

Major management factors associated with the variation in reproductive performance of Irish dairy herds



Final Report
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SUMMARY

BODY CONDITION SCORE

The results highlight the importance of BCS in achieving good reproductive performance. The likelihood of reproductive success was best predicted by BCS around the time of breeding and, for cows calving in good BCS (3.0 or greater) the level of BCS loss between calving and first service. A low BCS pre-calving (≤ 2.75) was associated with prolonged calving to first service, and calving to conception intervals. Very high BCS pre-calving (>3.5) results in excessive BCS loss (>0.5) post-calving. On the basis of these findings a pre-calving BCS of no greater than 3.25 is a sensible target for pasture-based spring calving systems in Ireland. It is necessary to maintain BCS at 2.75 or greater during the breeding season, and loss of body condition between calving and first service should be restricted to 0.5 BCS units.

UTERO-OVARIAN STATUS PRE-BREEDING AND FERTILITY TREATMENTS

Clear differences with respect to the likelihood of cows going back in calf were evident between ultrasound reproductive tract scores (URTS) recorded prior to breeding. Analysis highlighted that the level of routine fertility treatments (FT) being administered in these herds was unjustified. Many FT regimes were shown to be ineffective or detrimental. Appropriate FT, where cows have moderate to severe levels of uterine infection (URTS 3 to 5), was shown to give a positive response.

An analysis was undertaken to identify if factors exist that predispose cows to unfavourable URT scores. The analysis clearly indicated that a short calving to scan interval, older parities, calving difficulty and retention of the foetal membranes predispose cows to unfavourable URT scores. Cows in poor body condition around breeding are more likely to exhibit anoestrus (not cycle).

LATE EMBRYO MORTALITY

Just over 8% of cows suffered late embryo mortality ($>$ day 28). This ranged from 0% to 29% across the herds investigated. Of cows that suffered late embryo mortality, only 41% were scanned in-calf again at the end of the breeding season. High yielding cows ($>7,500$ kg) and cows that experienced serious calving difficulty were most at risk of late embryo mortality.

INSEMINATION FACTORS

No significant association was observed between category of AI operator (commercial or DIY AI operators) and likelihood of conception rate to first service. There was no difference between the level of variation observed within commercial AI or DIY operators. There were significant differences in the likelihood of pregnancy rate between different AI sires. Differences as large as 32 percentage units were observed between the best and worst sires. There was a tendency for reduced likelihood of pregnancy with the use of fresh semen compared to frozen-thawed semen. No significant difference in conception rate to first service was observed between AI and natural service.

CALVING DIFFICULTY

In total, 4.3% and 2.3% of cows were recorded as having serious calving difficulty and retained foetal membranes post-calving, respectively. Calving difficulty and retained foetal membranes decreased reproductive performance and reduced cow production. Factors contributing to calving difficulty and retained foetal membranes included calving period, lactation number, sex of the calf and breed of the calf. Serious calving difficulty resulted in a greater incidence of retained foetal membranes. Care in sire selection and calving management is needed to avoid trauma caused by calving difficulty.

HEIFER DEVELOPMENT AT FIRST CALVING

Age and weight at first calving are critical elements in achieving optimum production and fertility performance from replacement females. Calving heifers less than two years of age (2YO) resulted in lower milk yields compared to heifers calving at 2YO (5,771kg and 5,905kg, respectively). Heifers calving at more than 2YO produced higher yields (5,992kg). Calving heifers less than 2YO resulted in lower first service conception rates when compared to older animals at first calving. However, no difference in empty rates was observed. With the exception of days open (lower for animals calving younger in first lactation) second lactation production and reproductive performance was unaffected by age at first calving.

Weight at (prior to) first calving appeared to have a more long-term impact on animal performance. At first calving, light heifers (<530kg) produced significantly less milk compared to those calving at between 530kg and 600kg; 5,771kg and 5,905kg, respectively. Heavy heifers (>600kg) produced higher yields (6,130kg) compared to heifers calving down at 530kg to 600kg. Weight at first calving had no effect on milk composition. Empty rate at the end of first lactation was slightly higher for the heavy heifers. Weight at first calving also had a significant effect on milk yield in second lactation. Light heifers (<530kg at first calving) produced, on average, 6,785kg in second lactation compared to heifers calving down at 530 to 600kg in first lactation, which produced 7,027kg. Heavy heifers at first calving (>600kg) also produced higher yields in second lactation (7,301kg) compared to heifers calving down at 530 to 600kg. Milk composition was lower in second lactation for cows calving in first lactation at low body weights. Reproductive performance in second lactation was unaffected by weight at first calving.



Cow after Calving

INTRODUCTION

Milk production systems in Ireland are primarily grass-based and involve seasonal calving (Dillon *et al.*, 1995). In a typical spring-calving herd breeding starts on a fixed calendar date in spring, between late April and early May. The key breeding objective is to achieve the highest pregnancy rate in the shortest period of time after the start of breeding in order to achieve a compact calving pattern the following season (O'Farrell, 1994). A calving interval of around 365 days is targeted. Mee *et al.* (1999) showed a significant decline in calving rate to first service between 1991 and 1998 (0.9% per year) among dairy herds participating in the Moorepark Dairy Management Information System (Dairy MIS). This decline was substantiated by Evans *et al.* (2005), and associated risk factors were documented by Mee (2004a). The issue of reduced dairy cow fertility worldwide (Macmillan *et al.*, 1996; Beam and Butler, 1999; Royal *et al.*, 2000) presents considerable challenges for both genetic improvement and management strategies to help overcome the problem. Many countries have diversified their breeding goals to incorporate measures of survivability or functionality, as well as production traits (Philipsson *et al.*, 1994; Visscher *et al.*, 1994; Veerkamp *et al.*, 2002). This approach is essential and will likely lead to genetic improvement. However, it will inevitably take time. In the short to medium-term there is a need to identify farm-level factors where improvements can be made that will help improve reproductive efficiency.

Factors investigated in this project included:

- 1) **Body condition score** (energy balance) and its association with reproductive efficiency.
- 2) The application of **ultrasound scanning** to identify differences in utero-ovarian status pre-breeding (**ultrasound reproductive tract scoring**), and associations with subsequent reproductive performance. The effectiveness of commonly used **fertility treatments** and areas of management that may predispose cows to "poor" tract scores thus reducing the incidence of "problem cows".
- 3) The incidence of **late embryo mortality** and factors associated with its prevalence.
- 4) **Insemination factors**; whether differences in fertility performance are being achieved at farm level by DIY AI operators compared to commercial AI technicians, whether differences exist between frozen-thawed and fresh semen, or if different pregnancy rates are being achieved by AI compared to natural service.
- 5) **Calving problems** and their impact on subsequent cow performance.
- 6) The influence of **heifer development** at first calving on cow performance during first and second lactation.

MATERIALS & METHODS

DATA

The dataset employed in this project was collated in 1999 and 2000 (RMIS 4658). It comprised data from 78 spring-calving dairy herds with up to 13,000 cow lactations. Almost 4,500 cows had repeated records across the two years. The herds were representative of Irish pasture-based seasonal calving herds in which good practices for health and reproductive management were implemented. All herds were incorporated into the Dairy Management Information System (DairyMIS) run by Moorepark (Crosse, 1986). The DairyMIS is a recorder-based computerised system collecting detailed stock, farm inputs, production, and reproduction information on a monthly basis.

The mean calving date across the two years was February 28, with 58%, 27% and 15% of cows calving in January/February, March, and April or later, respectively. The mean conception rate to first service in year one and year two was 49% and 48%, respectively. However, there was large variation among herds, with actual herd averages ranging from 26% to 89% and 28% to 70% in years one and two, respectively. The mean calving to first service interval was 72 and 70 days for year one and year two, respectively, with herd averages ranging from 52 to 91 days and 58 to 91 days, respectively.



Tail paint

Test-day records for each individual cow were obtained from the Irish Dairy Recording Cooperative (IDRC). Milk recording was carried out in each herd at approximately 4-wk intervals. The lactation number of each cow was obtained from the IDRC files and calving date records were captured through the DairyMIS system. Calving difficulty information was recorded on standardised sheets and entered through the DairyMIS system.

Fifty-one of the 78 farms were visited seven to eight times from mid-January to mid-September to record body condition score (BCS) and body weight (BW). Visits were at intervals of 2.5 to 5 wk with visits being more frequent in early lactation. Each BW was recorded electronically, using portable weighing scales and Winweigh software package (Tru-test limited, 241 Ti Rakau Drive, Auckland, New Zealand). The scales were calibrated weekly against permanent scales at the Moorepark Dairy Production Research Centre and were calibrated again with known weights on arrival at each farm. BCS scores were on a scale of 1 to 5 (1 = emaciated, 5 = extremely fat) with increments of 0.25 (Lowman *et al.*, 1976).

Cows were examined prior to the start of the breeding season to record the ultrasound reproductive tract scores (URTS). The herds were subsequently visited at 40 to 50-d intervals to examine late calving cows pre-breeding and to detect pregnancy. Pregnancy examinations were carried out 28 or more d after insemination in cows that had not been observed in oestrus since insemination. Both pre-breeding and early pregnancy examinations were performed using a real time B-mode ultrasound scanner (Aloka SSD-210 DXII, Aloka Co. Ltd., Tokyo, Japan) equipped with a 5 MHz linear array transducer. At least eight weeks after the end of the breeding period all cows were examined by rectal palpation to confirm their pregnancy status.

Data were available from the DairyMIS database for each service indicating whether the cow was served by AI or natural service, and in the case of cows artificially inseminated, whether it was performed by commercial AI (CAI) or farmer do-it-yourself (DIY) AI. Details of whether the semen used was fresh or frozen-thawed and the identity of the AI sire were also available. All services recorded as AI were verified using service records provided by the relevant commercial AI companies. The identity of individual natural service sires was not available. A tele-questionnaire was conducted to obtain details such as age, experience at AI and the level of participation in retraining courses, for each AI (CAI and DIY) operator in the study.

Data were available from the DairyMIS database for each calving regarding the degree of calving assistance (scored 1 to 7) and incidence of retained foetal membranes (for greater than 12 hours) (0, 1). For analysis, the calving assistance scores were collapsed into three categories. Category 1 included cows that were unobserved calving or that were observed and unassisted at calving, category 2 included cows that received some (slight) assistance, while category 3 included cows

that had a high degree of difficulty, in some cases culminating in the use of a calving aid or veterinary assistance (including caesarean section).

Holstein UK and Ireland (HUKI) provided the breeding value for milk yield and the proportion of Holstein-Friesian genes for each sire/maternal grand sire contained in the data set. The proportion of Holstein-Friesian genes for individual cows was calculated as $0.5 \times \text{sire} + 0.25 \times \text{maternal grand sire}$, assuming that maternal grand dams to have zero Holstein-Friesian genes. The breeding value for milk yield (predicted difference for milk yield) for individual cows in the study was calculated similar to the proportion of Holstein-Friesian genes.

STATISTICAL ANALYSES

Descriptive statistics were generated using the PROC FREQ and PROC UNIVARIATE procedures in SAS (SAS Institute Inc., 1999). The impact of various independent variables on the fertility interval traits of interest e.g. calving to service/conception intervals, were investigated using the generalised linear model procedure (PROC GLM) in SAS. The statistical procedure implemented to investigate differences in the pregnancy rate variables e.g. PRFS and PR42 was the PROC LOGISTIC procedure (binomial distribution and logit link function) in SAS. For this analysis, independent variables of interest were categorised. One category was designated as the reference category for odds ratio (OR = 1). An OR of >1 implies increased likelihood and an OR <1 implies an inverse association. In this analysis, the reproductive outcome for each category of independent variable was compared to the reproductive outcome of the reference group for that variable. Analysis was undertaken to identify factors that predispose cows to unfavourable URT scores (URTS 2, 3, 4, 5, 6). A cumulative logit model approach using PROC LOGISTIC in SAS was used. Statistical significance for all models was defined as $P < 0.05$.

RESULTS & DISCUSSION

BODY CONDITION SCORE

After parturition, dairy cows experience a rapid increase in milk yield, a slow rise in DM intake, and increased mobilization of body adipose tissue (Garnsworthy, 1988; Nebel and McGilliard, 1993). It is normal for dairy cows to undergo a process of adipose tissue mobilization in early lactation (Bauman and Currie, 1980) because energy demand for milk production is greater than the energy provided by the diet. The severity and duration of the NEB may be influenced by genetic merit for milk yield (Buckley *et al.*, 2000; Grainger *et al.*, 1985; Veerkamp *et al.*, 1994) and energy density or quantity of the feed offered (Cowan, 1982). The reproductive performance of cows, particularly the probability of conception, may be negatively associated with the magnitude and duration of NEB in early lactation (Butler and Smith, 1989; Nebel and McGilliard, 1993; Domecq *et al.* 1997; Senatore *et al.*, 1996; Villa-Godoy *et al.*, 1988).

The objective of this study (see Buckley *et al.* 2003a) was to determine the association between reproductive efficiency and energy balance, as indicated by milk production, body condition score (BCS) and live weight performance. Here only the results pertaining to BCS are illustrated. Data from 74 spring-calving dairy herds with 6433 cows with fertility records were analysed. The data were recorded during 1999. The association with three key fertility variables was explored; submission rate in the first three weeks of the breeding season (SR21), pregnancy rate to first service (PRFS) and pregnancy rate after 42 days breeding (PR42). All analyses were adjusted for herd, lactation number, calving period, breeding value for milk yield (Pd milk), proportion of Holstein-Friesian genes, and degree of calving assistance. The proportion of Holstein-Friesian genes and genetic merit for milk production were adjusted for in the analyses with the objective of investigating the influence of management on reproductive performance.

From the BCS records, BCS at key periods in lactation were examined such as pre-calving, at first service, at herd start of breeding date, nadir BCS, DIM at which nadir was recorded, average BCS between 60 and 100 d of lactation. The BCS changes were also calculated, such as, from pre-calving to key periods thereafter and changes from key periods in lactation to later in lactation. In all 32 BCS (and change) variables were created. Those identified as important are highlighted.

Cows calving down in poor BCS had a longer calving to first service interval (CSI) and a longer calving to conception interval (CCI) (Table 1).

Table 1: Effect of pre-calving body condition score on calving to first service interval (CSI) and calving to conception interval (CCI) (days).

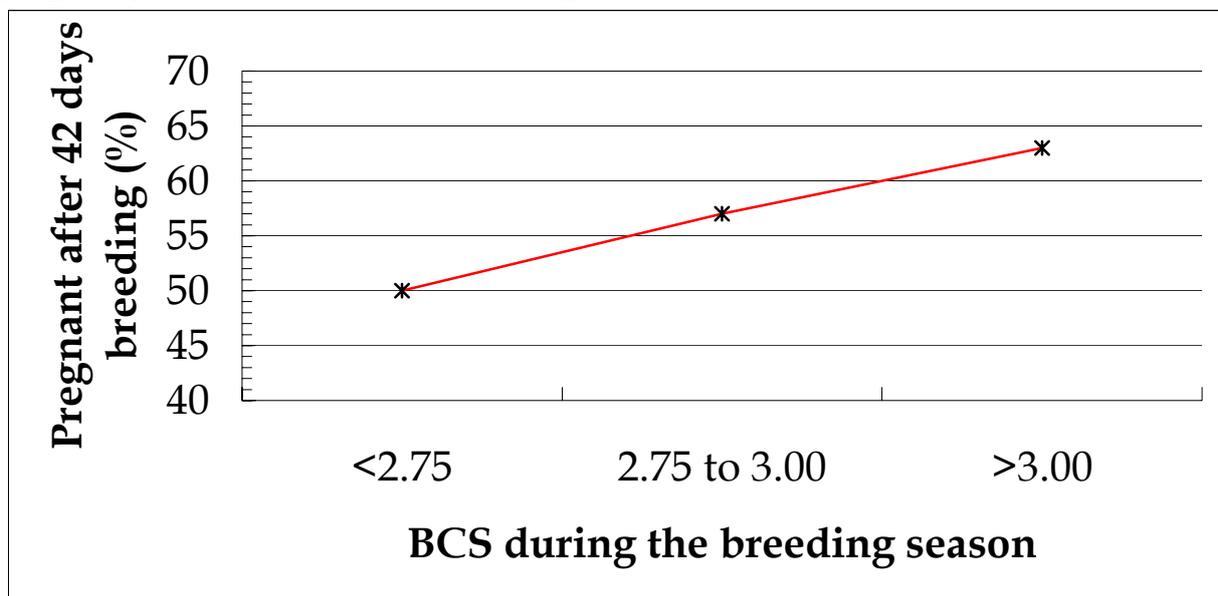
Pre-calving BCS category	CSI	CCI
≤2.50	67 ^a	84 ^a
2.75 to 3.00	62 ^b	80 ^b
3.25 to 3.50	59 ^c	77 ^c
≥3.75	58 ^d	75 ^c

Means, within columns, not having a common superscript differ significantly ($P < 0.05$).

A low average BCS between 60 and 100 d of lactation (around breeding) was associated with a lower probability of SR21. Cows with an average BCS of < 2.75 had a much lower SR21 (-9 percentage units) when compared to the reference group, which had a BCS of 2.75 to 3.0.

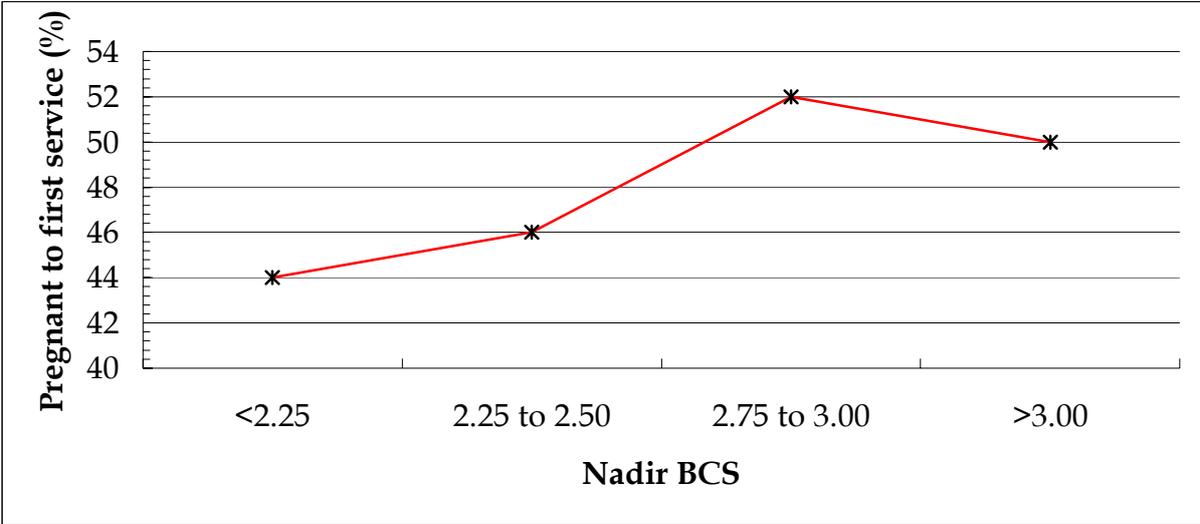
An average BCS between 60 and 100 d of lactation of < 2.75 was also associated with a lower ($P < 0.01$) probability of PR42 compared to the reference category (2.75 to 3.0) (Figure 1). An estimated decrease in PR42 of 7 percentage units compared to the reference category was observed. Cows with an average BCS between 60 and 100 d of lactation of > 3.0 tended ($P = 0.071$) to have a higher probability of becoming pregnant by day 42 of the breeding season (+6 percentage units).

Figure 1: Association between body condition score during the breeding season and pregnancy rate after 6 weeks of breeding.



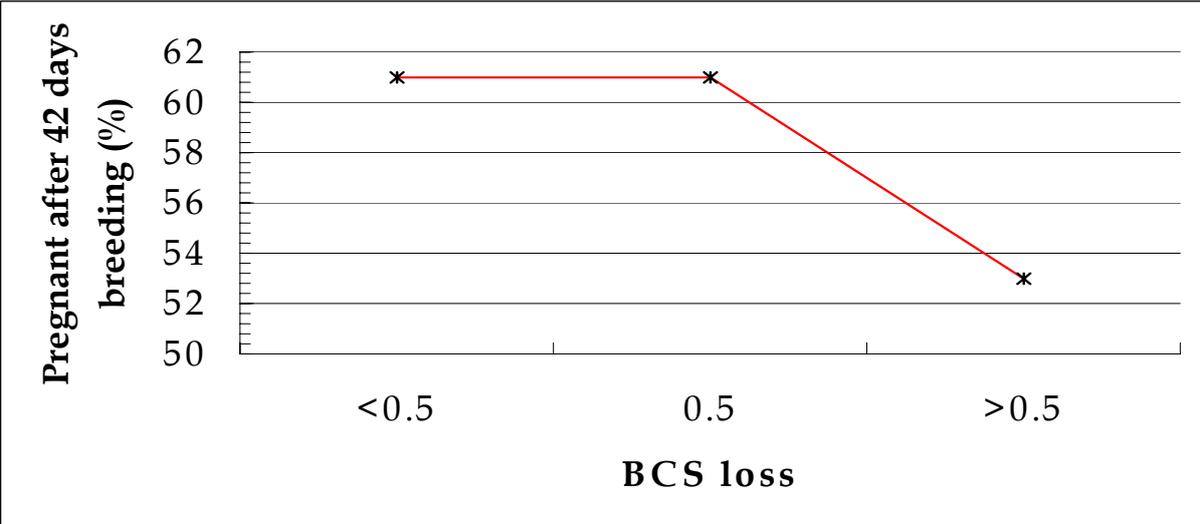
PRFS was most associated with nadir BCS (lowest BCS reached during lactation). Cows that reached a very low BCS (2.5 or lower) were less likely to become pregnant to first service; -8 percentage units when compared to the reference nadir BCS category (2.75 to 3.0) (Figure 2).

Figure 2: Association between nadir body condition score and pregnancy rate to 1st service.



Analysis of the data set using all cows did not identify any of the BCS change variables as potential predictors of SR21, PRFS or PR42. However, when the data set was restricted to cows with pre-calving BCS of greater than 3.0 (i.e. cows that had BCS to lose), it did transpire that cows experiencing excessive losses in BCS (>0.5 units of BCS) between pre-calving and the start of the breeding season were significantly less likely to conceive by day 42 of the breeding season (Figure 3). This corresponds to an estimated reduction in PR42 of 8 percentage units when compared to cows losing up to 0.5 units of BCS.

Figure 3: Association between body condition score change from pre-calving to start of breeding (for cows with a pre-calving body condition score of >3.0) and pregnancy rate after 6 weeks breeding.



These results highlight the importance of BCS in achieving good reproductive performance. The likelihood of reproductive success was best predicted by BCS around the time of breeding and, for cows calving in good BCS, BCS loss between

calving and first service. However, a low BCS pre-calving was associated with a prolonged CSI and CCI. Incidentally, pre-calving BCS does influence BCS change in early lactation. A BCS loss of greater than 0.5 BCS units between pre-calving and first service occurred in 30%, 47%, and over 60% of cows that had a pre-calving BCS of 3.25, 3.5, and greater than 3.5, respectively. On the basis of this, a pre-calving BCS of no greater than 3.25 is a sensible target for pasture-based spring calving systems in Ireland.

A waterproof chart of standard operating protocol (SOP) entitled “Body condition scoring - Benefits and guidelines” was jointly produced by Teagasc Moorepark and the Irish Farmers Journal to promote and the technique and benefits of body condition scoring dairy cows (Buckley *et al.*, 2002).

BODY CONDITION SCORING
Benefits & Guidelines

Teagasc
Association of Food Development Agencies

Three primary points assessed by handling:

- Pins
- Loin - short ribs
- Ribs

Four secondary points assessed visually:

- Backbone
- Hip bone
- Eye-muscle area
- Shoulder

What is Body Condition Scoring?

Body condition scoring is the appraisal of cow fat reserves through a combination of handling and visual assessment. It allows the subjective assessment of thin and fat cows regardless of frame size or breed on a scale of 1 to 5 (1 = extremely thin, 5 = extremely fat) with increments of 0.25.

Run hand firmly over 3 primary reference points

The flat hand is used to assess the degree of fat cover or bone prominence on the loin and rib areas.

LOIN

PINS

RIBS

The fingers are used to assess the area around the tail head and pin bones.

Visual Scoring Alone is Not Recommended!

UTERO-OVARIAN STATUS PRE-BREEDING AND FERTILITY TREATMENTS

Utero-ovarian status pre-breeding

Assessment of the dairy cow's reproductive tract post partum may be used to decide whether uterine involution is progressing normally, ovarian cyclicity has resumed and to detect utero-ovarian pathologies. Traditionally this has been achieved by rectal or vaginal palpation or by vaginoscopy or more recently using an intra-vaginal scoop (Mee, 2007). With the advent of relatively inexpensive ultrasound equipment, veterinary practitioners are increasingly using transrectal ultrasonography to examine the reproductive tract of dairy cattle. A number of studies have suggested that scoring the reproductive tract pre-breeding using vaginoscopy, rectal palpation or ultrasound may identify cows or maiden heifers at risk of poor reproductive performance (Tian, 1990; Aslan *et al.*, 2002).

Ultrasound examinations (7,797) were carried out on 5,734 Holstein-Friesian cows in 62 spring-calving herds during 1999 and 2000. Each cow was examined once pre breeding. From these data, a six-point ultrasound scoring system has been developed (Mee *et al.*, 2008). Such a scoring system is, however, only of benefit if it identifies cows truly at risk of impaired fertility, and importantly, results in effective corrective action. The use of fertility treatments to improve reproductive efficiency is becoming increasingly popular. From a producer perspective, there is cost associated with using antiseptics, antibiotics and hormonal treatments. And, from a consumer point of view, there may be concern long-term regarding the sustainability (or acceptability) of using antibiotics and hormonal treatments in food producing animals. It is therefore imperative that the effectiveness of commonly used fertility treatments is investigated, and that management factors that may predispose cows to "poor" reproductive tract scores are identified thus reducing the incidence of "problem cows" and the use of fertility treatments.

The ultrasound reproductive tract scoring (URTS) system was based on transrectal scanning of both ovaries and the uterus as described in Table 3. The uterine descriptors were based on cross sectional images of both uterine horns to determine luminal shape and intraluminal fluid quantity and quality.

A URTS of 1 was assigned to cows with a normal uterus, showing infolding of the endometrium forming a spoke-wheel shape that may contain some nonechogenic intraluminal fluid if peri-ovulatory (Fig 1). These cows had recommenced ovulation post partum (Figure 5) as indicated by the presence of one or more corpora lutea. Cows scored as 1 were likely to have completed uterine involution. Cows with a URTS of 2 had almost completed uterine involution and were ovulatory (Figure 6). This was evidenced by a small volume of mixed echogenicity fluid in the uterine lumen with an infolded endometrium (Fig 2). The uterus of these cows was indistinguishable from those of cows with a URTS of 1 by palpation per rectum. Cows with a URTS of 3 had partially completed uterine involution, had moderate endometritis and were ovulatory (Figure 7). A moderate volume of mixed echogenicity fluid in the uterine lumen, which distended the lumen but not the

endometrial folds was visible (Fig 3). The uterus of these cows could not be distinguished from those with a URTS of 1 or 2 by palpation per rectum. A URTS of 4 was assigned to cows that had partially completed uterine involution or had moderate endometritis and were anovulatory. A URTS of 5 was assigned to cows with pyometra with a persistent corpus luteum (Figure 8). In these cows the uterus is distended by a large volume of mixed echogenicity fluid containing hyperechoic particles giving a 'snow storm' appearance (Fig 4). The intrauterine fluid exhibited a wave-like motion when the uterus was ballotted. Infolding of the endometrium was absent. The thickness of the uterine wall and dilation of mesometrial blood vessels was variable. The uterus of these cows could be distinguished from those with a URTS of 1, 2, 3 or 4 by palpation per rectum. Cows with a URTS of 6 had a normal uterus and were anovulatory, i.e. they had not recommenced ovulation post partum as indicated by the absence of one or more corpora lutea or peri-ovulatory signs. The uterus of these cows could be distinguished from those with a URTS of 5, but not from those with a URTS of 1, 2, 3 or 4, by palpation per rectum.

The detection of a corpus luteum (CL) indicated that ovulation had occurred. Differentiation between a CL and a luteinized follicle was based on the criteria of Hanzen *et al.* (2000); a CL had a lacuna of less than 25mm and a wall thickness of >5mm. The incidence of cows with cystic ovarian follicles was also recorded; follicular cysts were diagnosed by the presence of a follicular antrum with an internal diameter greater than or equal to 25mm and a wall less than or equal to 3mm and partially luteinized follicular cysts were diagnosed by the presence of a follicular antrum with an internal diameter greater than or equal to 25mm and a wall greater than 3mm. In addition, adhesions and abscesses of the reproductive tract were recorded. Adhesions were diagnosed by the presence of strands or single or multiple foci of hyperechoic scar tissue and abscesses were detected by the presence of a wall surrounding heterogeneous contents, which did not swirl upon ballottement.

The uterine and ovarian findings were recorded in pro forma triplicate sheet books. One copy of the recordings was made available to the herd owner/manager.



Scanning

Table3: Description of ultrasound reproductive tract scores (URTS).

URTS	Uterus			Ovaries
	Contents	Lumen	Involution	
1	No fluid or small volume of black fluid	Spoke-wheel shape with infolding of the endometrium.	Complete	CL *
2	Small volume of mixed echogenicity (grey or white) fluid	Spoke-wheel shape with infolding of the endometrium and enlarged centre	Almost complete	CL
3	Moderate volume of mixed echogenicity (grey or white) fluid	Stellate distended shape with visible endometrial folds	Partially complete	CL
4	Small/moderate volume of mixed echogenicity (grey or white) fluid	Spoke-wheel shape with enlarged/stellate centre	Partially complete	No CL
5	Large volume of mixed echogenicity (grey) fluid with hyperechoic foci	Circular shape without infolding of the endometrium and variable uterine wall thickness and dilation of the mesometrial blood vessels	Pyometra	CL
6	No fluid	Spoke-wheel shape with infolding of the endometrium.	Complete	No CL

* Corpus luteum may be absent in the presence of peri-ovulatory signs; circular pre-ovulatory follicle (>15mm) with a well defined wall which may exhibit dorso-ventral specular reflection, accumulation of non-echogenic intrauterine, intracervical or intravaginal mucous, increased thickness and heterogeneous, hypoechoic appearance of the uterine horns, of which there are fewer cross sections



Figure 5: Ultrasonogram of a cross section of a uterine horn showing a spoke-wheel shaped lumen (URTS 1)



Figure 6: Ultrasonogram of a cross section of a uterine horn showing a spoke-wheel shaped lumen with an enlarged centre filled with a small volume of mixed echogenicity fluid (URTS 2).



Figure 7: Ultrasonogram of a cross section of a uterine horn showing a stellate shaped lumen filled with a moderate volume of mixed echogenicity fluid (URTS 3).



Figure 8: Ultrasonogram of a cross section of a uterine horn showing a circular shaped lumen filled with a large volume of mixed echogenicity fluid (URTS 5).

This study is the largest to report on the ultrasonographic utero-ovarian status of dairy cows before insemination. In total, 11.4% of cows were diagnosed as anoestrus (URTS 4 and 6) at the start of the breeding season. A substantial proportion of cows (22%) had a URTS of 2. The significantly shorter calving to scan interval of these cows (53 days) compared to cows with a URTS of 1 (61 days) indicates that these cows had not fully completed involution. However, the mean calving to scan interval of cows with a URTS of 2 is longer than that traditionally associated with completion of uterine involution. Less than 10% of cows had partially completed uterine involution (URTS 3 and 4; 5.6%) or had pyometra (URTS 5; 2.4%) at the start of the breeding season.

The mean (s.d.) interval between calving and the pre-breeding scan was 57 days (17.5) with a range from 15 to 117. The majority of cows (92%) were scanned 30 days or more post partum. The overall and between herd prevalence of URTSs and the interval between calving and examination for each URTS is shown in Table 2. The majority of cows (88.6%) had a CL by the time of the examination while in a minority of cows (11.4%) there was no CL at examination (URTS 4 or 6), with wide variation between herds (1.9% to 25.9%). The majority of cows (70.4%) had completed uterine involution (URTS 1 and 6) by the time of the examination. Very few cows had pyometra (URTS 5), (2.4%). The calving to scan interval was significantly different ($P < 0.05$) between each of the URTSs (Table 2).

Table 4: Prevalence of ultrasound reproductive tract scores (URTS) and interval between calving and examination (mean, SE) in 5,734 dairy cows in 62 herds.

URTS	Cows (%)	Herd range (%)	Calving to scan interval (days)
1	62.3	31-81	60.8 (0.29) ^a
2	21.6	11-41	53.1 (0.43) ^b
3	2.3	0-7	37.7 (1.24) ^c
4	3.3	0-17	35.3 (1.03) ^d
5	2.4	0-9	46.5 (1.21) ^e
6	8.1	0-20	50.2 (0.67) ^f

Means, within columns, not having a common superscript differ significantly ($P < 0.05$).

A total of 300 cows over the two years (3.9%) were identified as having one or more cystic ovarian follicles. This ranged from 0 to almost 15% across herds. The mean (s.d.) calving to scan interval was 52 days (17.3). Ninety three per cent of cows with one or more ovarian cysts had a URTS of 1. Of the remaining cows, 3.7%, 0.3%, 0.7%, 1.7% and 0.7% had URTS scores of 2, 3, 4, 5, and 6, respectively. Almost 1.2% of all cows scanned had adhesions or abscesses present on the reproductive tract. This ranged from 0 to almost 15% across herds.

Efficacy of fertility treatments

Excellent data pertaining to fertility treatments (FT) used on the farms were available. Fertility treatments were administered by the local veterinary practitioner or by the farmer, not by the research team. Treatments administered included prostaglandins (e.g. cloprostenol, Estrumate®, Schering Plough Animal Health Ireland; dinoprost, Lutalyse®, Pharmacia Ltd., UK and luprostinol, Prosolvin®, Intervet Ireland Ltd.), oestradiol benzoate (Oestradiol Benzoate®, Intervet Ireland Ltd.), intravaginal progesterone releasing devices (CIDR®, InterAg, New Zealand and PRID® Interpharm Animal Health Ltd. Ireland), gonadotrophins (e.g. buserelin, Receptal®, Intervet Ireland Ltd.; gonadorelin, Fertagyl®, Intervet Ireland Ltd and chorionic gonadotrophin, Chorulon®, Intervet Ireland Ltd), and intrauterine infusions (oxytetracycline hydrochloride, Metriject®, Intervet Ireland Ltd and iodine solutions). No attempt was made to differentiate between the relative efficacies of different commercial products. Only treatments, which could possibly have had an effect on the scan result, were included in the statistical analyses. The most commonly used treatment regimes are listed in Table 5.

The treatment to service interval was calculated from the first day of a treatment administration to the first service post partum. Initial analysis included all FT regardless of the scan to treatment or treatment to service intervals (unrestricted dataset; Table 6). A subsequent analysis was restricted to treatments where the FT commenced within 14 days of the scan and where the interval between FT administration was limited to include only animals with first services that closely followed treatments (restricted dataset: Table 6a). This was done by calculating the maximum number of days required to administer each treatment regime and allowing a maximum of 7 days thereafter for a first service to occur. Only cows

scanned prior to the start of breeding were included in both analyses (for more detail see Buckley *et al.*, 2008a).

Table 5: Typical treatment schedules administered by the local veterinary practitioner or farmer to cows based on URTS after ultrasound scanning and before first service post partum.

Treatment code	Treatment administered	Day of treatment schedule
PG	Prostaglandin	0
PG & OB	Prostaglandin	0
	Oestradiol benzoate	1
PG & OB & UI	Prostaglandin	0
	Oestradiol benzoate	1
	Uterine infusion	1d post oestrus
UI	Uterine infusion	0
OB & UI & P4/OB/PG	Oestradiol benzoate	0
	Uterine infusion & insert progesterone device & inject oestradiol benzoate	2
	Prostaglandin	9
	Inject oestradiol benzoate & remove progesterone device	10
P4/OB/PG	Insert progesterone device & inject oestradiol benzoate	0
	Prostaglandin	7
	Inject oestradiol benzoate & remove progesterone device	8
PG & OB & UI & P4/G/OB/PG	Prostaglandin	0
	Oestradiol benzoate	2, 5 & 8
	Uterine infusion	10
	Insert progesterone device & inject gonadotrophin	12
	Prostaglandin	19
	Inject oestradiol benzoate & remove progesterone device	20

Table 6: Number of cows administered treatments or untreated in each URTS category after ultrasound scanning and before first service post partum (unrestricted dataset).

	URTS					
	1	2	3	4	5	6
Untreated	3927	1130	66	98	33	208
PG	316	89	9			
PG & OB	153	51	7			
PG & OB & UI		56	54			
UI		51	1			
OB & UI & P ₄ /OB/PG				59	6	
P ₄ /OB/PG				44		258
PG & OB & UI & P ₄ /G/OB/PG				5	55	
Total treated	469	247	71	108	61	258

PG = prostaglandin, OB = oestradiol benzoate, UI = uterine infusion, P₄/OB/PG = progesterone plus OB plus PG, P₄/G/OB/PG = progesterone plus gonadotrophin plus OB plus PG.

Table 6a: Number of cows administered treatments or untreated in each URTS category after ultrasound scanning and before first service post partum (restricted dataset).

	URTS					
	1	2	3	4	5	6
Untreated	3927	1130	66	98	33	208
PG	229	58	5			
PG & OB	103	30	4			
PG & OB & UI		34	21			
UI		21	1			
OB & UI & P ₄ /OB/PG				28		
P ₄ /OB/PG				20		138
PG & OB & UI & P ₄ /G/OB/PG					23	
Total treated	332	143	31	48	23	138

PG = prostaglandin, OB = oestradiol benzoate, UI = uterine infusion, P₄/OB/PG = progesterone plus OB plus PG, P₄/G/OB/PG = progesterone plus gonadotrophin plus OB plus PG.



The reproductive outcomes observed for the various URT scores, and for cows treated and untreated within URT score, within the unrestricted and restricted datasets were almost identical. Therefore, only results pertaining to the restricted dataset are presented (Table 7). Differences in pregnancy rate to first service were observed between untreated cows with URT scores 2, 3, 5 and 6 when compared to URTS 1 ($P \leq 0.001$). FT resulted in a significantly lower PRFS with URTS 1 (8 percentage units) and URTS 6 (12 percentage units), compared to cows with the same URTS receiving no FT ($P < 0.05$). Intervention with URTS 2 and URTS 4 had no significant effect on PRFS, although was tending towards significance with URTS 4 ($P = 0.0896$). However, a positive response in PRFS to FT was observed with URTS 3 (+22 percentage units) and URTS 5 (+29 percentage units) ($P < 0.05$). With the exception of URTS 6, FT had no significant effect on PREG. However, differences in scan to conception interval (SCI) were evident as a result of FT (for URTS 3 and 5).

Table 7: Effect of ultrasound reproductive tract score (URTS) and fertility treatment (FT) within URTS on pregnancy rate to first service (PRFS), scan to first service interval (SSI), overall pregnancy rate (PREG) and scan to conception interval (SCI) for the restricted dataset.

URTS	FT	PRFS (%)	SSI (days)	PREG (%)	SCI (days)
1	Untreated	54	17	88	32
	Treated	46	17	84	35
2	Untreated	48	16	84	32
	Treated	42	14	87	37
3	Untreated	31	16	86	41
	Treated	53	16	72	24
4	Untreated	46	21	84	41
	Treated	30	16	72	41
5	Untreated	14	23	58	58
	Treated	43	26	62	38
6	Untreated	42	22	86	40
	Treated	30	17	74	39

Factors associated with URTS

Analysis was undertaken to identify factors that predispose cows to unfavourable URT scores (URTS 2, 3, 4, 5, 6). A cumulative logit model approach using PROC LOGISTIC in SAS was used. A range of variables were tested including interval from calving to ultrasound examination, calving period, lactation number, BCS at calving and at different stages during lactation, BCS change post calving, interval from calving to nadir BCS, milk production variables such as peak milk, peak SCM yield and milk composition, proportion of Holstein-Friesian genes, the degree of calving assistance, and the occurrence of retained after birth. All models were adjusted for the effect of herd and year.

Two separate sets of analyses were performed to investigate the occurrence of favourable and less favourable URTS within cyclic (URTS 1, 2, 3 and 5) and non-cyclic (URTS 4 and 6) cows. The dependent variable investigated in the first analysis

consisted of four ordered categories (URTS 1, 2, 3 and 5). A cumulative logit model was used to assess the likelihood of having a lower (more favourable) URTS compared to having a higher (less favourable) score. All numerical variables were quartiled or categorised into three or four groups. For categorical variables one of the groups was designated as the reference category for odds ratio (OR = 1). An OR of > 1 implies increased likelihood of having a more favourable URTS and an OR < 1 implies an inverse association. The model building process involved several steps. Firstly, for the three sets of independent variables reflective of milk production potential, body condition score and condition score change (see Buckley et al. 2003), separate multivariate backward cumulative logit regression models were constructed. These models identified the milk production variable, body condition score variable and condition score change variable which should be used in subsequent modelling. During this step, only cows that had a value for all variables within each of the three sets of analyses were used. The outcomes of this step were incorporated into a stepwise cumulative logit regression model which represented the likelihood of having a more favourable URTS as a function of interval from calving to ultrasound examination, calving period, lactation number, nadir BCS, BCS change from calving to nadir, peak daily milk yield, lactation average milk fat, protein and lactose content, proportion of Holstein-Friesian genes, the degree of calving assistance, and the occurrence of retained after birth. The final model was run incorporating the maximum number of cows i.e. all cows that had a value for each of the retained independent variables. The final model was assessed for proportional odds, which assumes that irrespective of how the dependent variable is dichotomised the effects of the independent variables are always the same. The validity of this assumption was tested using the score test. The proportional odds assumption was invalid and subsequently three dichotomised logistic regression models were considered where the dependent variable was dichotomised as follows: i) URTS 1 versus URTS 2, 3 and 5; ii) URTS 1 and 2 versus URTS 3 and 5, and iii) URTS 1, 2 and 3 versus URTS 5. All models were adjusted for herd and year.

The dependent variable investigated in the second analysis (URTS 6 versus URTS 4) were binary data (0, 1). A similar approach as described above was performed in determining the final model which represented the likelihood of having a URTS of 6 as a function of interval from calving to ultrasound examination, calving period, lactation number, BCS at the start of the breeding season, BCS change from calving to the start of the breeding season, solids corrected peak daily milk yield, lactation average milk fat, protein and lactose content, proportion of Holstein-Friesian genes, the degree of calving assistance, and the occurrence of retained after birth.

The final models were assessed using the Hosmer-Lemeshow test (Hosmer and Lemeshow, 1989) for goodness of fit. According to this test the model fitted the data well ($P > 0.05$). Multicollinearity with the independent variables was investigated using condition number (Montgomery et al, 2001) and also no evidence of departures were observed. Coefficient of determination (adjusted R^2) was used to estimate the proportion of variation explained by each model (Nagelkerke, 1991).

Variables associated with an increased likelihood of obtaining a URTS of 2, 3 or 5 (i.e. an unfavourable score) compared to URTS 1 are shown in Table 8. Calving to scan interval, period of calving, parity, the degree of calving assistance, and the occurrence of retained foetal membranes were all found to influence the category of URTS. Decreasing calving to scan interval and later calving date was associated with a lower likelihood of URTS 1. Compared to cows calved more than 75 days, cows calved 45 days or less were less likely to obtain a URTS of 1 (19 percentage units less). Age had a dramatic effect on the likelihood of cows having a URTS of 1 prior to breeding. Compared to first lactation cows all other parity groups had a significantly lower likelihood of a being scored with a URTS of 1. Cows in lactation 5 or greater had a substantially reduced incidence of URTS 1 (estimated at 44%) compared to cows in first lactation (estimated at 85%). Calving difficulty and retained foetal membranes post-calving also resulted in a reduced likelihood of URTS 1. Serious calving difficulty (category 3) reduced the incidence of URTS 1 by approximately 10 percentage units, while retained foetal membranes on average resulted in a 16 percentage unit reduction in URTS 1.

Table 8. Association between calving to scan interval, calving period, parity, degree of calving assistance, and occurrence of retained foetal membranes and the likelihood of occurrence of a URTS of 1 compared to a URTS of 2, 3 or 5 pre-breeding (n=6,693 observations).

	OR	95% CI	P-value
Calving to scan interval (days)			
≥ 76	1		
61 to 75	0.93	0.75 - 1.16	NS
46 to 60	0.83	0.64 - 1.08	NS
≤ 45	0.46	0.34 - 0.63	<0.001
Calving day of year			
≤ 37	1		
38 to 50	0.85	0.69 - 1.04	NS
51 to 67	0.76	0.60 - 0.96	<0.05
≥ 68	0.38	0.28 - 0.50	<0.001
Parity			
1	1		
2	0.45	0.37 - 0.56	<0.001
3	0.25	0.20 - 0.31	<0.001
4	0.21	0.16 - 0.26	<0.001
≥ 5	0.15	0.12 - 0.18	<0.001
Degree of calving assistance			
1	1		
2	0.89	0.76 - 1.04	NS
3	0.68	0.50 - 0.93	<0.05
Retained foetal membranes			
No	1		
Yes	0.53	0.38 - 0.75	<0.001

OR = Odds ratio, CI = confidence interval, NS = P > 0.05

Similar trends were evident with regard to the likelihood of occurrence of URT scores 1 or 2 compared to scores of 3 or 5. Cows that were calved longer were more likely to have a favourable URTS score by the start of the breeding season. Cows that had 4 or more parities had a significantly lower likelihood of achieving a favourable URTS. Calving difficulty and retained foetal membranes result in a significantly reduced likelihood of obtaining a favourable URTS.

Table 9. Association between calving to scan interval, calving period, parity, degree of calving assistance, and occurrence of retained foetal membranes and the likelihood of occurrence of a URTS of 1 or 2 compared to a URTS of 3 or 5 pre-breeding (n=6,693 observations).

	OR	95% CI	P-value
Calving to scan interval (days)			
≥ 76	1		
61 to 75	0.72	0.37 - 1.40	NS
46 to 60	0.40	0.19 - 0.81	<0.05
≤ 45	0.15	0.07 - 0.33	<0.001
Calving day of year			
≤ 37	1		
38 to 50	0.72	0.42 - 1.21	NS
51 to 67	0.90	0.50 - 1.61	NS
≥ 68	0.50	0.26 - 0.95	<0.05
Parity			
1	1		
2	0.80	0.53 - 1.22	NS
3	0.71	0.47 - 1.09	NS
4	0.48	0.31 - 0.73	<0.001
≥ 5	0.49	0.33 - 0.72	<0.001
Degree of calving assistance			
1	1		
2	0.59	0.43 - 0.79	<0.001
3	0.38	0.23 - 0.62	<0.001
Retained foetal membranes			
No	1		
Yes	0.24	0.15 - 0.39	<0.001

OR = Odds ratio, CI = confidence interval, NS = P > 0.05

Table 10 illustrates that later calving cows, older cows, cows with increased calving difficulty and those that had retained foetal membranes had a lower likelihood of a more favourable URTS or an increased chance of being diagnosed with a URTS of 5 (pyometra). Older cows (parity 5 or greater) are expected to have a slightly increased incidence of URTS 5 compared to first lactation cows (+ 2 percentage units). Compared to the average (2.4%), cows experiencing severe calving difficulty (category 3) or retained foetal membranes are estimated to result in approximately 8% and 15% URTS 5, respectively.

Table 10. Association between calving to scan interval, calving period, parity, degree of calving assistance, and occurrence of retained foetal membranes and the likelihood of occurrence of a URTS of 1, 2 or 3 compared to a URTS of 5 pre-breeding (n=6,693 observations).

	OR	95% CI	P-value
Calving to scan interval (days)			
≥ 76	1		
61 to 75	0.79	0.35 - 1.77	NS
46 to 60	0.46	0.19 - 1.09	0.08
≤ 45	0.31	0.12 - 0.82	<0.05
Calving day of year			
≤ 37	1		
38 to 50	0.55	0.28 - 1.10	NS
51 to 67	0.59	0.27 - 1.25	NS
≥ 68	0.36	0.15 - 0.84	<0.05
Parity			
1	1		
2	0.91	0.53 - 1.58	NS
3	0.84	0.48 - 1.49	NS
4	0.68	0.39 - 1.20	NS
≥ 5	0.53	0.32 - 0.87	<0.05
Degree of calving assistance			
1	1		
2	0.54	0.37 - 0.80	<0.01
3	0.27	0.08 - 0.24	<0.001
Retained foetal membranes			
No	1		
Yes	0.14	0.15 - 0.39	<0.001

OR = Odds ratio, CI = confidence interval, NS = P > 0.05

Within cows that were not cycling when scanned pre-breeding (URTS 4 and 6) calving to scan interval, parity and BCS were associated with the likelihood of being assigned a URTS of 4 as opposed to 6 (Table 11). There was a greater tendency for cows with a URTS of 6 to be calved longer. Younger cows were more likely to have a URTS 6 compared to older cows. Also a URTS of 6 was associated with poor BCS at breeding.

Table 11. Association between calving to scan interval, calving period, parity, degree of calving assistance, and occurrence of retained foetal membranes and the likelihood of occurrence of a URTS of 6 compared to a URTS of 4 pre-breeding (n=766 observations).

	OR	95% CI	P-value
Calving to scan interval (days)			
≥ 76	1		
61 to 75	0.52	0.16 - 1.65	NS
46 to 60	0.64	0.21 - 1.97	NS
≤ 45	0.10	0.04 - 0.30	<0.001
Parity			
1	1		
2	1.42	0.75 - 2.69	NS
3	0.55	0.29 - 1.02	0.06
4	0.49	0.23 - 1.03	0.06
≥ 5	0.22	0.12 - 0.40	<0.001
BCS at breeding			
≤ 2.5	1		
2.75 to 3.00	0.48	0.29 - 0.79	<0.01
> 3.25	0.42	0.25 - 0.69	<0.001

OR = Odds ratio, CI = confidence interval, NS = $P > 0.05$

Genetic analysis of utero-ovarian scores

Genetic analysis (see Buckley *et al.*, 2008b) carried out on these data indicated that the utero-ovarian traits investigated were heritable but the h^2 estimates obtained were low (less than 0.08). However, they are easily measured and recorded and are favorably genetically correlated with conventional fertility traits. Although the incidence of delayed uterine involution/severe uterine infection tends to be low, the results of this study indicate that genetic selection for early postpartum resumption of cyclicity may lead to an increased genetic predisposition for decreased uterine health. Of practical significance also, was the finding that with the exception of cyclicity prior to the breeding season, the repeatability of the utero-ovarian traits in subsequent breeding seasons is low also (less than 0.04).

Summary

The URT scores as defined by Mee *et al.* (2008), recorded prior to first service did reflect subsequent reproductive performance. Clear differences between URT scores were evident with respect to the likelihood of going back in calf. The analysis also highlights that the level of routine FT being administered in these herds was

unjustified. Most of the treatments carried out resulted in no benefit. Appropriate FT where cows have moderate to severe levels of uterine infection (URTS 3 to 5) will likely have a positive response. An analysis was carried out to identify if factors exist that predispose cows to unfavourable URT scores. The analysis clearly indicates that a short calving to scan interval, increased parity, calving difficulty and retained foetal membranes do predispose cows to unfavourable URT scores. Cows in poor body condition around breeding are more likely to exhibit anoestrus (not cycle). Evidence presented also indicates some level of genetic predisposition to various URTS.



LATE EMBRYO MORTALITY

Fertilisation rate in the cow is reported to be close to 90% (Sreenan and Diskin, 1983). However, recent documentation of pregnancy rate in Irish dairy herds indicates a figure of around 48% (Buckley *et al.* 2003a). Thus, early embryonic mortality accounts for high reproductive wastage. In the majority of cases, embryo death occurs within the first 8 to 16 days after fertilisation. When this occurs the cow simply returns to heat at a regular interval and the farmer is unaware that the cow has been pregnant. Later embryo death will result in delayed return to heat. Literature estimates suggest that between 5% and 20% of pregnancies between day 28 and 60 of gestation are lost due to late embryo death (Silke *et al.*, 2002). A cow not returning to heat 21 days after insemination may be presumed pregnant by the farmer. Therefore, late embryo death is a frustrating problem. The object of this study was to determine the incidence of late embryo mortality in Irish dairy herds, and to examine associations with common cow factors.

The data used comprised 11,286 lactations from 78 spring-calving dairy herds. The data were recorded during 1999 and 2000. Embryo mortality was defined in three ways. 1) where a cow was scanned at 28 to approximately 35 days post-service and embryo mortality was detected by the absence of an embryonic heartbeat with or without other signs of pregnancy failure such as detached foetal membranes, reduced embryo size, reduced volume of placental fluid, and increased echogenicity of placental fluid or the embryo, 2) where a cow was confirmed pregnant by ultrasonography at 28 to approximately 35 days post-service and later returned to heat or was scanned not in-calf, 3) the combination of definitions 1 and 2. The incidence of late embryo mortality as defined in 1 and 2 above was similar at 3.94% and 4.20%, respectively. Therefore a total of 8.14% of cows suffered late embryo mortality. This ranged from 0% to 29% across the herds.

Only 41% of cows that suffered late embryo mortality were in-calf when the final pregnancy diagnosis was carried out late in the year (October/November). This indicates that just over 33% of all cows not in-calf at the end of the breeding season did conceive earlier in the breeding season but subsequently suffered embryo mortality.

Associations with factors such as year, parity, calving period, calving to first service interval, proportion of Holstein-Friesian genes, BCS, milk yield and degree of calving assistance showed that high milk yield and serious calving difficulty were associated with increased risk of late embryo mortality. Cows yielding over 7,500kg had a significantly higher (11% v. 7%) incidence of late embryo deaths compared to cows yielding less than 6,000kg. Cows that had serious calving difficulty were twice as likely to suffer late embryo mortality compared to cows that calved unassisted (8% v. 16%).



Fetus

and



Dead fetus

INSEMINATION FACTORS

In the majority of Irish dairy herds artificial insemination (AI) is used for approximately six weeks at the start of the seasonal breeding period to generate replacement females and a natural service sire is used thereafter. Artificial insemination may be carried out by operators from commercial AI companies (CAI) or by farmers/farm managers (do-it-yourself (DIY)). Although DIY AI has been practised for over 60 years worldwide and since 1984 in Ireland, very few studies have evaluated the success of DIY operators compared to CAI. Early reports concluded that either there was no difference between the two categories (Peters *et al.*, 1984; Schermerhorn, 1986) or that DIY operators had a wider range and lower overall conception rates (Brightling, 1985). The AI-industry has to balance the need of farmers to get cows pregnant and to obtain as many inseminations as possible per ejaculate, particularly in the case of popular sires. Previous studies have shown differences in conception rates between AI sires (Den Daas, 1997). In the early days of use, non-return rates following frozen-thawed semen tended to be lower than that following fresh semen (Boyd and Reed, 1961). Now, however, similar conception rates are reported with frozen-thawed or fresh semen (Nadir *et al.*, 1993; Vishwanath, 2003). Recent statistics show the level of AI usage in Ireland at 37% (ICBF, 2002) indicating a high usage of natural service sires. While convenience is likely to be the primary reason, there may be those who feel that conception rates achieved by AI are inferior to that achieved by natural service sires. It is necessary to clarify if differences in fertility performance are being achieved by commercial AI technicians compared to DIY operators, whether differences exist between frozen-thawed and fresh semen, and between AI and natural service.

The data used here comprised 12,933 lactations from 77 spring-calving dairy herds (see Buckley *et al.*, 2003b). The data were recorded during 1999 and 2000. The fertility variable of interest was pregnancy rate to first service (PRFS). Thirty three percent of first services were recorded as CAI (22 operators), 63% were recorded as DIY (55 operators) and 4% as natural service. Ninety two percent of all first AI services were recorded as frozen-thawed semen.

No significant association was observed between category of AI operator and likelihood of PRFS, having adjusted for herd, year, calving period, calving to service interval, parity, proportion of Holstein-Friesian genes, peak milk yield, herd size, the history variable, semen fresh or frozen-thawed status and AI sire (Table 8). There was a tendency for a reduced likelihood of PRFS with the use of fresh semen compared to frozen-thawed semen.

Table 8. Association between category of AI operator (CAI v. DIY), fresh or frozen-thawed semen status, year, calving period, parity, calving to service interval, proportion of North American Holstein-Friesian genes, peak milk yield, herd size, and history variable with likelihood of PRFS¹ (n=8,122 observations) (from Buckley *et al.* 2003b).

	OR	95% CI	P-value
Category of AI operator			
Commercial	1		
Do-it- yourself	0.67	0.36 – 1.23	NS
Semen status			
Frozen-thawed	1		
Fresh	0.80	0.63 – 1.02	0.067
Year			
1999	1		
2000	0.98	0.83 – 1.17	NS
Calving period			
January and February	1		
March	0.82	0.71 – 0.95	<0.01
April and later	0.64	0.51 – 0.80	<0.001
Parity			
1	1		
2	1.11	0.94 – 1.32	NS
3 and greater	1.08	0.90 – 1.29	NS
Calving to 1st service interval (days)			
>75	1		
61 to 75	0.82	0.73 – 0.93	0.001
46 to 60	0.73	0.61 – 0.86	<0.001
<46	0.62	0.49 – 0.77	<0.001
Holstein %			
<50	1		
50	0.98	0.85 – 1.12	NS
51 to 74	0.99	0.87 – 1.13	NS
75	0.91	0.77 – 1.07	NS
Peak daily milk yield (kg/day)			
<26	1		
26 to 29	0.94	0.81 – 1.09	NS
30 to 33	0.84	0.71 – 0.99	<0.05
>33	0.81	0.68 – 0.97	<0.05
Herd size			
<75	1		
75 to 149	1.11	0.86 – 1.43	NS
>149	1.28	0.76 – 2.16	NS
History variable			
Unsuccessful Preg1 in year 1	1		
Successful Preg1 in year 1	1.18	1.00 – 1.40	0.052
Null information	1.09	0.88 – 1.35	NS

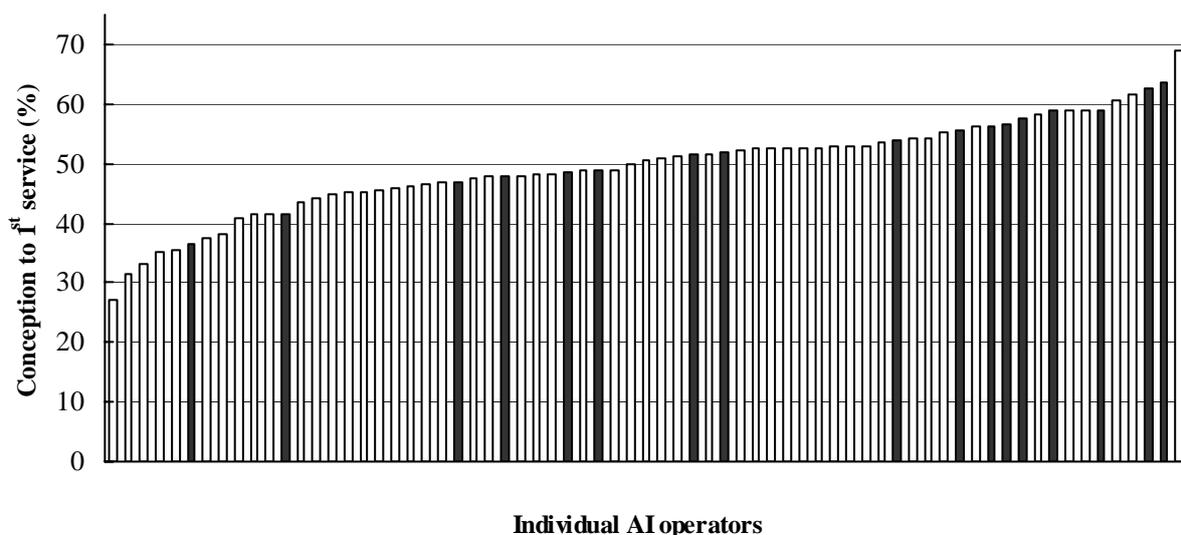
¹PRFS = conception to first service, OR = Odds ratio, CI = confidence interval, NS = $P > 0.050$.

However, there were significant differences in the likelihood of PRFS between different AI sires. Of the forty most commonly used AI sires (each with greater than 47 first inseminations), three had a lower likelihood of PRFS compared to the reference AI sire. These sires had 210, 83 and 61 first inseminations represented in the analysis, respectively. The mean OR for these three sires (0.43) corresponded to a 20-percentage unit lower likelihood of PRFS for these sires compared to the reference sire. Changing the reference AI sire to the AI sire with the highest conception rate for the group (57% PRFS from 99 first inseminations) resulted in nine sires with a lower likelihood of PRFS compared to this reference sire. These sires had between 61 and 927 first inseminations represented in the analysis. The mean OR (OR=0.48) for these sires equates to an 18-percentage unit lower likelihood of PRFS compared to the best sire, or conception rate differences of between 12 and 32 percentage units for individual sires when compared to this reference sire.

No significant difference was observed between natural service and AI for PRFS having adjusted for herd, year, calving period, calving to service interval, parity, proportion of Holstein-Friesian genes, peak milk yield, herd size and the history variable (not shown).

The results showed a similar level of variability in conception rates within CAI and DIY, with standard deviations of 7.2 and 8.0 within CAI and DIY operators, respectively (P=0.829). The analysis conducted (Levene's test for homoscedasticity) tested for differences between the variances of different groups. The conception rate to first service of different AI operators (CAI and DIY) are illustrated in Figure 4.

Figure 4. Variation in conception rate to first service within category of AI operator; CAI, ■; DIY, □.



There was wide variation in the level of experience and age of operator within both the CAI and DIY categories. Commercial AI and DIY operators in the current study had, on average, 29 and 8 years experience practising AI, respectively. This ranged

from 1-37 (SD=10.3) and 1-19 (SD=4.1) years for CAI and DIY, respectively. The mean age of operator within both CAI and DIY was 52 and 41 years, ranging from 27-67 (SD=11.1) and 24-62 (SD=9.1), respectively. Official retraining was not commonly practised among DIY operators in the current study. Thirty two percent of DIY operators attended between 1 (73%) and 4 refresher courses since the initial training course. These were generally carried out in the first few years after the initial course. In contrast, CAI operators received refresher courses each year and extra tuition was provided if individual non-return rates warranted it.



The results of this analysis showed no difference in the likelihood of PRFS between CAI and DIY operators. No interaction between herd size and category of AI operator was found. AI sire had a significant effect on the likelihood of PRFS. Previous studies report non-return rate differences of 15 to 16 percentage units between the best and worst sires. In the current study differences as large as 32 percentage units were evident in conception rate to first service. A possible contributor to the more extreme differences in conception rates observed in the current study may be the relatively low number of inseminations present for some sires. Smaller sample sizes will, due to chance, result in greater variability among sires. However, for the most part the number of inseminations per sire should have been sufficient to provide a good indicator of the performance of individual sires. Closer attention by AI companies must be paid to individual sire non-return rates. Differentiation between maiden heifer and lactating cow inseminations, for example, would likely remove some bias in estimated non-return rates. First service

conception rates in this study were estimated to be as low as 25% for individual sires. This is not satisfactory in practice.

Although the results of this study provide no evidence that the PRFS achieved by natural service was higher than that achieved from AI, it must be recognised that the number of first services available for natural service was small when compared to that for AI. However, the results concur with studies carried out by O'Farrell (1977) and Williamson *et al.* (1978), which found no significant difference between natural service and AI.

CALVING ASSISTANCE & RETAINED FOETAL MEMBRANES

Calving assistance

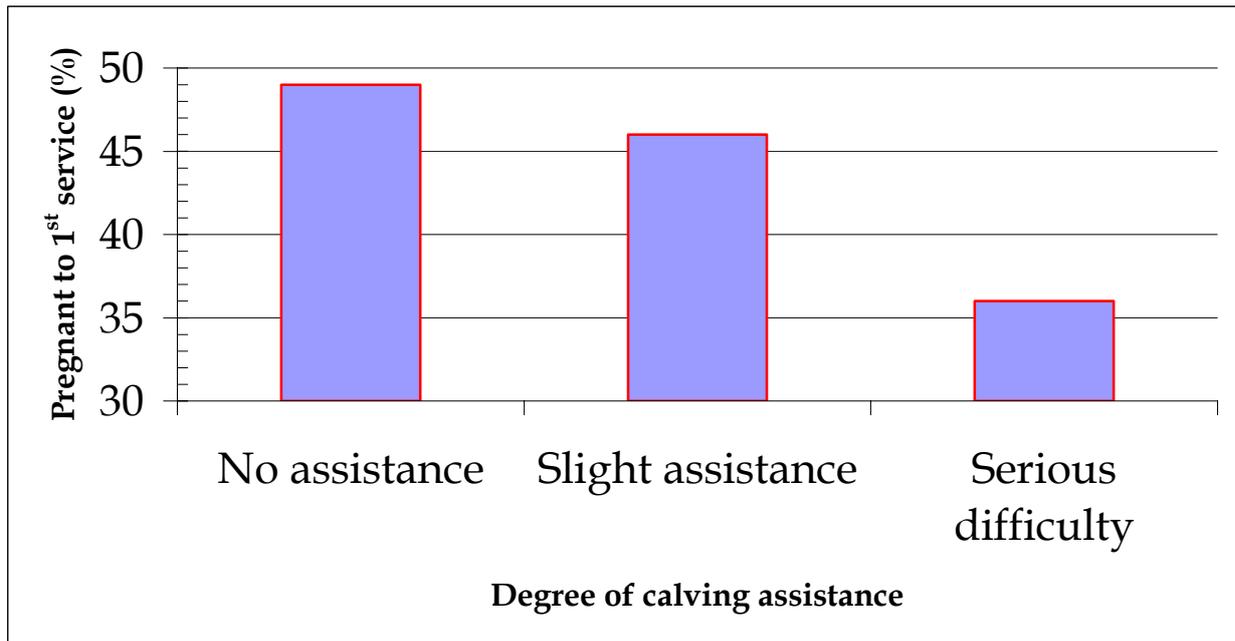
Successful management of the dairy cow at calving aims to ensure delivery of a viable calf and a smooth transition of the cow from the dry to the milking herd. The economic impact of calving difficulty is associated with decreased productivity and increased morbidity, culling and mortality (Mee, 2004b).

Data from both years of the study was used (12,537 records). The proportion of cows categorised as calving with no assistance, slight assistance and serious difficulty was, 77%, 19% and 4%, respectively.



Pregnancy rate to first service was significantly reduced in cows with slight assistance (-3 percentage units) and serious assistance (-13 percentage units) when compared to cows that calved without assistance (Figure 9).

Figure 9: Association between degree of calving assistance and pregnancy rate to first service.



Serious calving difficulty resulted in significantly higher empty rates after the end of the breeding season compared to cows calving unassisted or with slight assistance, and cows calving with serious difficulty tended ($P=0.099$) to have a longer CCI compared to cows calving unassisted (Table 8). The incidence of serious calving difficulty was significantly associated with calving period, lactation number, sex of calf, and breed of calf. Late calving cows had the lowest recorded incidence of serious calving difficulty; January/February (6%), March (5%) and April or later (3%). The incidence of serious calving difficulty reduced as cows matured; 7%, 4% and 3%, for cows in first, second and subsequent lactations, respectively. Male calves posed a greater risk compared to female calves (6% compared to 3%). Calves sired by HF and early maturing beef breeds (Angus and Hereford) were more easily calved than calves sired by late maturing continental beef breeds or dual-purpose breeds (3% compared to 6%). The proportion of HF genes and pre-calving BCS were found to have no effect. Peak milk yield was reduced by 0.8kg/day in cows experiencing serious calving difficulty.

Table 8: Association between degree of calving assistance and subsequent reproductive performance.

	CSI (days)	PRFS (%)	PR42 (%)	Empty rate (%)	CC1 (days)	No_SER
No assistance	64	49 ^a	58 ^a	13 ^a	81	1.82 ^a
Slight assistance	64	46 ^b	55 ^b	14 ^a	82	1.85 ^a
Serious difficulty	64	36 ^c	42 ^c	28 ^b	85	2.07 ^b

CSI = calving to service interval, PRFS = pregnancy rate to 1st service, PR42 = proportion pregnant after 6 weeks breeding, CCI = calving to conception interval, No_SER = number of services.
Means, within columns, not having a common superscript differ significantly (P<0.05).

Just over 2.3% of cows were recorded as having retained foetal membranes (RFM) post-calving. This resulted in lower reproductive efficiency with these cows. Pregnancy rate to first service and PR42 were reduced by 10 percentage units when the placenta (afterbirth) was retained post calving (Table 9).

Table 9: Association between retained foetal membranes (RFM) and subsequent reproductive performance.

	CSI (days)	PRFS (%)	PR42 (%)	Empty rate (%)	CC1 (days)	No_SER
No RFM	63 ^a	48 ^a	57 ^a	14 ^a	81 ^a	1.87
RFM	67 ^b	38 ^b	47 ^b	21 ^b	86 ^b	1.98

CSI = calving to service interval, PRFS = pregnancy rate to 1st service, PR42 = proportion pregnant after 6 weeks breeding, CCI = calving to conception interval, No_SER = number of services.
Means not having a common superscript differ significantly (P<0.05).

Retained foetal membranes

The incidence of RFM was associated with calving period, parity, and degree of calving assistance. The incidence of RFM was highest early in the calving season, i.e. January/February (3%), lower during March (1.6%) and April or later (1.8%). Older cows had a higher incidence of RFM. Cows in first lactation had the lowest incidence; 1.5% compared to 2% for cows in second lactation, and almost 3% for cows in subsequent lactations. Over 6% of cows experiencing serious calving difficulty had RFM compared to 2% where cows calved without serious difficulty. RFM resulted in a significantly lower peak milk yield; 28.8kg/day compared to 29.8kg where there was no RFM.



Calving difficulty and RFM decreased subsequent reproductive performance and reduced milk production. Factors contributing to calving difficulty and RFM included calving period, parity, sex of the calf, and breed of the calf. Serious calving difficulty resulted in a greater incidence of RFM. Successful management of the dairy cow at calving will result in the birth of a healthy calf and a smooth transition of the cow into the milking herd. Attention should be given to sire selection and calving management in order to avoid trauma and subsequent economic loss caused by calving difficulty.

HEIFER DEVELOPMENT AT FIRST CALVING

The decline in reproductive efficiency in Irish dairy herds is likely to have a negative impact on the number of replacement heifers born on Irish dairy farms or at least result in a change in the age structure. Three options are available to address this problem; 1) serve maiden heifers regardless of age to calve down early in the following calving season, 2) serve the younger heifers late in the breeding season, or 3) allow the younger heifers to slip to the following calving season. The objective of this study was to investigate the implications of differences in age at first calving for animal performance in first and second lactations, and also to examine the effect of weight as an indicator of heifer development.

Data on 2,380 first lactation cows calving in 1999 and 2000 were available for analysis. Calving at 2 years of age (2YO) was defined as 2 years \pm 2 weeks of age at first calving. The data were adjusted for herd, year, calving period, proportion of HF genes and weight at first calving.

Cows calving for the first time less than 2YO had significantly lower milk yield in their first lactation compared to cows calving at 2YO, while cows calving older produced significantly more milk compared to cows calving at 2YO (Table 9). No difference in milk composition was evident between the age groups. PRFS was lower in the younger heifers compared to the 2YOs while no difference was observed between older and 2YO heifers. No difference in empty rate was observed between age groups. Differences in days open between age groups were attributable to differences in reproductive performance (pregnancy rates) and calving date. Heifers calving at less than 2YO tended to calve earliest.

Three weight at (prior to) first calving categories were designated; heifers calving at <530kg, calving between 530kg and 600kg, and those calving at >600kg. Weight at first calving had a significant effect on milk yield in first lactation but no effect on milk composition. Empty rate at the end of first lactation was significantly higher in the larger heifers.

Table 9: Effect of age at first calving and weight at (prior to) first calving on animal performance in first lactation.

		Cdate	Yield	Fat %	Prot %	PRFS	Empty	DO
Age	<2 years	6 Feb ^a	5771 ^a	3.87	3.38	50 ^a	11	100 ^a
	2 years	13 Feb ^b	5905 ^b	3.86	3.37	56 ^b	11	93 ^b
	>2 years	5 Mar ^c	5992 ^c	3.85	3.37	54 ^{ab}	10	90 ^c
Weight	<530kg	11 Feb ^a	5682 ^a	3.86	3.36	53	10 ^a	95
	530-600kg	19 Feb ^b	5855 ^b	3.85	3.37	55	9 ^a	94
	>600kg	23 Feb ^c	6130 ^c	3.87	3.38	52	13 ^b	95

Cdate = calving date, DO = days open.

Means, within columns, not having a common superscript differ significantly ($P < 0.05$).



The performance in second lactation of those cows that calved for the first time in 1999 (n=1082) and reappeared in 2000 (n=862; 80%) was investigated. Calving dates in second lactation were similar across all age and weight categories (Table 10). Age at first calving had no effect on the milk production parameters in second lactation. Cows calving at less than 2YO in 1999 had better reproductive performance during second lactation; higher PRFS (P=0.061) and lower DO (P<0.01), compared to those calving in first lactation at 2YO. Weight at first calving had a significant effect on milk yield in second lactation. Light heifers (<530kg at first calving) produced significantly less milk in second lactation compared to heifers calving down at 530 to 600kg. Heavy heifers (>600kg at first calving) produced higher yields in second lactation compared to heifers calving down at 530 to 600kg. Milk composition was lower in second lactation in cows calving down in first lactation at low body weights. Reproductive performance in second lactation was unaffected by weight at first calving.

Table 10: Effect of age at first calving and weight at first calving on animal performance in second lactation.

		Cdate	Yield	Fat %	Prot %	PRFS	Empty	DO
Age	<2 years	3 Mar	6960	3.80	3.45	61	12	75 ^a
	2 years	1 Mar	7065	3.81	3.44	51	12	84 ^b
	>2 years	4 Mar	7089	3.76	3.42	52	11	86 ^b
Weight	<530kg	1 Mar	6785 ^a	3.74 ^a	3.41 ^a	52	13	85
	530-600kg	2 Mar	7027 ^b	3.81 ^b	3.45 ^b	56	14	81
	>600kg	4 Mar	7301 ^c	3.82 ^b	3.45 ^b	55	8	79

Cdate = calving date, DO = days open.

Means, within columns, not having a common superscript differ significantly (P<0.05).

It is clear that age and weight at first calving are critical elements in achieving optimum performance from replacement females. Calving heifers less than 2YO results in lower milk yields compared to older animals at first calving. However, weight at first calving appears to have a more long-term impact on animal performance.

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