the end of mating). However, the choice of 25 days is a compromise. If a shorter period were used, more cows would be incorrectly classified as successfully mated. If a longer period is used more matings have an unknown result and are discarded.

Figure 2 below shows the hazard function for return to oestrus for each day after service. This is the daily probability of failure among cows that have not returned by that day. There is a large increase in the “risk” of returning at 20-21 days after mating and a small peak 41-43 days after mating. Interestingly, there is also a small peak at day 9 after mating coinciding with reported increases in ovarian follicular activity and oestrogen secretion around this time. Whether these “returns to service” represent a true failure to conceive is not clear.

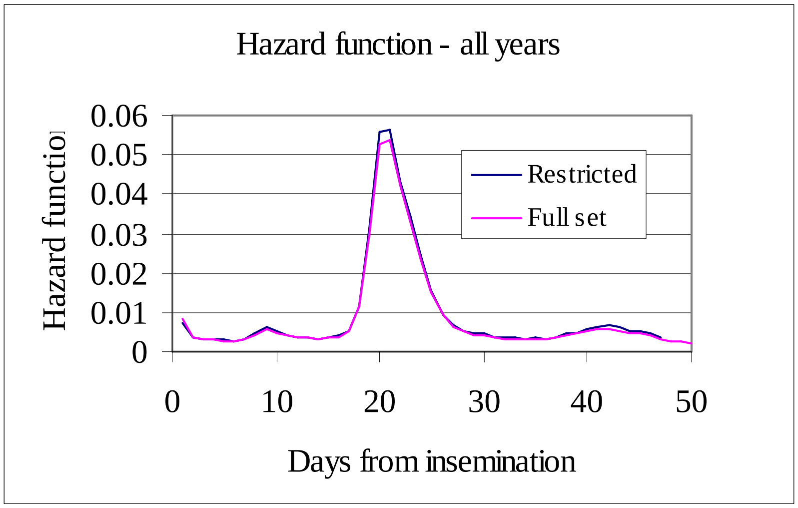


Figure 2 The hazard function for return to service following insemination in the seasonal part of the full data set and the restricted data set.

The cumulative probability of failure in Figure 3 shows that most of the returns to service occur in the first 25 days after mating - most between 18 and 25 days. The cumulative probability of failure is different in the full versus restricted data sets, because the full set contains the non-seasonal herds in which returns to service continue to be recorded for a longer period after mating. All observations shown in Figure 3 after 90 days are non-seasonal herds.

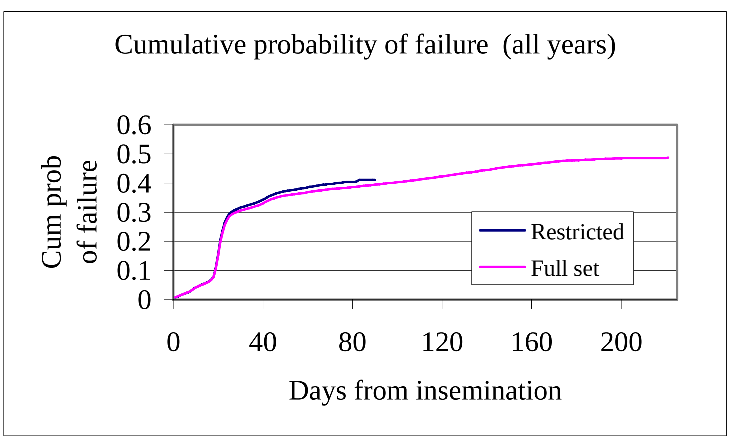


Figure 3 The cumulative hazard function for failure following insemination.

Although most returns to service occur by 25 days after mating, a significant number occur after 25 days. Thus the longer a cow is observed after mating, the higher the probability that the mating will be classified as a failure. We have accounted for this in the statistical analysis by fitting the effect of the number of days from insemination to the end of the mating period on the probability of success.

Figure 2 shows a small peak at day 1, corresponding to cows that are inseminated on two consecutive days. Obviously, these should not be regarded as a failure despite the "return" on day 1.

Factors affecting NRR

In the full data set the average NRR was 0.56.

The statistical analysis produced estimates of the effect on NRR of the fixed effects (eg month of mating and days since last calving), the amount of variance in NRR due to the random effects (sires and inseminators) and predictions of the effects of individual sires and inseminators.

Except where otherwise noted, the effects described below showed significant F values in the analysis of variance.

Days before end of mating

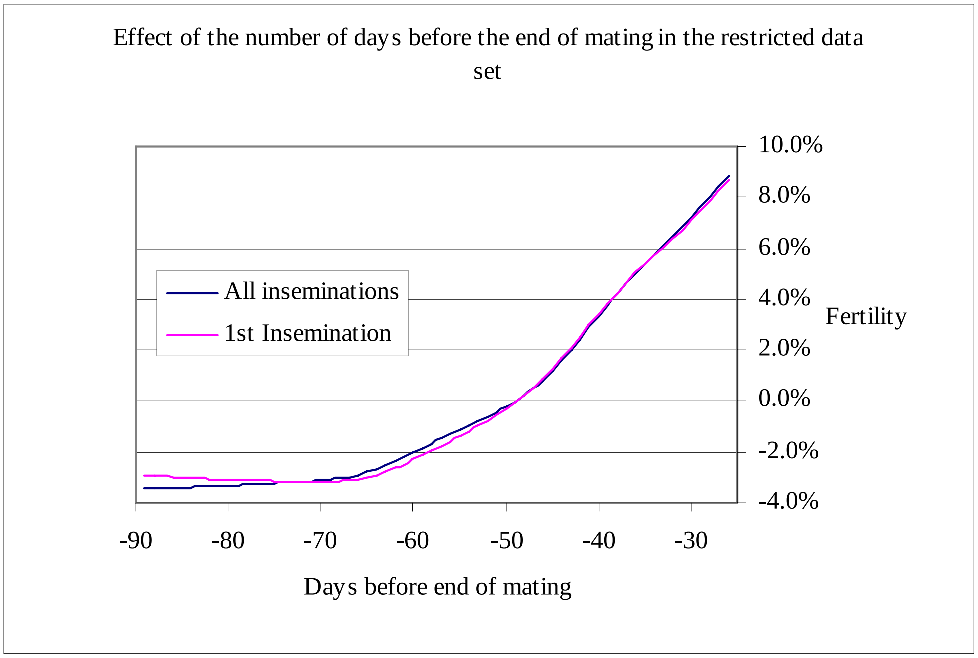


Figure 4 The effect of the number of days before the end of the mating period in seasonal herds.

As cows are mated later in the mating period, there are fewer opportunities for a return to service to be observed. This effect is reflected in Figure 4. The results in Figure 4 mirror those in Figure 3 although they are derived quite independently. Both show that when the period of recording is extended from 25 days to 70 days after insemination, the proportion of failures increases by 10%. Failure to include this effect in the statistical analyses can lead to bias in the estimates of some effects, such as the month of mating.

Days since last calving

The number of days since last calving was fitted in the model as a linear regression plus a cubic spline fitted as a random effect.

Figure 5a shows the effect of the number of days since last calving on NRR for all or 1st inseminations in the full data set showing seasonal and non-seasonal herds. These curves are the sum of a linear fixed effect plus a cubic spline fitted as a random effect.

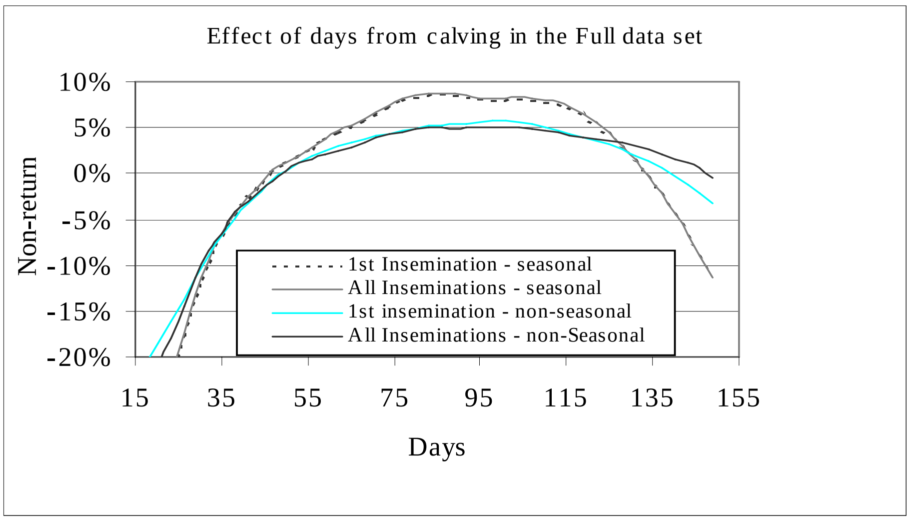
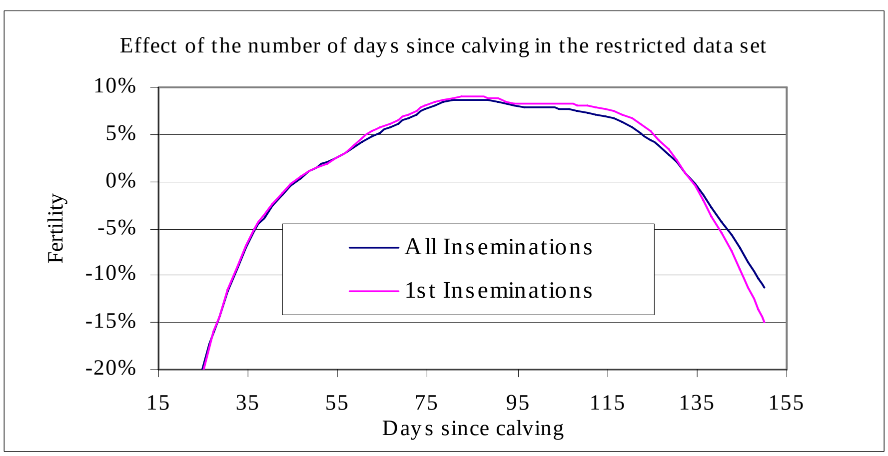


Figure 5a The effect of the number of days since last calving on NRR in the full data



set

Figure 5b The effect of the number of days since last calving on NRR in the restricted data set

The restriction of adult cows in seasonal herds to those inseminated by professional inseminators had no discernable effect on the shape or magnitude of the effect of the number of days after calving.

To test whether or not the spline was giving a good fit to the data, the effect of days since calving was also fitted by classifying the time into 10-day intervals and estimating the effect of each interval on NRR. (**Figure 5c)** (i.e. interval 1 includes days 10 to 19 etc).

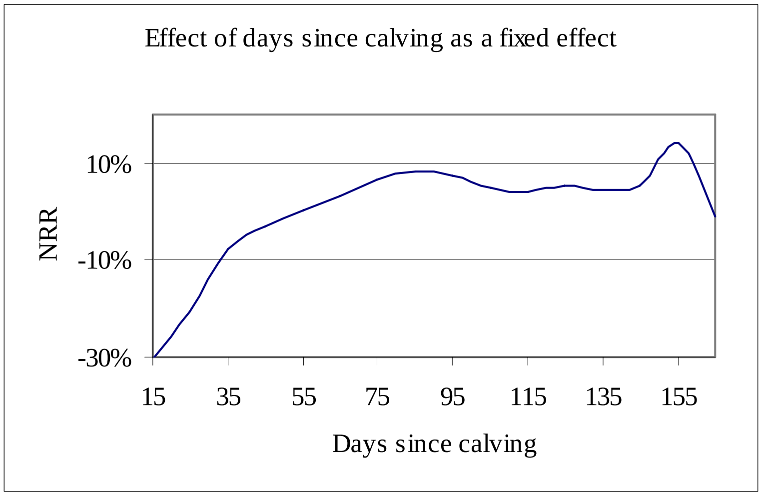


Figure 5c The effect of number of days since calving treated as a fixed effect (15 intervals of ten days) in the seasonal part of the full data set.

The two analyses produce very similar results except Figure 5c has a small peak at 150 days. There are very few observations at that end of the graph, so the spline smoothes out the curve and regresses it towards the mean and probably produces a more reliable estimate.

NRR increases greatly from 10 days post calving until about 80 days and then levels off and may even decline.

The number of days after calving at which conception takes place is often modelled as a linear effect plus a quadratic effect. This approach gives a smooth curve approximating the effect associated with this time period.

There are a number of dynamic variables in operation at this time and the combined effect of them may be quite complex and is almost certain to be non-linear. Variables that are likely to influence the probability of conception include time-related changes in involution of the reproductive tract after calving, in hormone secretion related to parturition and to initiation of lactation, in the nutritional demands on the cow from lactation and possibly also in nutrient supply from seasonal climate and pastures. Therefore use of a linear plus quadratic partial regression is a completely arbitrary approximation of these non-linear effects. Use of splines gives a more flexible curve which better fits the data (Verbyla et al, 1998). The spline component also has the virtue of being a random effect and is thus appropriately regressed as a result of numbers of observations and other effects.

An interesting observation is that there is a peak in NRR at 83 days after calving, coinciding with a peak in numbers mated at that time after calving. Whether this is a small fertility effect of seasonal mating systems or a biological effect is unclear, but it is not related to induction of calving.

In seasonal herds, the NRR increases more rapidly as the time post-calving increases from 10 days to 80 days. This could be because farmers with seasonal herds do not inseminate cows which they feel are "not ready".

Cow age

Figures 6a and 6b show the effect of cow age on NRR

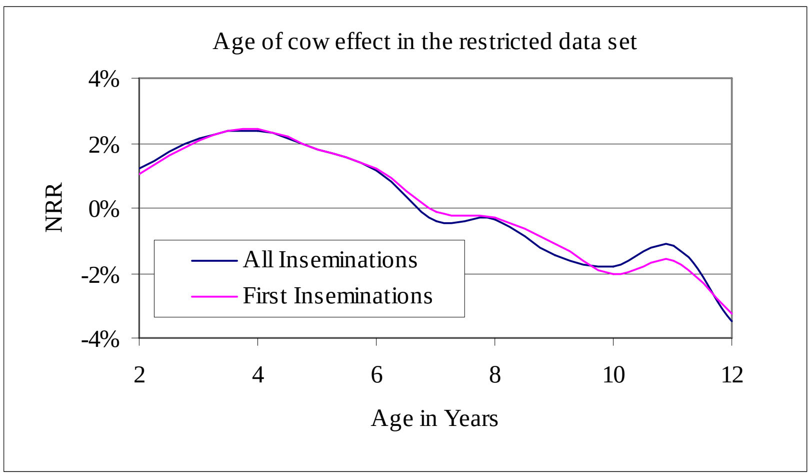


Figure 6a The effect of cow age on NRR in the restricted data set (Seasonal herds, professional inseminators)

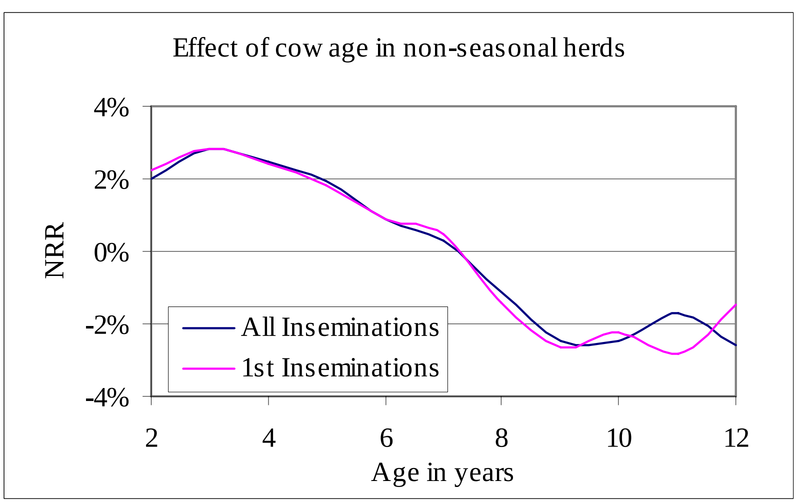


Figure 6b The effect of cow age on NRR in non-seasonal herds (full data set)

The age of the cow was a small but consistent effect in the model. Three and four-year old cows were the most fertile after which there was a small but steady decline. In the present data set it was not possible to correct for selection effects and these may have affected the older ages to some degree.

Breed of bull and cow

Table 4a The effect of Bull Breed in the restricted data set

	1st Inseminations		All Inseminations	
	NRR	SE	NRR	SE
Holstein	0.0%	0.0%	0.0%	0.0%
Jersey	0.5%	0.7%	0.1%	0.8%
Beef	4.0%	1.2%	3.6%	1.3%
Australian Red	5.8%	2.4%	6.2%	3.1%
Ayrshire	1.4%	2.5%	2.8%	2.9%
Illawarra	4.9%	3.2%	3.4%	4.2%
Brown Swiss	-2.0%	3.0%	-2.6%	3.9%
Guernsey	-1.0%	2.9%	-2.8%	3.5%
AFS	-2.1%	5.3%	-1.8%	5.3%

Table 4b Effect of bull breed in non-seasonal herds (full data set)

	All Inseminations		1st Inseminations	
	NRR	SE	NRR	SE
Holstein	0.0%	0.0%	0.0%	0.0%
Jersey	0.4%	0.9%	1.7%	0.9%
Beef	9.3%	1.5%	10.3%	1.7%
Australian Red	-0.5%	3.1%	-0.1%	3.4%
Ayrshire	-3.7%	3.2%	-5.7%	3.8%
Illawarra	-1.4%	2.8%	-1.8%	3.2%
Brown Swiss	-4.4%	3.5%	-4.8%	4.1%
Guernsey	-2.5%	3.7%	-1.0%	4.6%
AFS	-3.4%	3.7%	-5.4%	4.4%

Breeds are referenced to Holstein and the results show that there is little difference between using all insemination data or first insemination data only. Bull breed effects appear to be of the same order of magnitude as their standard errors with the possible exception of beef breed bulls which appeared to show a significant improvement in NRR. Since at least some of these may have been follow-up matings, returns may have been missed.

Table 4c Shows the major cow breed effects in the restricted data set

Cow Breed	All Inseminations		First Inseminations	
	NRR	**Std Error**	**NRR**	**Std Error**
Jersey	1.2%	1.7%	1.3%	1.8%
Holstein	0.0%	1.6%	0.0%	1.7%
JJJF	2.9%	2.7%	0.9%	2.9%
JJFF	2.1%	1.7%	2.2%	1.8%
FFJJ	0.1%	1.7%	0.3%	1.8%
FFFJ	0.7%	1.8%	1.3%	1.9%
Ayrshire	0.5%	3.1%	-0.2%	3.3%
Australian Red	5.4%	2.9%	5.7%	3.0%
Guernsey	0.1%	3.9%	2.9%	4.2%

The effect of breed of cow is also small, although there appears to be a slight advantage to crossbreds.

Month of mating

Table 5a Shows the effect of month of mating in the restricted data set.

	All Inseminations		First Inseminations	
Month of mating	**NRR**	**Std Error**	**NRR**	**Std Error**
June	0.43%	2.40%	0.47%	2.60%
July	0.13%	1.50%	0.47%	1.60%
August	-0.07%	0.00%	-0.93%	0.00%
September	-0.07%	1.00%	-0.73%	1.10%
October	0.13%	1.70%	0.27%	1.90%
November	0.13%	1.80%	0.27%	2.00%
December	-0.67%	2.30%	0.17%	2.60%

In the restricted data set (seasonal), the effect of the month of mating was small and not statistically significant. However in the non-seasonal part of the full data set the effect of mating month was greater.

Table 5b The effect of month of mating in the seasonal herds of the full data set.

	All Inseminations		First Inseminations	
Month of mating	**NRR**	**Std Error**	**NRR**	**Std Error**
June	-1.8%	0.0%	-1.0%	0.0%
July	-1.1%	2.0%	-0.9%	1.8%
August	-1.5%	1.6%	-0.5%	2.3%
September	-0.8%	2.3%	-0.2%	2.5%
October	0.5%	2.7%	1.0%	2.8%
November	0.2%	2.6%	1.4%	2.9%
December	2.1%	2.9%	3.6%	3.3%
January	2.4%	6.2%	-3.4%	13.1%

Table 5c The effect of month of mating in the non-seasonal part of the full data set

	All Inseminations		First Inseminations	
Month of mating	**NRR**	**Std Error**	**NRR**	**Std Error**
June	-9.7%	0.8%	-7.5%	1.0%
July	-8.5%	0.7%	-7.7%	0.9%
August	-9.9%	0.6%	-8.3%	0.8%
September	-5.9%	0.0%	-5.7%	0.0%
October	-3.0%	0.6%	-2.9%	0.8%
November	2.8%	0.6%	2.8%	0.8%
December	14.1%	0.7%	13.3%	0.9%
January	20.2%	1.1%	15.9%	1.6%

Although the effects of month of mating are small in the seasonal data sets, they are large in the non-seasonal data. The major difference between them (apart from the production system) is that the effect of days before the end of the mating period could not be fitted in the non-seasonal data set. There is thus a possibility that censorship of the non-seasonal data in some way has produced a biased result. For example, cows that return to service in January or February may not be inseminated and hence the return is not recorded.

Insemination number

Table 6 shows the effect of Insemination number on fertility

	Restricted data set		Full data set (seasonal)	
Insemination Number	**NRR**	**Std Error**	**NRR**	**Std Error**
1	0.0%	0.0%	0.0%	0.0%
2	-0.6%	0.4%	0.2%	0.4%
3	-3.5%	1.5%	-1.2%	1.2%
4	-15.8%	5.4%	-5.5%	4.1%

Second and later inseminations appear to have lower NRR than first inseminations. This is expected but there may also be some downward bias. The standard error was large for insemination number four and most of the observations were for the first and second inseminations.

Bull and inseminator effects

Table 7a shows the variance components for random effects in the restricted data set.

	All Inseminations		First Inseminations	
Source	**Variance Component**	**Component/ Std. Error**	**Variance Component**	**Component/ Std. Error**
Bull Number	0.00129	6.12	0.00136	6.04
Inseminator	0.00104	2.63	0.00105	2.69
Bull number x Year	0.00031	2.75	0.00031	2.65
Inseminator x Year	0.00075	2.42	0.00058	1.93
Total	0.21231	300.14	0.21200	286.03

Table 7b Variance components for random effects in the seasonal part of the full data set.

	All Inseminations		First Inseminations	
Source	Variance	Component/	Variance	Component/
Bull Number	0.00118	5.97	0.00131	6.21
Inseminator	0.00130	2.49	0.00105	2.51
Bull number x Year	0.00058	4.08	0.00054	3.81
Inseminator x Year	0.00162	3.53	0.00095	2.65
Total	0.21119	349.62	0.21031	331.27

Table 7c Variance components for random effects in the non-seasonal part of the full data set

	All Inseminations		First Inseminations	
Source	Variance	Component/	Variance	Component/
Bull Number	0.00263	8.56	0.00201	6.45
Inseminator	0.00157	2.17	0.00080	1.27
Bull number x Year	0.00048	2.89	0.00035	2.22
Inseminator x Year	0.00331	4.54	0.00318	3.96
Total	0.19428	267.64	0.19545	223.54

The variance in NRR due to bulls is approximately 0.0013 in seasonal herds. This is less than 1% of the total variance but it still indicates considerable differences among bulls. A variance of 0.0013 implies a standard deviation of 0.04 or 4%. Thus bulls range in NRR from about 8% below average to 8% above average ie 47% to 63%.

The bulls x years variance is about 0.0003. Thus the repeatability across years of a bull's effect on NRR is 0.0013/(0.0013+0.0003) = 0.81. This is a surprisingly high repeatability. There is little difference between results with first or all inseminations in the restricted data set or in the seasonal part of the full data set suggesting that either can be used. The variance due to bulls is slightly lower in the full data set and the repeatability is lower (0.67) suggesting that the restricted data set may be more accurate.

The variance due to inseminators in about 0.001 and due to inseminator x year is about 0.00075. Thus the repeatability of inseminator effects is only 0.58. That is, an inseminator can be relatively good in one year and poor in the next. Perhaps inseminators with low NRR in a season are detected by the centres and action is taken to improve their technique for the next season.

Using these estimates of variances, BLUP solutions for bull and inseminator effects have been calculated. These are predictions of future NRR expected in a new season. They are regressed back towards the mean as are all BLUP solutions. They are regressed more when the repeatability across years is low (ie for inseminators) and when there is little information about an effect such as a bull with only a small number of inseminations performed.

Table 8 Bull (BLUP) predictions for the most used 100 bulls sorted in ascending order of NRR prediction

Bull	NRR	Std Err
269	-7.6%	2.0%
6	-6.1%	1.2%
179	-5.4%	2.1%
73	-5.2%	1.9%
63	-3.8%	1.5%
225	-3.6%	2.5%
76	-3.5%	2.4%
85	-3.5%	2.5%
185	-3.2%	2.1%
207	-2.7%	2.0%
318	-2.6%	2.1%
38	-2.4%	2.4%
676	-2.0%	2.6%
454	-1.8%	2.3%
449	-1.6%	1.8%
82	-1.4%	1.9%
166	-1.4%	2.0%
201	-1.3%	2.2%
147	-1.2%	2.2%
144	-1.1%	2.1%
42	-1.0%	1.2%
323	-1.0%	2.4%
316	-1.0%	1.8%
88	-0.8%	2.5%
93	-0.6%	1.8%
87	-0.5%	1.9%
59	-0.5%	2.6%
540	-0.4%	2.0%
206	-0.3%	2.1%
2079	-0.3%	2.6%
315	-0.3%	2.5%
75	-0.3%	1.2%
345	-0.2%	2.2%
218	-0.2%	1.5%
4	-0.2%	1.5%
11	0.1%	2.1%
18	0.1%	2.3%
90	0.1%	2.6%
43	0.2%	2.3%
1	0.3%	1.3%
1268	0.3%	2.4%
273	0.5%	1.5%
277	0.5%	2.6%
21	0.5%	1.0%
46	0.6%	2.0%
72	0.6%	1.4%
112	0.7%	2.5%
284	0.7%	2.4%
245	0.9%	2.4%
104	0.9%	2.5%
1925	1.0%	2.6%
162	1.2%	2.6%
309	1.3%	2.1%
97	1.3%	1.7%
299	1.4%	2.1%
439	1.4%	2.4%
1442	1.4%	2.0%
100	1.5%	1.7%
74	1.7%	1.5%
128	1.7%	1.7%
19	1.8%	2.3%
47	1.8%	2.0%
1709	1.9%	2.6%
817	2.0%	2.3%
7	2.0%	1.3%
234	2.1%	2.2%
1384	2.2%	2.4%
22	2.2%	2.2%
133	2.2%	1.3%
343	2.3%	1.9%
317	2.3%	2.6%
62	2.3%	1.8%
27	2.4%	2.3%
757	2.4%	2.2%
65	2.4%	2.5%
962	2.5%	2.5%
462	2.5%	1.9%
5	2.6%	1.0%
327	2.6%	2.3%
241	2.6%	2.5%
111	2.7%	1.3%
115	2.7%	1.3%
95	2.8%	2.0%
17	2.8%	1.4%
54	3.0%	2.0%
84	3.0%	1.2%
230	3.0%	2.2%
80	3.2%	1.7%
159	3.2%	2.4%
221	3.3%	1.5%
223	3.3%	2.5%
51	3.4%	1.1%
94	3.6%	2.0%
165	3.6%	2.5%
610	3.7%	2.5%
2	3.7%	1.1%
239	3.8%	2.3%
173	4.5%	2.4%
83	4.9%	2.6%

132	6.4%	2.1%

Standard errors show that reliable differences between bulls in NRR can be detected and that, among the 100 most used bulls, the NRRs ranged from –7.6% to +6.4%.

Inseminators

Table 9 BLUP predictions for the twenty inseminators with most inseminations.

Inseminator	Prediction	Std Error
1	-5.3%	2.1%
2	-4.1%	2.1%
3	-3.7%	1.9%
4	-2.5%	1.7%
5	-2.4%	2.2%
6	-1.8%	2.1%
7	-1.5%	1.9%
8	-1.5%	2.2%
9	-1.1%	2.1%
10	-0.8%	1.9%
11	-0.7%	1.8%
12	0.0%	1.7%
13	0.4%	1.9%
14	0.6%	1.8%
15	0.8%	2.0%
16	0.9%	2.1%
17	1.5%	1.8%
18	1.7%	2.0%
19	2.8%	1.9%
20	3.0%	2.1%

Although inseminators had a lower repeatability than bulls, the 20 inseminators with most inseminations ranged in prediction from –5.3% to + 3.0%.

Discussion

Overall, the results support the concept of a BLUP set of predictions for bull and inseminator effects since these were significant contributors to the variance in fertility as measured by filtered non-return rates.

Validity of the data

Non-return rates are often said to be useless as a measure of fertility because of the unreliability of individual observation and recording of return to oestrus. We have attempted to maximise the validity of the data by classifying the result of an insemination as unknown when it occurred within 25 days of the end of the AI period. This eliminated 32% of inseminations. Also we have attempted to restrict the data to a more reliable subset. Three sources of information can be used to judge the validity of the remaining data:

- the subsequent calving dates
- the estimates of fixed effects
- the comparison of results from the full and restricted data sets

Most cows calve exactly when expected following a successful insemination which suggests the data is of high validity provided the regression on number of days from the end of the mating period is included in the model. The high repeatability of bull effects across years indicates that they are not too biased unless a bull suffers the same bias each year. The comparisons of bull solutions suggest that the use of the restricted data set and first inseminations only would be slightly more accurate than the use of the full data set. However this would mean that data from non-seasonal herds would be ignored and this should be investigated with a data set containing more NSW and Queensland data. It is possible that further examination of a more complete set of non-seasonal herds will result in a separate model for such data.

Factors affecting NRR

There are large effects on NRR from days since calving, insemination number within the mating period, year and herd, and small effects due to month of mating, cow age, cow and bull breed. Inclusion of these effects in the statistical analysis should increase the accuracy of the bull solutions.

The analysis of NRR is potentially a very useful source of information to the dairy industry concerning factors affecting fertility. The large size of the data set means that more accurate estimates are possible from this field data than from experimental data. For instance, the results show clearly the effect of days since calving on NRR. Therefore there is a need for further analysis of the data to determine if any remaining biases can be overcome.

Use of predicted bull effects

Both a permanent effect of a bull on NRR and an effect which is specific to a given year have been included in the analysis. The permanent effect is the more important as shown by the high repeatability. Predictions of these permanent effects are illustrated in Table 8 which shows that there is variation for NRR identifiable by bulls. Of the most used 100 bulls shown in the table some very widely used bulls were as low as 6% to 8% less fertile and others up to 5% more fertile than average. Predictions such as these are only likely for bulls with many inseminations recorded because bulls with fewer matings will be regressed more towards the mean.

This information could be used by industry in two ways:

- semen producers could increase the sperm concentration in semen from bulls with a low predicted NRR. If successful this would make the prediction self defeating. The high repeatability of bulls’ NRR shows that semen producers have not been able to do this in the past but that may be because they lacked accurate predictions of bulls’ NRR.

- Dairy farmers could avoid buying semen from bulls with a low NRR

In either case the information only becomes available after the end of the main AI season and so it is can only be used for decisions about the next year's mating season. Therefore it is the prediction of a bull's NRR next year (ie his permanent effect) which should be used by semen producers or dairy farmers. However semen producers might also find predictions for individual years useful so they could relate them to changes in semen processing or bull health.

If action by semen producers, based on predictions of a bull's NRR, will destroy the accuracy of that prediction, then it can be argued that these predictions should not be released to dairy farmers. However an alternative policy would be to release the predicted NRR publicly and to monitor the accuracy of these predictions in future years.

Use of inseminator predictions

There is also significant differences in NRR between inseminators but these are poorly repeatable between years. Among the 20 most active professional inseminators, the predicted permanent effects vary from –5.3% to +3.0%. Larger differences exist in the effects for a given season. This information could best be used by the inseminators themselves and the centres employing them. Both the predicted permanent effect and the effect for the last season would be useful.

Conclusions

- The method of defining inseminations as successes or failures appears to produce good estimates of a bull's effect on NRR. Restricting the data used to first inseminations by professional inseminators, in mature cows in seasonal herds increases the accuracy of the estimates of bull effects slightly. Additional methods of selecting more reliable subsets of data may be useful. Collaboration with John Morton and the use of the more controlled data set of the National Fertility Project should help to validate the results obtained from the herd recording data.

- There is variation between bulls in NRR and it is reasonably repeatable from year to year. Bulls used for a large number of inseminations vary in the NRR predicted in future years from approximately 8% below to 8% above average.

- Variation also exists among inseminators raising the possibility of remedial action to boost insemination success to levels achieved by the better inseminators. However the repeatability across years is only moderate perhaps because some remedial action is already taken.

- The organisations involved in the current study (NHIA, GA, VIAS and ADHIS) should consider how the results will be released and put in place mechanisms for routine analysis and release of the results.

- The combination of the insemination data with ADHIS data on dates of calving could be used to study the effect of many factors on cow fertility including the selection of sires with highly fertile daughters and the correction of milk yields for days open during ABV calculations.

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