The Development of an Expert System for Diagnosing Reproductive Problems in Seasonal Dairy Herds.

A thesis presented in partial fulfilment of the requirements for the degree of Master of Veterinary Science at Massey University

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Abstract

An expert system for investigating the reproductive performance of seasonally calving dairy herds (DairyFIX) was designed and developed. The system uses information retrieved from an on-farm information system (DairyMAN) to identify the primary causes of reduced performance and make recommendations for further action. The current performance of DairyMAN user herds and a sample of herds from the National Dairy Database were initially measured. Realistic targets for each performance indicator were then calculated using this information. The associations and interactions between the performance and diagnostic indicators used in DairyMAN were more clearly defined using multivariate statistical analyses and path models. Additional information was obtained from the literature for incorporation into the DairyFIX system.

The reproductive performance studies covered one complete year (1993/94 season) and were limited to spring calving seasonal herds which are typical of the New Zealand dairy industry. Such herds are managed so that all cows calve on a synchronous annual cycle as close as possible to the "ideal" calving date in that location. A typical aim is to have calvings spread over 6 to 8 weeks with a narrow spread being strongly favoured. The herd planned start of calving (PSC) date defines the beginning of this optimal period of calving and the planned start of mating (PSM) the first day of mating that must be used to achieve the desired calving pattern.

Expert system development is introduced in Chapter 1 with some historical information that supports the use of on-farm information systems. The concepts and design methods used for developing expert systems are then reviewed in brief. Examples are provided to illustrate the different levels of sophistication that can be used for developing expert systems. These demonstrate that relatively simple designs are often the most successful. Examples including Bovid and Dairy Expert are discussed in detail. The methods used to monitor seasonally calving dairy herds are then reviewed with an emphasis on the main performance and diagnostic indicators used in DairyMAN. These include the four and eight week calving rates, 21 day submission rates, non-return and conceptions rates and four and eight week in-calf rates. Empty rates can be considered the final definitive measure of performance by many dairy farmers, but the difficulties with interpreting this figure are presented. The limited mating period in seasonally calving dairy herds means that the assessment of heat detection is difficult and often inaccurate. For this reason several alternative methods for assessing heat detection efficiency and accuracy are discussed in detail.

A detailed description is given in Chapter 2 of herd and individual cow performance for DairyMAN user herds and the National Dairy Database sample. These data show that the reproductive performance of New Zealand herds is often below that previously reported. Calving rates are on average above industry targets, but only with a significant level of calving induction. Removal of inductions for welfare and marketing reasons will have a significant effect on the performance of many herds. Submission rates are the earliest available measures of performance during a mating season. New Zealand herds do not, on average, achieve the necessary targets. All measures of heat detection efficiency, although imprecise, show this is not a major problem with about 6 % of heats missed. This has a negative effect on submission rates. Detection efficiency is an important issue for some individual herds as the consequences of poor heat detection are dramatic. The performance

levels suggest that nutritional anoestrus and the effects of a spread calving pattern are the major causes of low submission rates.

Conception rates of less than 60 % are reported. These are below those often suggested as typical for New Zealand herds. Much of the previous data has been taken from small study groups that may not adequately represent all herds. The common use of non-return rates may have created expectations that cannot be achieved in average herds as these are an optimistic measure of performance.

Health events such as lameness are only reported for reference. Only limited health data is recorded although DairyMAN provides the flexibility to records such data. The variability in the type and degree of recording of these data is identified as a significant problem that limits the use of the available records. Some of the health events and especially lameness may have a large effect on the reproductive performance of many herds.

Path models are developed in chapter 3 as an essential prerequisite to the development of the DairyFIX expert system. The models statistically confirm most of the relationships that have been previously considered important when evaluating herd reproductive performance. A number of factors including herd size and breed are shown to be associated with differing calving rates. The four week calving rate is shown to have strong indirect effects on submission rates, conception rates and herd in-calf rates. As such, it is one of the most important variables in seasonal herds. The importance of submission rates and conception rates is confirmed. Daily per cow milk production is shown to be a useful indicator of submission rates as both of these variables are directly influenced by nutrition. The models identify some limitations with using non-return rates as measures of conception. These generally give optimistic results that do not accurately reflect true performance. Such problems are compounded if reasonably accurate measures of heat detection cannot be obtained in herds with a very restricted mating period. Although the interactions between the performance and diagnostic indicators are largely understood from previous work this is the first time they have been brought together in statistically verified path models.

The use of an on-farm information system (DairyMAN) was shown to be associated with improved herd performance including daily per cow milk yield and reproductive outcomes. DairyMAN user herds had cows of the same breed and genetic capacity. So DairyMAN users were able to produce more milk with animals of equivalent genetic merit, indicating that users achieved better management of the herd through improved attention to managerial details. This was associated with their adoption of DairyMAN, but not shown by this study to be a direct consequence of it. These findings are important because there is very little information confirming that on-farm information systems or central databases give true performance gains. This is despite the historical recognition of these systems and the rapid expansion in recent years. Justifying the use of more sophisticated tools such as an expert system would be more difficult if gains were not being achieved with the current technology.

Calving induction was shown to be associated with some negative effects on milk yield and reproductive outcome. The New Zealand dairy industry does not currently favour the use of this management tool, but the impact any changes in management practices would have need to be evaluated with consideration of these effects. Calving induction is typically not used as recommended in New Zealand as many of the treatments are done too late to provide sufficient economic gains through increased lactation length and increasing the number of days from calving to the planned start of mating.

Regional differences in performance were identified. DairyMAN user herds in the Manawatu had inferior conception rates while herds in the Taranaki had superior reproductive performance. These observed differences suggest a need to further identify causes of these differences, if performance is to be improved in some regions.

The performance of individual cows and groups was examined in detail and statistical models developed for use in DairyFIX. Breed, lactation number, days calved at the start of mating and some health events were all shown to have an important impact on performance. The inferior performance of lactation 1 and 2 groups is having a large effect on performance. Cows in lactation 3 and 4 generally have the best performance with some reduction for aged cows. These aged cows do not dramatically affect overall herd performance because they are only a small proportion of most herds Jersey cows tended to show superior calving and submission rates. A number of complex models were developed for herds that pregnancy test and those that use non-return as the measure of conception.

DairyFIX was developed to achieve two primary objectives. The first was to simplify the epidemiological approach to investigating herd reproductive problems. The system automates procedures that would otherwise be followed using DairyMAN and uses a graphical diagnostic interface to achieve this. DairyFIX quickly focuses on the important aspects of any performance deficit and reduces the time required to investigate a herd problem. Although DairyMAN is a comprehensive software package, users have difficulties due to its complexity and may invest a considerable amount of time exploring the program rather than focusing on the task required. The second objective of this project was to make expertise available for the user when examining herd performance. This required the use of the more sophisticated aspects of an expert system including the development of a "knowledge base" of information.

DairyFIX consists of three sections. The first simply evaluates performance and determines if any problems exist. The second part considers the effect of the major components of performance such as the calving pattern and heat detection so that the primary causes of poor performance are identified. This section uses the statistical models previously developed to estimate expected performance. The third part of DairyFIX consists of several specific interrogation procedures for each area of poor performance. This section is not necessarily required for an operational system as the user can otherwise be referred to the appropriate reports in DairyMAN. Another module within DairyFIX was designed to assess the expected performance of a herd in subsequent seasons given a predicted herd profile. The models used for this purpose are similar to those that retrospectively evaluate performance.

DairyFIX simplifies the investigative task and identifies the major causes of poor reproductive performance. It is anticipated that this tool will allow more dairy farmers and veterinarians to make effective use of DairyMAN while reducing the investment in time that is currently required.

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I am one of the few practising veterinarians who have had the opportunity to do postgraduate training after spending many years in private practice. There are several people who were instrumental in achieving this goal. I thank Bill Tranter for his enthusiasm in practice and his encouragement when I chose to apply for a postgraduate position. Bill always demonstrated an attention to quality, detail and accuracy. I am grateful for the initiative that created the training position for dairy cattle practitioners some years previously at Massey University. The quality of the persons who previously filled this position and the constructive roles they now have in the dairy industries in Australia and New Zealand shows this position in the Department of Veterinary Clinical Science has provided a quality training environment.

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To thank those people involved in DairyMAN development for their input and dedication to an often difficult and stressful task. John Lockhart has succeeded in developing DairyMAN and now DairyWIN into a truly professional product that will contribute to the long term productivity of New Zealand dairy herds. His clear thinking, attention to detail and quality computer coding have formed an essential foundation for the development of this software product.

I thank the DairyMAN users who have shown the foresight to trial the program during its early development, for the positive feed back and for freely providing their herd data that made possible many of the investigations presented in this thesis. I thank Livestock Improvement Corporation and Rose Barnes in particular for providing data from a representative sample of New Zealand herds under difficult circumstances.

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Dedication

This thesis is dedicated to my wife and children

Thank you for the opportunity

David Hayes 1997

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Introduction

The application of computer programs to the reproductive management of dairy herds has increased in recent years. DairyMAN was developed at Massey University to meet the analytical needs of seasonally calving dairy herds that dominate the New Zealand dairy industry. This computer program manages data and converts it into useable information in the form of reports. Farmers and veterinarians use this information to monitor herd performance. They may take action where reproductive performance, health or production are below predetermined targets or goals. In all cases the expert knowledge of a veterinarian or the skill of the producer is necessary to interpret and make judgments from the available information.

Expert systems are computer programs that use information provided from other sources to aid the decision process. Such systems use the knowledge of experts within a particular domain of investigation that has been stored within the program as a knowledge base of information. There has been active development of expert systems in most areas of veterinary endeavour and some systems are now commercially available. There are few systems that are directly linked to another computer program that can provide much of the data to be processed by the expert system. Systems linked to milking machines and associated data management software are however an exception.

Although there is an enormous knowledge base that veterinarians can use to assist with the investigation of herd reproductive performance there is little information describing the expected performance of New Zealand herds in recent years. In addition the interactions between recorded data, information and the interpretation of the information depend to a significant extent on the types of data stored and the methods of processing the data. DairyMAN uses sophisticated systems to ensure that the reports accurately represent the performance of a dairy herd. To establish expected performance criteria for herds using DairyMAN a knowledge of achieved performance using the information generated by DairyMAN must first be known.

This thesis reports some of the findings from a survey of DairyMAN and other herds in New Zealand during the 1993/94 season and the analysis of this data at herd and individual cow level. In the final chapters the development of an expert system called DairyFIX (Dairy Fertility Information eXpert) to aid the interpretation of DairyMAN reports and make recommendations for further action or investigation is described. The information derived from the analysis of herd and individual cow data and from the literature is used as the knowledge base for this expert system.

David Hayes   February 1997

Chapter 1

Literature Review

Literature Review

Historical Perspectives

In 1924 the first annual report of the "New Zealand Dairy Produce Control Board" described the establishment of milk yield testing facilities and noted "that all matters relating to the economic production of a quality article are closely allied to marketing results" (NZDB 1931). That is, the New Zealand industry had recognised that production information was important, not only for monitoring performance at individual cow level, but also to optimize the financial returns in the international marketing environment. As a consequence of farm management changes and the selection of higher producing animals, milk yield per cow had increased from 148 lb. of milkfat in 1910 to 219 lb. by 1930. The dairy board considered that recording systems for milk yield had contributed to the production increase. The improved efficiency significantly reduced the economic stress of the depression years. Milk yield became the first information recorded at cow, herd and industry level in New Zealand. The information recording systems were manual and butterfat production was the most important measurement.

Milk yield was also the first dairy herd performance data item recorded and analyzed by computer. An early application of computers in the dairy industry was by Crandall, who in 1951 used a mainframe computer and punch card data entry systems to calculate lactation milk production for the DHIA (United States Dairy Herd Improvement Association). Production recording systems continued to evolve as computers and software became more powerful and the amount of information expanded. Mainframe computers have remained a central part of dairy information systems until the present time. By the early 1980s personal computers also had become sufficiently powerful to record data and perform analyses at farm, herd and individual animal level. Since that time, software has become available for individual farms to record and analyze most aspects of dairy farm management. These include production, reproductive performance, health, pasture budgeting, nutrition, financial management and production forecasting.

Herd Health Programmes

Veterinarians have provided structured services to improve the reproductive performance and production efficiency of dairy farm enterprises with the development of herd health programmes. Early programmes had information systems that did not require the use of computers. The most common of these were card based hand written recording systems that were used to manage individual cows and to manually collate data to monitor and evaluate herd performance. The benefits of herd health programmes on cow health and productivity have been widely reported (Blood et al. 1978, Tranter 1982, Williamson 1980). The pioneering developments in herd health programmes required the design and implementation of computer software to record, analyze and report the data collected during routine farm visits. The system developed in Australia, called "Advice" was used successfully as part of a bureau service for several years, using mainframe computers. It was then re-coded for personal computers in 1981. Software has evolved in different countries including DairyCHAMP (Udomprasert and Williamson 1990), Daisy, DairyCOMP and others.

Herd health programs have been successfully operated as a bureau service in a limited number of Veterinary practices (Tranter 1985). These practices provide a recording, data entry and reporting service for clients on herd health programs. Most examples have operated in non-seasonal dairy farm systems where regular monthly veterinary visits are an integral part of the service.

McKay (1988) stated that seasonal herds may be less successful at adopting management information systems because data management systems were not available to perform the necessary seasonal reproductive analyses. DairyMAN has removed some of these limitation, but there are few operational bureau services operating in veterinary practices in New Zealand. One of these manages Autumn /Spring herds and therefore has some similarities with the non-seasonal herds. The other services rely to a large extent on the farmers entering data and maintaining the information system. In each example, computer programs that record and analyse herd reproductive, health and production data have been an important part of the service. Tranter (1985) describes the provision of a whole farm service for clients with differing requirements from the purchase of drugs to complete herd health and management programs Record keeping and analysis of data to determine problems in reproductive performance were considered central to the successful operation of this type of veterinary service.

Management Information Systems

Large amounts of data are now routinely collected on dairy farms. This is because herd size and the amount and type of data is increasing. More than 90 percent of New Zealand dairy farmers record individual cow data on the National Dairy Database. This includes reproductive events, milk yield and genetic indices for individual cows. This information base is likely to expand. Recent developments, including new animal evaluation models will, for example, result in live weight becoming more commonly recorded in New Zealand. These systems aim to provide useful information at appropriate times that will aid herd management decisions. Management Information Systems (MIS) consist of several integrated components that include data collection facilities, transfer systems and computer software (Lazarus et al. 1990). Systems must maintain a continuous flow of relevant information to enable effective decision making. A bureau service operated by veterinarians is an MIS operated for farm clients where effective systems to transfer and validate data are particularly important.

On-farm Information Systems

On-farm computer systems are also a realistic option for many farmers and can be successfully incorporated into the existing data management systems. DairyMAN is an on-farm information system used by herd managers and veterinarians to monitor production, health and reproductive performance (Tranter 1991, McKay 1991). A total management information system for dairy farms could include on-farm systems for data retrieval, storage and analysis, the national database and information transfer systems. The development of electronic weighing equipment, electronic identification, and sophisticated milking machines that can measure production statistics and monitor for mastitis are examples of electronic data sources that will require on-farm systems if the data is to be integrated and utilized adequately.

Dairy farmers have many priorities and goals that determine the management systems used on-farm. Improving herd milk production is however the most common goal of New Zealand dairy farm managers (McKay 1988). Veterinarians have focused on reproductive performance, health and nutrition which directly influence herd milk production. Improved performance is possible through herd health programmes and consultant services. On-farm information systems must also demonstrate that improved productivity will result from their use, but few studies have looked at the effects of such systems independent of veterinary inputs. A 1994 survey of New Zealand dairy farmers (Ward and McQueen 1994) showed that 16 percent used computers. Of these 39 percent used some type of animal management package and 27 percent used a pasture management package. This cross sectional study also found a positive association between the use of DairyMAN and milk production per hectare. In the 1995/96 season there are 730 farmers (5 percent) and 20 veterinary practices using DairyMAN.

Despite the documented benefits of management information systems and herd management programs their use has remained limited on dairy farms. The lack of complete or sufficient veterinary expertise has been suggested as one factor reducing program adoption (Radostits and Blood 1985). Dairy farmers repeatedly rate ease of use as an important aspect for the improvement of computer programs like DairyMAN (Livestock Improvement Corporation 1995).

Failure to Adopt Computer Technologies

The veterinary herd health program has not been well adopted in Australia and New Zealand despite extensive publication of the positive benefits of these systems and extension work since the early 1980s, Indeed the adoption of the associated computer technologies have also been restricted primarily to accounting procedures within Veterinary practices. McKay (1988) suggested a number of reasons for this result in New Zealand.

- Seasonal herds
- Industry uncertainty
- Failure to demonstrate gains in New Zealand
- Lack of a suitable management information system for seasonal herds

Esslemont (1995) discussed the economic viability of herd health programs. He suggested that veterinarians in some countries where the profession is highly regulated had a limited approach and that poor competency may produce a negative economic benefit to the farmer. He contrasted this with other regions where many of the traditional veterinary procedures are done by lay staff, technicians and farmers. In this environment the veterinarians is often an expert farm management consultant who is highly skilled and utilises all of the tools that an analyst, consultant and nutritionist would need.

A phone survey of New Zealand veterinarians using DairyMAN (Farrow, personal communication, 1993) identified some general difficulties using the software within a practice environment. Problems ranged from difficulties establishing sound herd data, program bugs and charging effectively for the time required to investigate a problem.

In recent years many of these issues have become less important and the enormous advances in computer technology and increased availability of specialized software including expert systems has increased adoption.

Expert Systems

The development of software that could interpret rather than simply report information could address some of the historical problems associated with the use of management information systems. Such programs are called Expert Systems.

An expert system has been described as :

> **"A computer program that behaves like a human in some useful ways"** (Winston and Prendergast 1984)
>
> **and can "solve problems efficiently and effectively in a narrow problem area"** (Waterman 1986)

Management Information Systems (MIS) process and analyze data to produce information. A knowledge based expert system takes the additional step of interpreting the information. Expert systems use the knowledge of human experts or professionals to draw useful conclusions about information within a specific subject domain. They attempt to replicate, in a simple way, the logical thought processes of humans. They are not a form of artificial intelligence because the "knowledge" is pre-defined and the systems do not learn from experience.

Humans think using a variety of methods. These thought processes that expert systems attempt to replicate can be considered under the following headings:

We **create categories**

eg. Compare the performance of two year olds and mature cows in a herd

Use **specific rules**

"If the cell count is above 200,000 then use dry cow therapy"

Use **heuristics**. These are simply "rules of thumb" or conventional wisdom

"Herds that pregnancy test will have more accurate information on in-calf rates"

Make judgments based on **past experiences**

"Calvings at this farm are always difficult"

We have **expectations** for current events

"Milk production is below normal today"

Expert systems commonly use "rules" as the basis for knowledge processing. A rule consists of a list of criteria, an hypothesis and a list of actions which may follow, depending on whether the hypothesis is accepted or rejected. The outcome of testing a rule can be "true", "false" or "unknown". If all criteria are true, then the rule is true and the hypothesis is true. The outcome for one rule may be included among the criteria for any number of other rules. Rules are linked together in a network such that an investigative process can move either forwards or backwards within the rule network. The mechanisms for processing rules is controlled by an "inference engine" that sets a dynamic rule agenda and is part of an expert system. Such systems may be quite specific to a particular process or may be much more general. These general purpose programs are termed expert system shells. They contain the software that controls how knowledge should be processed, plus various development tools and a user interface. A rule gives a precise interpretation of data and a course of action if a set of criteria are met. The strength of an expert system lies in the proper networking of a large number of simple rules into a complex web of knowledge.

Table 1. An example of a rule showing the criteria on the left side and the hypothesis and actions on the right.

If	submissions poor		then	Nutritional Anoestrus
and	Calving pattern good			
and	Cows in poor condition		and do	run analyses by lactation
and	Milk production low			
and	High proportion of anoestrous cows at vet visit		else	examine heat detection

Expert Systems in Dairy Medicine

The theory and then the development and application of advanced computer systems using various concepts of artificial intelligence began in the 1960s, but it is only recently that knowledge-based expert systems have shown significant development in the dairy industry.

Expert systems have been developed for many aspects of veterinary medicine and within most aspects of the dairy industry. They include systems to aid in the clinical diagnosis of small animal and bovine disease (Blood et al. 1989), production and data management on pig farms (Sugimoto et al. 1993) and sow replacement (Huirne et al. 1991). A considerable number of systems have been developed to assist with the management of mastitis and milk quality in dairy herds. These include the clinical diagnosis and treatment of mastitis (Berthelot 1991, Hogeveen et al. 1991), epidemiological diagnosis (Benas and Lebret 1988), investigation of stray voltage problems (Goodrich et al. 1987), milking machine testing (Kerr et al. 1992) treatment and replacement decisions (Houben et al. 1992) and mastitis management in herds (Allore et al. 1992). Knowledge-based systems are in the developmental stages to control the operation of automatic milking machines (Fourdraine et al. 1992). Other systems have focused on the production performance of the individual cow or herd. Examples include systems to predict the production capabilities of individual cows (Oltjen et al. 1992) and evaluate the milk yield of cows from a herd database(Overveld et al 1992). The concepts for drying off decisions in seasonally calving dairy herds have been reported, but a practical system has not been implemented (Gray et al. 1992). Surprisingly, there are few systems that focus on nutrition, although an expert system has been designed to make decisions on the transfer of cows between high and low energy ration groups (Grinspan et al. 1994, Maltz et al. 1992). The lack of systems within the domain of dairy cattle nutrition may be because there is an enormous amount of technical information available on the nutrition of dairy cows that has been incorporated into conventional software. This analytical, or procedural software uses detailed mathematical models, which are well suited to nutrition planning (Kellaway 1983). The decisions relating to the timing and amount of nitrogen fertiliser to be used on crops or pasture has also received the attention of expert system designers (Geypens et al 1994). Other expert systems examine whole farm management (Overveld et al 1992), opportunities for economic reorganisation and expansion (Schmisseur and Gamroth 1993), the technical management of the complete dairy enterprise (Pellerin et al. 1994), and production and economic constraints (Kalter and Skidmore 1991).

Clinical Diagnostic Expert Systems

One of the earliest expert systems developed for use in veterinary science was the dairy cattle diagnostic program called Bovid (BOVine Information and Diagnosis System) (Blood et al. 1989). The system aided in the diagnosis of individual bovine clinical cases. Bovid interrogated the user on the observed clinical signs of individual animal cases to provide a list of the most likely differential diagnoses. The system uses a data base of diseases and expert knowledge of the clinical and laboratory signs for each disease. The probability of each clinical sign occurring in a particular disease was used as the basis of the inference process that produced a list of differential diagnoses listed in order of probability. The knowledge base was derived from the information on clinical diseases contained in the reference textbook (Radostits and Blood 1985).

Bovid illustrates the operation of an expert system and some of the limitations. Bovid contains the basic components of an expert system including:

Knowledge base

Information on the type and probability of clinical signs occurring for each disease.

Inference engine

A computer program that uses a list of signs provided by the user and compares that with the data base of diseases and signs (the knowledge).

User interface

Consisting of an interface for obtaining information from the user and for reporting a list of differential diagnoses listed in order of likelihood as determined by this expert system.

Expert systems produce a complete, reproducible output, however they cannot incorporate into recommendations, information not contained within the knowledge base. Bovid achieves the goal of performing like an expert and is useful for new graduates and inexperienced veterinarians who may not include some appropriate differential diagnoses or may place inaccurate emphasis on some diseases based on previous experience. For example a veterinarian in the tropics would need to consider babesiosis as a possibility if haematuria is diagnosed in an adult Friesian dairy cow. Bovid will not omit this differential diagnosis, but the inexperienced veterinarian could. The converse is also true. An expert veterinarian will produce a more precise list of differentials because common sense and a more extensive personal knowledge base including regional disease prevalence makes this possible. For example the examination of a Brahman calf may indicate to the experienced veterinarian that Pompes disease should be considered in the differential diagnosis. Bovid will not include this in the differential diagnosis, regardless of the detail or clinical signs provided by the user because it is not in the knowledge base.

More recently another expert system called "PHYTOX" (McKenzie 1994)has been developed as an ancillary to BOVID. It includes information on plant poisoning in the knowledge base to aid in the diagnosis of individual clinical cases. Unlike BOVID it includes information for all domestic species.

Reproduction

Expert systems to aid the diagnosis of reproductive disease for individual cows and herd performance have been reported in the literature (Pellerin et al. 1994, McKay et al. 1988, Levins and Varner 1987). Most were conceptually designed and developed using an expert system structure although this is not essential. Usually a knowledge base of facts and expert opinions is derived from interviews of experts and research of the literature. This is then coded into the knowledge base of the particular expert system. The user is interrogated to provide the necessary external data and the system produces a report based on the knowledge available for the data provided. Few of the systems are directly linked to an external data base or analytical program although Fetrow (1985) did describe a system that extracted information from the DHIA (Dairy herd Improvement Association in the USA) database to evaluate herd reproductive performance. An advantage of acquiring data from users is that their perception of performance may be important determinants of actual herd reproductive performance (Levins and Varner 1987). Collection of data from the user is however subject to errors including bias and subjective views of performance rather than factual data. Information from an external database will be affected by the analytical methods used to calculate the required information.

Because reproductive performance is a major functional component of any dairy farming enterprise this is considered in many systems dealing with overall farm or herd operation. In these examples however the results of reproductive performance are used to evaluate the impact on herd and farm productivity. There are few examples of expert systems designed to aid in the diagnosis of reproductive performance problems or evaluate performance indicators to identify areas of reduced reproductive efficiency. Domecq (1991) developed a system that investigated reproductive performance of North American non-seasonal dairy herds. It was developed using an expert system shell and conventional programming tools. The system initially examined the key reproductive performance indicators including days open, days to first mating, heat detection and conception rates. If a problem was identified the severity was quantified and then a detailed investigation into specific areas was initiated using information provided by the user and from DHIA reports. Levins and Varner (1987) used standard programming tools to design a simple diagnostic system for herd reproductive problems. The design of this system utilized a tabular system of rule definitions that aided the design and implementation of the required computer code. In the table design each column represented a question and each row a possible combination of answers.

The National Dairy Database CD-ROM (Smith 1992) has several operational expert systems included on a CD-ROM. They include:

1. Dairy management consultant
2. Dairy Expert
3. "Smartpitchfork"

Dairy Expert

The national dairy data base expert system "Dairy Expert" is used for diagnosing reproductive performance problems in North American dairy herds. It produces a text-based report after an interrogation procedure to determine the performance of the herd, the type of data recorded and the user's perception of performance. This knowledge system is applicable for a high-producing North American herd.

Expert systems were developed in part because the rule-based system could focus on the domain of well defined knowledge either as factual data or heuristcs. This removed problems that became apparent with the early artificial intelligence systems where the design could result in an exponential growth in design and code if all aspects were to be considered. Dairy Expert uses a list of predefined test output options that are retrieved and combined to form a final report (Figure 1). The selection of each part of the text is determined by the results of the investigation for each aspect of performance.

A disadvantage inherent in the rule-based system approach is that omissions of logic can occur. This should not be significant because all important aspects should be considered in a well designed system and the unimportant or entirely improbable scenarios can be excluded. This allows the developer to clearly focus on the knowledge "islands" Omissions of logic can result in a system reaching illogical conclusions. Dairy Expert for example queries the user if veterinary examinations of cows for reproductive problems are used in the herd. Subsequent to receiving this data the system may seek information on the number of cows with endometritis. The omission is the failure to determine if this conclusion or diagnosis (ie endometritis) can be reached by the farmer without veterinary involvement. In the case where no veterinary expertise is used and the user reports that endometritis has not been detected the system draws two conclusions:

That veterinary examinations are required.

Endometritis is not a problem.

This is an invalid conclusion especially since the knowledge that veterinary examinations are not used is known. Additional knowledge is required for this conclusion to be accurate or this important aspect of reproductive disease could be incorrectly excluded from the investigative process.

DAIRY EXPERT Diagnostic Report
Lumen Software Inc, PO Box 778, Adelphi, MD 20783
General Information

Number of cows:	200
Days Open	130 days
Calving Interval	14.0 months

HERD REPRODUCTIVE STATUS
Days open for this herd indicates a slight problem. Herd status during the past year showed little change
DAYS IN MILK AT FIRST SERVICE (DFS)
There is a DFS problem in this herd. Palpation records indicate the main cause is anoestrus, but some heats may also be missed.
FERTILITY
The herd-wide fertility level is acceptable, but there is a fertility problem in some cows. Milk progesterone samples are needed to determine if heat detection accuracy is contributing to the problem. Further, regularly scheduled veterinary examinations of the herd are advisable.
CYSTIC OVARIAN DISEASE
Cystic ovarian disease is not contributing to infertility problems in this herd.
ABORTIONS
Abortions are not causing fertility problems in this herd.
OTHER FACTORS
Dystocia, retained placenta, and metritis do not contribute to the infertility problem in this herd. However, because dry cows are being housed with lactating cows, the dry cows can easily become too fat. This, in turn, can lead to dystocia, retained placenta, and/or metritis problems in the future.
HEAT DETECTION EFFICIENCY
The days open and services per conception values for this herd indicate that heat detection efficiency is a severe problem. The producer's estimate of heat detection efficiency underestimates the severity of the problem with missed heats. The conclusion from the records is probably correct, so the producer likely has a more severe heat detection problem than is suspected. This lack of awareness on his or her part is a serious problem, and may itself be causing the heat detection efficiency problem. In the short run, the producer should consider using oestrous synchronization drugs to alleviate the heat detection efficiency problem, but the only real long term solution is to improve heat detection efficiency by both refining observational techniques and improving his or her methods of evaluating heat detection efficiency.

End of Report

Figure 1.Sample output file from DAIRY EXPERT

Dairy Expert uses heuristic knowledge in important ways. For example, a comparison is made between a calculated measure of heat detection and the operator's perceptions of the heat detection performance for the herd. If there is a significant discrepancy between the "factual" data and farmer perceptions then the conclusion is that the lack of awareness of a heat detection problem is a contributor to the problem.

Other Expert Systems on the National Dairy Database

Dairy Management Consultant

This is a package of DOS based applications that use an expert system approach for investigating some aspects of herd performance. These include herd production diagnostics and an evaluation of clinical mastitis problems.

"Smartpitchfork"

This application uses a knowledge based application to interrogate the user about the manure and effluent disposal problems for a farming operation. The output provides some recommendations for disposal and yield of nutrient that could be used as a resource or pollution problems in alternative disposal systems.

Mastitis

Some of the more advanced expert system technologies and methods of representing dairy herd management knowledge have been described in detail (Hogeveen et al. 994) and applied to herd mastitis investigations. The authors described declarative and procedural knowledge. The declarative knowledge is the understanding or interpretation of facts within a domain of investigation and procedural knowledge is the knowledge of how to use this declarative knowledge. Characteristics of both types were described including completeness, certainty and level. Systems for diagnosing mastitis problems at herd level using information from milking machines and a probabilistic approach to pathogen identification of individual cases was developed and evaluated using data collected form several dairy herds.

Many articles on expert systems provide only superficial understanding of the concepts and it is not possible to determine if a functional system is operational. Only a few authors describe the testing and implementation of the system to provide some data to support the usefulness of the particular system. Expert systems that are available either as commercial software or distributed as free-ware or share-ware have achieved the important aim of providing a useable package. The system developments have been largely experimental and the application of a reproductive expert system in commercial software or as part of a Management Information System is yet to be achieved.

Reproductive Performance: The Knowledge Base for Seasonally Calving Dairy Herds

Seasonal Reproductive Performance Indicators

Seasonally calving dairy herds require different reproductive performance information to the more common non-seasonal herds if the herd performance is to be interpreted accurately and at the appropriate times. The reasons for developing seasonal-specific reproductive variables has been described (MacMillan 1984, Jolly 1986). Many commonly used measures of performance based on means do not consider the skewness of much of the seasonal herd data and therefore do not accurately represent the performance. Seasonal herds are also limited in the type of data that can be analysed because the period of recording is often very short.

Calving Patterns

Dairy herds in New Zealand generally adopt a seasonal calving pattern to optimise the utilisation of pasture. This can be achieved by matching the pasture growth rates or feed supply to the nutritional demands of the dairy herd. A seasonal calving pattern requires a seasonal mating system with a defined start of mating date. For this reason, seasonally calving dairy herds commence mating at a herd-dependent date termed the "planned start of mating" (PSM). Cows are mated during the following 6 to 12 weeks using a variable combination of artificial breeding and natural mating. The PSM determines the planned start of calving (PSC) for the following season and the pattern of calving in any year is determined primarily by the reproductive performance in the previous season (MacMillan 1984). This PSM imposes a voluntary wait period for each cow that is herd-dependent and varies inversely with calving date of the cow.

Because the number of days from calving to service is known to affect reproductive performance and is a common measure of performance in non-seasonal herds (Fetrow et al. 1990) the herd calving performance was recognised as an important seasonal parameter affecting subsequent mating. The calving pattern achieved and the date on which calving starts are also important when planning the herd's nutritional requirements (Brookes 1994). Culling, replacements, abortions and calving induction will modify the calving pattern. Because the calving pattern is not distributed normally, but rather skewed toward the PSC, various measures have been used to evaluate performance (Macmillan et al. 1990). The proportion of cows calving up to the end of the fourth week after the PSC and to the end of the eighth week are commonly used (McKay 1986). Calving rates also affect milk yield. This is because lactations are usually terminated within a herd, at a common date in the Autumn, and an earlier calving date for an individual cow will increase the number of days in milk and total lactation yield.

Other Measures of Calving Performance

The inter-calving interval is commonly used in non-seasonal dairy herds to monitor overall performance and has been used to assess the calving performance of seasonal herds (Macmillan and Moller 1977). It has not been widely used in recent years because it does not describe the pattern of calvings for a herd. The number of days from the PSC to median calving date has also been used (Macmillan et al. 1990) and is reported in some herd management reports (Livestock Improvement 1994).

Submission Rates

Efficient reproductive performance in seasonally calving herds is based on the premise that achieving a high percentage of the herd pregnant in a short time frame is the most desirable outcome. Mating starts on a specific day of the year and all cows in oestrus are mated from that date for a period of several weeks, so the distribution of matings is not normally distributed, but is skewed toward the start of mating date.

A cow is submitted when served, generally by AI, for the first time during a mating period. Herd managers aim to have 90 percent of cows submitted in the first 21 days (Tranter 1991). The submission rate, that is, the proportion of cows submitted in the first 21 days of mating is a key reproductive indicator in seasonal herds (Macmillan and Moller 1977) in New Zealand. Seasonal herds in Australia more commonly use a 28 day submission rate (Brightling et al. 1990) but there have been no specific reasons reported for the use of the different time frames. Theoretically the 28 day submission rate may be more appropriate as all cows including those cycling at greater than 21 day intervals have at least one opportunity to be detected on heat. Conversely, the increased period gives some cows more than a single opportunity to be submitted. Measuring the submission rates for the entire mating period may be more appropriate when assessing overall outcome however such figures often approach 100% and may not provide a good discriminatory measure of performance.

Provided that appropriate targets are set for performance at 21 or 28 days the two variables should give equivalent information.

Heat detection

Cows in oestrus must be identified in all mating programmes except an entirely natural mating program. The failure to adequately detect oestrus has been consistently identified as a major cause of poor reproductive performance in seasonal and non-seasonal dairy herds (Esslemont 1993, Hackett et al. 1984, Heersche and Nebel 1994, Brightling et al. 1990, MacMillan 1982, Malmo 1977, Senger 1994, Tranter 1982, Williamson 1981). Some authors consider heat detection to be the single most important problem limiting the reproductive efficiency in their national herds (Senger 1994). Non-seasonal herds tend to have poorer heat detection than seasonal herds because the oestrous activity level is lower with smaller groups of cows on heat at any particular time and because heat detection in these herds is year-round activity rather than confined to a short period of the year (Tranter 1985), so requires constant vigilance.

Improvements in heat detection have also been reported as the most common reason for improving herd performance when a herd program has been used (Macmillan 1990, Brightling et al. 1990, Williamson 1982). Heat detection was identified as one of the aspects most responsive to veterinary input and therefore the greatest impact on overall reproductive performance could often be achieved by focusing on heat detection issues (Tranter 1982).

Despite this, the measurement of heat detection in dairy herds is at best imprecise and at worst confounded by other factors. The evaluation of heat detection is generally separated into the two distinct components of this farm management skill.

Missed Heats

The degree of ability to not miss heats is determined by the sensitivity of the monitoring for oestrous activity in the dairy herd. An evaluation of missed heats has obvious implication for performance because submission rates will be reduced and an unmated cow has a nil chance of conception. This of course assumes that bulls are not running with the herd during the period of Artificial Breeding.

False Heats

The proportion of false heats is a measure of the specificity of heat detection. False heats are usually measured as the number of recorded matings to cows that were not actually on heat, but heats recorded prior to the PSM can be included in the analysis. Additional matings to cows not on heat may not be as serious a concern as missing a heat. There will however be additional costs associated with inseminations or matings and the data may confound other measures of performance such as non-return rates.

Measures of Heat Detection Efficiency

The various analytical methods used to assess heat detection in seasonal dairy herds have been extensively discussed by several authors. (Brightling et al. 1990, Grusenmeyer 1992, Macmillan 1990, McKay 1993, Tranter 1991). MacMillan reviewed the techniques and the applicability in different situations. Warren (1984) recognised that the various methods are only applicable to the population of herds from which the particular method was derived.

Detailed information is available on the interpretation of North American DHI records and some methods are accepted standards in that country (Coleman 1991, Ferry 1992, Fetrow et al. 1990, Grusenmeyer 1992). Such methods however are not appropriate for New Zealand herds or other seasonally mated herds. DairyMAN (Tranter 1991) was in part developed because of the requirement for analytical methods to be available for reproductive analysis, that would be appropriate for New Zealand herds.

Average Breeding Interval

The average number of days between heats or matings is a crude measure of heat detection efficiency. The variable can be calculated as;

$$ABI = \frac{D}{N}$$

where;
ABI = Average Breeding Interval
D = Total number of days cows could be in oestrus
N = All heats recorded in the period being analysed for eligible cows.

Table 2. The average breeding interval (ABI) and calculated percent of heats detected and heats missed.

Average breeding interval	Percent heats detected	percent heats missed
23	90	10
26	80	20
30	70	30
35	60	40
41	50	50
50	40	60
60	30	70

Heat Detection Rate

The Heat Detection Rate (HDR) is a variation on the average breeding interval calculation. There is a direct inverse relationship between the HDR and ABI. This is a estimate of the percentage of possible heats detected. It does not measure the accuracy (false recorded heats)with which the herd manager detects oestrus.

$$HDR = \frac{21}{ABI} \times 100$$

Some adjustments to this calculation are made to improve accuracy and remove some confounding factors. Non-seasonal herds often have a voluntary wait period after calving where cows are not mated and heats are not detected, and this needs to be excluded from the analysis. The number of days that cows could be in oestrus (D) includes oestrous days only for eligible cows. These are all cows past the voluntary wait period. "To be culled" cows are excluded because they are not being detected and pregnant cows because they are not cycling.

This method provides a reasonably accurate assessment of heat detection where the management system is continuous, but does not take into account:

1. Short oestrous intervals.

2. Anoestrum

3. Abortions and other reasons for delayed returns

4. Time frame of detection. Seasonal herds may detect heats and record matings for as little as three weeks. This implies there can be no inter-oestral interval of more than 21 days recorded and the calculation will be biased towards short intervals.

Both the ABI and the HDR are estimates of heat detection efficiency after a first mating is recorded. If the post-partum voluntary wait period after which cows can be mated is known then the HDR for a herd can be estimated as

$$HDR = \frac{21}{mean\_CaSI - (VD - 10)} \times 100$$

where CaSI is the number of days from calving to first service and VD is the voluntary wait period. If the voluntary wait period in a herd was 60 days and the average number of days from calving to first service was 75 days then the HDR would be 84 percent.

Heat detection at the first service can be very different to that for subsequent serves (Tranter 1991) but the above calculation does not take anoestrum into account.

DairyMAN and Return Intervals Analysis

DairyMAN reports a number of variables that can be used to make interpretations on oestrus detection efficiency and specificity.

These are;

1. The percentage of returns between 2 to 17 days. This is one of the few variables that can be used to estimate the number of matings to cows not in oestrus, but it is also influenced by the number of true short cycles that occur during the period of heat detection. Macmillan (1990) noted that this error is not an important consideration for non-seasonal herds because they tend to be eliminated from the analyses because of a voluntary wait period after calving for each cow. In seasonal herds, cows have a different voluntary wait period to mating that depends on the calving date. For example some cows may calve close to or actually after the PSM and therefore have very short wait periods. Such cows are more likely to have short cycles (McDougall and Macmillan 1993).

2. The percentage of returns in the normal range of 18-24 days. This is considered the range of normal oestrous intervals for dairy cows. The higher the percentage of normal returns the more specific is the heat detection within the herd.

3. The percentage of returns that are in the range for double cycle length (36-48 days). This variable is interpreted as a measure of the number of heats that have been missed. The assumption is that such returns indicate that the cow returned to heat at the normal time but was not detected. It does not however take into account true 36-48 day returns due to abortion. It also requires that there has been sufficient period of heat recording to have actually recorded double cycle intervals.

Proportion of Normal to Double Cycles

A commonly reported method of evaluating heat detection efficiency in New Zealand and Australian herds is to consider the proportions of normal single cycle returns (18-24 days) to double cycle returns (36-48 days) (Morris 1978). This can be defined as

$$HDR = \frac{(\%18-24)-(\%36-48)}{(\%18-24)} \times 100$$

This has the advantage of excluding abnormal intervals that may be associated with early embryonic loss or detection of cows not actually on heat so is more specifically measuring the percentage of heats missed. It is also subject to the errors of each variable included in the calculation and particularly the %36-48 day returns.

Distribution of Return Intervals

Oestrus detection can be evaluated visually by examining the distribution of return intervals for a herd. This gives an expert a graphical interpretation of the recording of returns to oestrus. Information on the number of short cycles occurring in the herd and the efficiency and specificity of detection can be determined. The pattern of return-intervals has been used as a simple example of pattern matching where the shape of the distribution is associated with measures of heat detection accuracy (specificity) and quality (sensitivity). The shape of this curve includes all the information that is summarized in the measures of different return interval proportions and ratios. There are at least five aspects of heat detection and the pattern of returns exhibited by the herd. These are

1. The relative height of a peak of returns at 10-12 days. This peak occurs because some cows have true short returns. An increased number of these returns indicates either nutritional problems causing delayed oestrus or a consequence of delayed calving. Most seasonal herds show a small peak of returns in this range.

2. The relative height of the peak of normal returns. This peak will increase as the oestrous activity of the herd and heat detection specificity improve.

3. The relative height of a peak at 36-48 days. These indicate missed heats as previously discussed.

4. The number of "background" returns distributed randomly across the pattern. This gives an indication of false heats being recorded and provides a baseline comparison for the relative magnitude of each of the peaks discussed above

5. In non-seasonal herds an indication of an increased number of late returns may be visible on the return -interval distribution. This may indicate an abortion problem within the herd

Seasonal Herds and the Period of Heat Detection

The length of time that heats are recorded will have an impact on the variables measuring heat detection although this receives little consideration in the literature. Brightling et al. (1990) simply evaluated performance if at least 10 weeks of matings were recorded and concluded that for less than 10 weeks a reasonable evaluation of performance was not possible. In many seasonal herds matings are recorded for 5 or less weeks. In these cases it is not possible to calculate the ratio of normal to double cycles and the proportions of short and normal returns will be greater than if heats were recorded for a longer period.

Measures of Conception

Non-return Rates

The absence of a recorded oestrus (non-return) after mating is commonly used as a measure of conception. The use of non-return analysis in New Zealand was summarized by Jolly (1986) and further discussed by McKay (1993). Non-return is commonly used because few herds have pregnancy test data. The analyses can provide a useful comparison of performance between groups and herds however the values obtained will be influenced by several confounding factors. These primarily relate to heat detection accuracy and period of heat detection. It is essential that the same non-return criteria be applied to each group in a comparison. The most important criterion is the period after mating for which the non-return applies. This figure must be the same regardless of the time of mating within season. Twenty one, 24 and 49 non-return figures are commonly calculated. The shorter periods are used soon after a mating season to maximise the amount of data that can be evaluated. Longer periods are used to improve accuracy. It has been suggested that a comparatively high rate of heat detection errors in New Zealand seasonal herds will depress calculated non-return rates (Macmillan 1985). In contrast a short period of heat detection and a high proportion of missed heats will tend to increase the calculated non-return rates. Methods have been refined for some comparative investigations to improve the accuracy. An 18-24 day non-return analysis has been used to compare the performance of sires. This removes some of the effects of inaccurate heat detection but ignores the effect of true short returns.

Pregnancy Rates

Pregnancy testing using skilled operators may be considered the gold standard for assessing conception rates in dairy herds. The variable does not account for embryonic losses up to the point of pregnancy testing. The average stage of gestation at herd pregnancy testing may therefore influence the measured outcome. Also the ability of a skilled operator to age pregnancies reduces as gestation length increases. Many herds in New Zealand pregnancy test the herd at 4 to 5 months after mating. In these cases there is the risk that a confirmed pregnancy to a recorded service may be due to an earlier or later service (recorded or unrecorded) and inaccurate measures of conception will result. Also cows that aborted prior to the pregnancy diagnosis will be incorrectly classified as failures to conceive.

In-calf Rates and Empty Rates

The reproductive performance of seasonally calving dairy herds is monitored using a variety of measures. Ultimately the performance of a seasonal mating is measured by the final outcome and the efficiencies obtained in achieving the particular result. The final outcome is usually a measure of the proportion of the herd that becomes pregnant. These have been widely documented and include the four week in-calf rate and eight week in-calf rate (Tranter 1991). The empty rates or the inverse of the number pregnant is the most common overall measure of mating performance in New Zealand. However in a seasonal herd the empty rate has little meaning unless a time period to achieve the result is defined. Analyses of these variables must consider the number of animals included in the denominator of the proportion. Usually the number of cows in the herd at the start of mating is used as the denominator however some cows may die or be removed for non-reproductive reasons early in mating season and have therefore not had an opportunity to become pregnant.

DairyMAN Performance Targets

Reproductive performance variables are of little use to management unless they can be compared with a standard of performance. This may be the results for the same herd in previous seasons or a comparison with other herds within the same season using an inter-farm comparison. The DairyMAN computer programme (Tranter 1991, Hayes and Morris 1996) uses a set of targets for the main reproductive indexes (Table 3) that have been derived from herd performance in New Zealand and from veterinary expectations for adequate performance.

The Causal Relationship Between Seasonal Reproductive Variables

The relationship between the different variables measuring reproductive performance in seasonally calving dairy herds must be understood when investigating problems (Brightling et al. 1990). The design and menu structure of DairyMAN and the epidemiological approach to investigating herd problems takes account of these associations (Tranter 1991). Most investigators of seasonal herd performance consider that the herds current calving pattern and heat detection efficiency have the greatest effect on reproductive performance and inadequacies in these are the most common causes of poor performance. They should therefore be evaluated before any other variables. If these factors do not explain poor submission rates, conception rates or in-calf rates then a more detailed investigation of other factors is required. This includes a comparison of different groups within herd. For submission rates this could include a comparison by lactation number, disease (lameness) and condition score of cows being mated. For conception rates the service sire, technician, service type and time frame are important additional factors to consider.

Table 3. Reproductive performance targets used in DairyMAN.

DairyMAN reproductive variable	Performance Targets
Calving Performance	
Planned start of Calving	
Cows to calve	
Cows Calved	
Induced	10
Four Week Calving rate	67
Eight Week Calving rate	95
Submission Rates	
Planned start of mating	
Cows to mate	
Percent 2 year olds	25
Percent calved < 40 days	10
Percent reproductive disease	20
Submissions 21 days	90
Submissions 28 days	92
Return Intervals	
Return Intervals 2-17 days %	13
Return Intervals 18-24 days %	69
Return Intervals 39-45 days %	7
Ration single to double cycles	9:1
Conception Rates	
1st Service 49 day Non-return rate	61
Total Service 49 day Non-return rate	61
1st Service Pregnancy rate	60
Total Service Pregnancy rate	60
Serves per conception	1.7
In Calf Rates	
Four week In-calf rate	62
Eight week In-calf rate	86
% not in-calf 100 days after PSM	7

There is a large body of information available in the literature on the reproductive performance of seasonally calving dairy herds. Many studies investigating factors affecting individual cow performance in non-seasonal herds can also be applied to a seasonally calving environment. This review is not a comprehensive discussion of the reproductive performance of seasonally calving dairy herds, but rather considers the important variables used for monitoring performance. Heat detection was considered in greater detail as the measures are rather imprecise for herds with a restricted mating period. The intention of the following chapters is to expand on the knowledge discussed in this review and provide more current information that is directly applicable to herds that are likely to use a DairyFIX expert system. It was also an important part of this project to describe all aspects of performance that could be considered given the available data, even though much of this would not be used in the development of an expert system. The investigations have therefore gone well beyond what was required for the development of DairyFIX. Chapter 2 describes the performance of different groups of herds in New Zealand. From this the achievable goals or targets were set for use in the DairyFIX system and the reader is able to gain an appreciation of normal herd performance in New Zealand. DairyMAN already includes default targets, but it was necessary to confirm the accuracy of these values. The chapters following this exam in detail the performance at herd level and at individual cow level.

Detailed statistical models are developed for inclusion in DairyFIX, but a more detailed study of DairyMAN herds, health events and other factors is also included. The closing chapters then describe the general structure of an expert system beyond what was covered in this review and the development and design of DairyFIX

Chapter 2

Data Collection and a Description of Herd and Individual Cow Reproductive Performance in New Zealand

Data Collection and a Description of Herd and Individual Cow Reproductive Performance in New Zealand

Objectives

The relationships between many reproductive indices have been previously reported and discussed in Chapter 1. Some of this information may not be applicable to New Zealand herds under current management conditions because the information has not been recently gathered or has been derived from overseas data. In addition, DairyMAN uses specific reproductive performance indicators that require further investigation. To develop an expert system for the diagnosis of reproductive performance the hypothesised relationships between performance variables required confirmation. Quantification of the associations between specific variables from DairyMAN must also be known if an expert system is to contain adequate knowledge to estimate expected reproductive performance.

The purpose of this data collection and the statistical evaluations described in the following chapters include;

1. Quantify the reproductive performance of New Zealand dairy herds using data from the National Dairy Database.

2. Evaluate the performance of herds using DairyMAN and compare with other New Zealand herds.

3. Identify factors contributing to improved reproductive performance.

4. Develop a path model for the reproductive performance of herds.

5. Define statistical models of the association between reproductive parameters used in DairyMAN

6. Use this knowledge in an expert system for the identification of poor reproductive performance in individual dairy herds and the diagnosis of causes where reduced performance is identified.

Data Collection and Management

Population of Interest: The New Zealand Dairy Herd and Users of DairyMAN

There were approximately 15,500 herds in New Zealand that supplied milk to factories in the period July 1993 to June 1994. Over 90 percent of these herds were seasonal with peak production during late spring. These herds concentrate calving into an 8 to 12 week period in early spring to optimize pasture utilization and milk production. Farm managers generally do not milk cows during the winter and dry cows off in the autumn at a date that is dependent on seasonal factors including stock numbers, pasture growth rates, pasture availability (pasture cover) and the supplies of conserved feed. Small numbers of herds calve year round or in the autumn and supply factories that market whole milk for consumption in New Zealand. There is also a very small number of dairy herds that raise calves exclusively and do not supply any milk.

National Data Base

Livestock Improvement provides services to the dairy industry including semen, insemination technicians, monitoring of individual milk production, data storage and reporting. Because the company has an industry monopoly on these activities except the supply of semen, virtually 100 percent of dairy herds that supply milk to factories have some information stored on the national data base held at Livestock Improvement. More than 90 percent of the dairy herds in New Zealand monitored individual cow production using the "Herd Test " service. Cows in each herd are sampled for milk yield, milkfat and protein for a morning and afternoon milking on nominated days. Seasonal herds generally test production four times at two monthly intervals, commencing 8 to 10 weeks after the start of calving. Individual animal details, genetic information and some reproductive data are stored for individual cows on a national data base together with these production records. Herd details including location, herd size, owner and factory are also stored.

The individual cow details for a herd on the National Dairy Database is called the Animal Register for that herd.

DairyMAN

DairyMAN is a management information system for individual dairy herds. It is intended for use by both dairy farmers and veterinary advisers to monitor dairy herd performance and to assist with day to day herd management. Development of DairyMAN at Massey University began in 1985 and was prompted by the need for a software package that could record and comprehensively analyse dairy herd information in a way that was relevant to seasonal New Zealand dairy farming systems. The program is marketed in New Zealand by Livestock Improvement and approximately 350 farmers and advisers were using DairyMAN by mid 1993. DairyMAN records the three main components of a dairy farming system: Milk production, reproduction and health. As well as individual cow data, some farm and herd information can be recorded and analysed including bulk milk production.

Unit of Interest

Herd Investigations

The unit of interest was the commercial seasonally calving dairy herd in New Zealand that was supplying milk to a dairy company. Samples of the population of New Zealand herds and of DairyMAN users were investigated separately.

Individual Cow Data

The unit of interest was the New Zealand dairy cow within herds being investigated. The population of interest was all cows in these herds. The National Dairy Database data set closely represents this population of cows for a single year. The herds using DairyMAN provided and alternative data source for individual cow performance for a subset of New Zealand herds with potentially different performance. The analysis of DairyMAN data was used to develop models required by an expert system to estimate and predict performance because the calculated coefficient estimates within these statistical models may more closely represent the effects in herds likely to use an expert system linked to DairyMAN. The data from DairyMAN had additional information including pregnancy results, pre-mating heats and a record of some disease events. The National Dairy Database records were analysed using similar models and provided an independent validation of findings from the herds using DairyMAN and quantification of important associations within typical New Zealand dairy herds.

The results of the analysis of data from the National Dairy Database is strictly valid only for cows belonging to herds that met the selection criteria that are described below. The inclusion criteria were designed to ensure that the sample most closely represented New Zealand dairy herds that did not use on-farm management information systems. This specifically excluded all users of DairyMAN and some other dairy herd management software. There were 600 users of DairyMAN and other down-loads out of approximately 14,500 herds recorded on the National Dairy Database. The criteria were also intended to exclude herds that could have inaccurate or incomplete data.

Data Collection

A stratified random sample of Animal Registers from the National Dairy Database was used to characterise the performance of dairy herds in New Zealand. DairyMAN users were asked to provide their herd data on disk for analysis.

Selection Criteria

National Dairy Database

Herds were selected using several criteria to ensure that they were representative of New Zealand dairy herds but did not use management information systems such as DairyMAN.

The criteria for herd inclusion in the population to be sampled were ;

1. The herd was not using DairyMAN or other on-farm information systems. This was achieved by excluding all herds that received down-loads of Animal Register data on floppy disk. For the comparison of DairyMAN and Animal register herds to be valid a herd could not be in both categories.

2. At least one record of herd testing in the four months prior to May 1994. This excluded herds that may not be currently active. For example some herds may be dispersed without updating the database records. This criterion also excluded those herds that did not production test on a regular basis (less than 10 percent of all herds in New Zealand).

3. The cow records on a herd Animal Register had been updated in the four months prior to May 1994. This again excluded non current herds and herds without accurate records.

4. The herd used Livestock Improvement semen and technicians. It was not certain if records for other semen companies would be accurate so these herds were excluded. Only one other company operated in New Zealand during the period of investigation and accounted for less than 5 percent of inseminations.

5. Herds were seasonally calving for peak production in spring. Autumn or year-round calving herds were not a part of this investigation.

Livestock Improvement's direct involvement in the AI mating program ensured that data would be available for the artificial breeding period. AI technicians complete details of inseminations at each visit to a farm and these records are entered on the herd's animal register. Companies other than Livestock Improvement offer semen for sale and farmers may inseminate their own animals. In these examples it is possible that the animal register would not be complete and valid interpretations of the data would be difficult.

Distribution of Herd Size

Data collected from the Livestock Improvement data base showed that herd size in March 1994 for herds with a record of matings in the 1993/94 season ranged from less than 50 cows to greater than 800 with a mean of 188 cows (Figure 2).

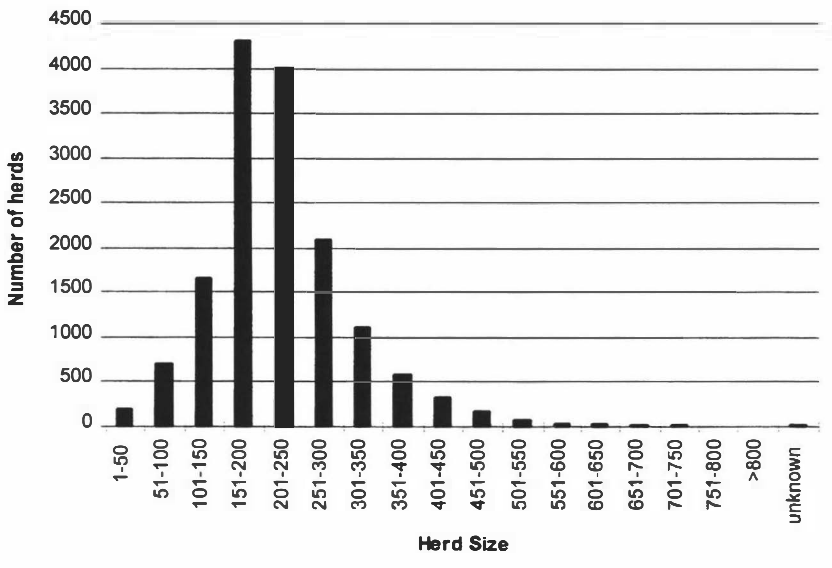

Figure 2. The size distribution of New Zealand herds in 1993/94 from a total population of 15442 herds.

The sample size was small relative to the total New Zealand herd population so a simple random technique may have excluded some herd size categories. To ensure that the sample distribution approximated the New Zealand herd population a stratified proportionate technique using four herd size groups was used. The strata were 0-100, 101-250, 251- 450 and greater than 450 cows in the herd at the start of mating. This technique also allowed for estimations of performance for each strata and comparisons to be made between these herd size groups.

DairyMAN

All users of DairyMAN were potential candidate herds. Herds that were not seasonal spring calving herds or had not down-loaded data from the National database in the previous four months were excluded from the analyses.

Required Sample Size

Herd Analyses

To determine a sample size that would allow sufficient power to detect biologically and economically relevant differences the data available from users of DairyMAN in the Manawatu (in Region 5) was utilized to obtain some approximation of herd performance. This information was used in the program Pass (Copyright 1992 by Dr. Jerry L. Hintze Kaysville, Utah. September 1992) to determine an appropriate sample size.

Based on the data available the sample size for each parameter shown in Table 4 provides a power of 0.80 of detecting the difference shown between two independent populations at a 0.05 level of significance.

Table 4. Means, standard deviation (S.D.) and required sample size for some herd reproductive performance parameters for some herds in the Manawatu

	Mean	S.D.	Difference to detect	sample N
Calving Performance				
Cows calved	221.30	68.74	20	183
Induction rate	2.70	4.03	1	253
Four week calving rate	59.90	15.71	5	156
Eight week calving rate	84.80	13.83	5	122
Submission Rates				
Percent 2 year olds	20.91	7.20	2	205
Calved less than 40 days	17.82	9.92	2	388
Reproductive disease rate	0.91	1.22	1	25
21 day submissions rate	70.73	11.01	5	78
28 day submission rate	78.45	10.08	5	65
Return Intervals				
Return intervals 18-24 days %	59.1	12.86	5	105
Conception Rates				
1st service 49 day non-return rate	57.4	9.38	5	57
1st service pregnancy rate	44.71	13.44	5	114
Serves per conception	2.26	0.55	0.2	120
In-Calf Rates				
Four week in-calf rate	43.60	12.28	5	96
Eight week in-calf rate	70.20	9.52	5	58
Empty rate (100 days after PSM)	13.60	6.62	1	29

The differences chosen for each variable were considered to be biologically and economically relevant and should be detectable if the data analysis is to be of value. Only the number of cows calved less than 40 days required more than 300 hundred herds to meet the required power based on the nominated criteria. It was concluded that 300 animal register herds would be an appropriate number of herds to achieve the required power and within available resource limits.

It was known from Livestock Improvement sales records that approximately 350 herds used DairyMAN in 1993. A survey response of sixty percent was considered achievable. The DairyMAN support at Livestock Improvement indicated however that a significant but unquantified number of herds could have unusable data. A response of 150 useable data sets from DairyMAN users would be a favourable response and realistically it could have been as low as 100. This sample size was considered to have adequate power for most aspects of these investigations.

Individual Cow Investigations

It was expected that 150 sets of DairyMAN herd records would include approximately 28,500 cows if the herd size is assumed to average 190 cows. The power to detect a difference in submission rates with an expected proportion of 0.8 cases submitted would require approximately 4000 animals in two comparison groups to detect a difference of 0.02. For variables with a lower expected proportion the sample size is less. It was concluded that there would be ample power to detect differences in major factors affecting individual animal performance. Power was expected to be limiting in some situations where cows were excluded due to missing data. Examples include the recording of pre-mating heats or health events where only a proportion of herds would be expected to have valid cases.

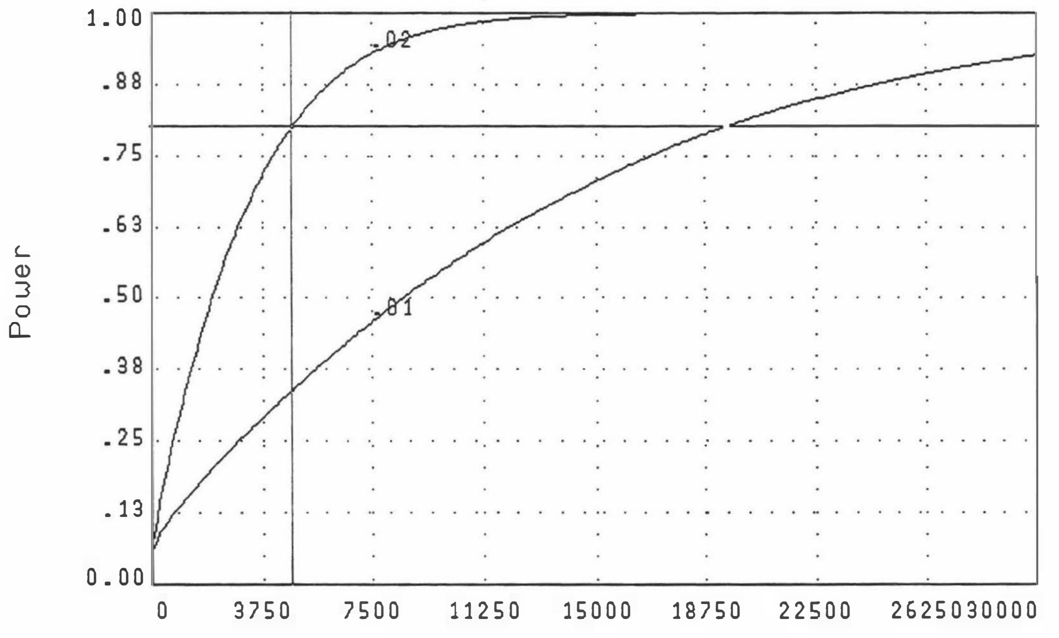

Figure 3. Power to detect a difference of 0.01 and 0.02 between two proportions for a sample size in each group of 0 to 30000. Four thousand cases are required to provide a power of 0.8 to detect a difference in the proportions of 0.02 for an expected base proportion of 0.8.

Sampling Techniques.

National Dairy Database

Herds were randomly selected from all herds meeting the criteria detailed above. The data from selected herds was provided on individual floppy disks in a standard text file format.

There were some limitations to this sampling technique. It under represented the performance of individual cows in large herds and over represented those from small herds. Selection bias did exist because herds with poor recording systems or non users of the National Dairy Database and herd testing were excluded. It was possible that these herds also had different reproductive performance to the sampled herds.

DairyMAN Users

All users of DairyMAN during the 1993/94 season were sent a letter (Appendix1) in early May 1994 requesting a copy of their herd's DairyMAN data on floppy disk. Information outlining the reasons for requesting data was provided and computer software prizes were offered as an incentive. Non-respondents were sent a second letter three weeks later. Veterinarians were also sent a similar request asking that herd DairyMAN data be provided after obtaining the approval of the herd owner or manager.

Sample Results

Livestock Improvement staff collected the National Dairy Database data using the specified criteria. A total of 300 herds was sampled. Forty-seven of these herds (15.7%) were less than 100 cows, 205 herds (68.3) had between 100 and 250, 43 (14.3) between 250 and 450 and 5 herds (1.7%) were larger than 450 cows (1.7%). Four herds selected from the National Dairy Database were excluded after sampling because they did not meet the criteria for seasonal calving.

There were 168 respondents to the DairyMAN survey (Table 5). Of these, 11 record sets were not retrievable from the computer disk or there was no information or files on the disk. A further 8 herds had corrupt data or there was insufficient information recorded for the herd. Six herds were not strictly spring calving seasonal herds.

All data sets were loaded into DairyMAN. National Dairy Database herd data was created in DairyMAN from the data disks and DairyMAN data sets were loaded. All loaded data sets were checked for integrity and any with significant corrupt data were excluded. Herds that did not demonstrate a spring calving pattern were also excluded. The reasons for exclusion are listed in Table 5.

Table 5. The number and reasons for herd data exclusion

	DairyMAN	National Database
Unreadable disk	5	2
Corrupt data	3	-
Insufficient cow records	5	-
No files on disk	6	-
Autumn or non-seasonal herd	6	4
Valid data sets	143	294
Total	168	300

In summary there were 143 DairyMAN herd records that were suitable for inclusion in the herd and individual cow analysis and 294 National Dairy Database herds for comparative investigations of performance.

Regional Distribution

The number of sampled herds was distributed across the major New Zealand regions in similar proportions to the true distribution of herds. Except for the Waikato region the number of herds was low and may not have provided sufficient power to investigate performance differences between some regions.

Table 6. Regional distribution of seasonal dairy herds in New Zealand, herds using DairyMAN included in the analyses and herds sampled from the National Dairy Database

	New Zealand*		DairyMAN		National Database	
	Count	Percent	Count	Percent	Count	Percent
Northland	1576	10.8	12	8.3	23	7.8
Waikato	6541	44.8	63	43.4	135	45.6
Bay of Plenty	879	6	3	2.1	29	9.8
Taranaki	2573	17.6	25	17.2	59	19.9
Manawatu	1407	9.6	20	13.8	21	7.1
South Island	1621	11.1	22	15.2	29	9.8

* Source Livestock Improvement Dairy Statistics 1993/94

Data Management

Planned Start of Mating and Planned Start of Calving

The calculation of seasonal reproductive parameters include the planned start of calving (PSC) and the planned start of mating (PSM) as critical event dates. The PSM was defined as the first date of recorded matings that was followed by at least seven subsequent days of mating. Isolated or individual random matings recorded before the bulk of herd matings were excluded from the determination of the PSM using this technique. The PSC is the expected start of calving based on the start of mating for the previous season. The PSC is therefore 282 days after the previous PSM, but some cows calve before the planned start due to natural variation in gestation length and other factors. The PSC was provided by the DairyMAN users and checked against the previous PSM (if available) and current season PSM. For animal register herds the PSC was the date as defined by the individual farmer. This information was obtained by Livestock Improvement as part of an annual visit to all herds before the start of each season by consulting officers. These PSC dates were provided as a separate file extract and checked against the PSM date.

No reliable information was available on the PSM for the heifers for the previous season, but this determined the start of calving for the lactation 1 cows for the season being investigated and may have been different from that for the adult cows. The PSC of the first calve cows was assumed to be the same as the rest of the herd.

Calving, submission, return intervals, non-return and in-calf rate reports were evaluated for data validity and errors. Low calving rates for some herds identified them as non-seasonal and they were then excluded. Performance outliers were checked and corrections made if data entry errors or incorrect PSC or PSM dates were identified. Outliers were otherwise not excluded from the analysis.

Some cows on the National Dairy Database had events recorded after a removal event was recorded. These cows were considered culled on the removal event date and included in the analysis if present in the herd at the PSM.

Data Limitations

National Dairy Database

The National Dairy Database contains records for individual cows that are identified by a unique identifier, owner, location and herd. The information for cows belonging to one herd makes up the Animal Register for that herd. Information stored for individual cows includes the data shown in Table 7.

Table 7. Data available in down-load from the National Dairy Database

Record type	Comment
Cow key	unique numerical identifier
Tag number	physical tag number in cows ear
location code	Geographical location of herd
herd code	Herd identifier
owner	Owner of the dairy herd
Birth date	day month and year of birth
Breed	The first two breed classifications stored on the database
Breeding and Production indexes	Measures of genetic capacity of the animal
Calving dates	day month and year of last calving
Mating details	All AI matings including date technician and semen are recorded
Drying off dates	These are poorly recorded by farmers
Culling record	Poorly recorded
Milk Production and Somatic cell counts	Cows are usually production tested four times annually

Pre-mating heats, health events and pregnancy status are not recorded on the National Dairy Database. Pregnancy status can be determined by non-return to oestrus analyses or retrospectively from a subsequent calving date or failure to calve. Subsequent calving dates were not available in this study and could therefore not be used as a confirmation of pregnancy. The use of a subsequent calving date as the criterion for pregnancy also excludes all culled animals and this creates a severe bias as all non-pregnant cows are excluded. Natural matings are recorded, but the accuracy of this information varies between herds.

DairyMAN

Health Events

Users of the DairyMAN information system can record data for any health events for individual cows and results of veterinary examinations can be recorded. The level of recording for these events is however unknown. Analysis of health information is therefore only indicative of a herd's health status and may represent the lower limit of disease within a herd. The methods of diagnosis are also unknown and may modify the recorded disease level. For example the diagnosis of endometritis by visual inspection may give a substantially different disease prevalence level compared with vaginal speculum examination of cows post calving. The are no guidelines for recording events. For example a chronically lame cow that shows episodes of differing lameness signs may have several new lameness event recorded. Herd managers vary in the methods used for determining new disease episodes.

Different herd managers record different health events so the inclusion of this data in multi variate analyses was restricted to key health events such as lameness and calving induction.

Pre-Mating Heats

DairyMAN users can record pre-mating heats but the level of recording in each herd varies. Where pre-mating heats were included in the analyses all herds without a recording of heats in greater than 25 percent of cows were excluded from the analysis. Herds were classified using this criterion into herds that record pre-mating heats and those that do not for the herd data investigations.

Pregnancy Test Herds

Information on some reproductive parameters such as pregnancy status was not available in the Animal Register data sets and many herds using DairyMAN. Herds that used whole herd pregnancy testing were used to investigate factors affecting pregnancy rates and in-calf rates calculated using pregnancy results. Herds that recorded a pregnancy status from veterinary examination in greater than 98 percent of cows in the herd at the end of mating were categorised for the purpose of this study as pregnancy test herds. Forty eight herdso f 143 met this criterion for the 1993 season. These herds were expected to have more accurate information on herd reproductive performance including in-calf and empty rates for the mating period because of this additional information. All other herds used non-return as the indicator of pregnancy. This method of analysis is dependent on the quality and duration of heat detection and the level of anoestrum in the dairy herd. The categorisation of herds into pregnancy test and non-return herds allowed for a comparison of performance between the two management groups and may quantify the level of error that can be expected when using non-return as the pregnancy indicator. Models including non-return and in-calf rates calculated from non-return data were also evaluated using the complete DairyMAN data set because this may be the only measure of conception rates available for use by an expert system in many New Zealand herds.

Most herds using DairyMAN included some pregnancy testing. Farmers may selectively pregnancy test to check cows due for culling or because they already considera cow empty based on other criteria and require confirmation. Only herds that used whole herd pregnancy testing were included in analyses of pregnancy and empty rates because of this selection bias.

A significant proportion of a herd may be culled between the end of mating and pregnancy testing. These animals may be sold for dairying but are more likely to be culled due to a low feed availability and consequentially a requirement to reduce herd size in the early Autumn. These animals will often be culled before they can be pregnancy tested. In this case the projected in-calf rates can only be estimated using non-return data.

In summary there were 295 herds containing 52,842 cows included in the data from the National Dairy Database and 143 herds using DairyMAN containing 34,623 cows. Forty eight of the herds using DairyMAN containing a total of 12,816 cows used whole herd pregnancy testing.

Calculation of Herd Data from Individual Cows Records

Herd reproductive variables were taken from standard DairyMAN reports. Individual cow records were exported from DairyMAN and stored in an Access database (MS Access, Microsoft Corporation). These data were also used to calculate herd production and breed demographics for herds. Milk production was calculated from total lactation to date (LTD) production for cows included in the last herd test for the season. For each cow included in the last herd test, the lactation to date cow production was divided by the number of days in lactation at the LTD date to give a lactation average production per day. The herd mean of this value for litres, fat and protein was included in the statistical analysis of herd performance.

$$P / \text{day} = \frac{\text{LTD (P)}}{\text{LTD date - Calving date}}$$

This formula used for P= Litres, Fat (Kg's) and Protein (Kg's)

The LTD date is 4 days after the herd test date and is the date used to calculate the lactation to Date (LTD) production. LTD's are calculated from production information from all herd tests within the lactation.

The Animal Register for the 300 herds sampled for the spring 1993 season included the last herd test for each herd for that season. All 300 herds had production information because one of the criteria for selection was that the herd must have been production tested in the four months of January 1994 to April 1995. Herds using DairyMAN had production records for all herd tests during the season. For the analysis of these herds the milk yield at intermediate herd tests was included in some analyses.

Herd Descriptive Statistics

The demographic and reproductive performance observations for each herd study group are reported here. The demographics for the herds using DairyMAN are shown in Table 8 and for the herds from the National Dairy Database in Table 9. The reproductive performance for the herds selected from the National Dairy Database are shown in Table 10. The reproductive performance for herds using DairyMAN in the 1993/94 season that pregnancy tested are shown in

Table 11 and for the non pregnancy test herds in Table 12. The results for herds using DairyMAN in the seasons prior to the 1993/94 period are shown in Table 13 and Table 14. The data from these previous years was not otherwise evaluated because the data was incomplete and could not be adequately verified.

The average breeding index for herds using DairyMAN was 127.3 ± 0.5 days and the average age of cows in the herds was 4.3 ± 0.1 years (Table 8). Equivalent variables from the National Database herds were similar (Table 9). In both cases Friesians were the main breed with crossbreeds representing approximately one third of the animals in each herd on average. Jerseys were represented the least. Pre-mating heats were recorded in 54 herds using DairyMAN with a mean of 63.9 ± 4.8 percent of cows in these herds being detected on heat before the start of mating. Thirty three of the herds using DairyMAN recorded the use of CIDR's at veterinary visits and 46 had recorded anoestrous cow examinations. Prostaglandin use was recorded in only 14 herds.

The mean mating period for all National Dairy Database herds was 74.7 ± 3.4 days or about 11 weeks. The minimum period for any single herd was 13 days for AI mating. A mating period of less than four weeks implies that not all cows were mated or that oestrus was synchronised. In either case there will generally be a proportion of cows requiring repeat services that were not recorded and the records for this herd must therefore be incomplete. Some herds recorded matings for up to 133 days or approximately 19 weeks. This analysis did not account for isolated individual matings that may have extended the calculated mating period nor is there any record of when bulls were removed from a herd.

All National Dairy Database herds recorded some artificial matings (Table 9). It is likely that this information is accurate for most herds because it is a contractual requirement of AI technicians to complete insemination records at each farm visit. The reason for very short mating periods in some herds is unexplained. The mean seasonal AI mating period was slightly less than 6 weeks at 39.0 ± 1.6 days for the National Database herds. A 5 to 6 week artificial mating period is typical of New Zealand dairy herds. Artificial breeding must continue for a sufficiently long period to provide adequate replacements for the herd, taking into consideration the planned herd size, survival and expected in-calf rates for heifers and culling patterns in the milking herd. Some herds with high performance are able to restrict artificial breeding to 4 weeks. Poor reproductive performance can require that calves born later in the season are retained for replacements. These animals may have an age disadvantage that can further reduce the performance of the heifer replacement group and first lactation cows.

The period of bull matings was also calculated for the National Database herds (Table 9). This was defined as the number of days from the first to last recorded natural service during the mating period. The average period of natural matings was 35.7 ± 3.3 days or approximately 5 weeks. Some herds selectively used bulls for some matings during the AI period so there may be overlap between the calculated artificial and bull mating periods in these herds. The mean total mating period was similar to the sum of each period type which indicated that there was little effect from overlap. Eighty-nine animal register herds or 30 percent of the sample did not record any matings to bulls. The interpretation of non-return rates from these herds is difficult and subject to significant errors because matings (and therefore heats) have not been recorded for a sufficiently long period.

The period of recorded matings for herds using DairyMAN showed a normal distribution with a mean of 93.0 ± 3.8 days or approximately 13 weeks (Table 8). The pattern of artificial inseminations for these herds was similar to that for National Database herds with a mean of 42.7 ± 2.0 days. Eleven of 144 herds using DairyMAN (7.6 percent) did not record any natural matings. The recording of natural matings was otherwise similar to the animal register herds in those herds that did record these event. (50.3 ± 4.0) days.

Reproductive Performance: An Expert's View

The pregnancy tested herds using DairyMAN showed acceptable overall reproductive performance (

Table 11) if the data is considered relative to the industry targets used in DairyMAN (Table 15). The average four week calving rate was similar to the industry target of 67.5 ± 3.4 % and the eight week calving rate was only one percentage unit below the average target level of 95 percent. As a consequence the average proportion of these herd calved less than forty days at the start of mating was 11.8 ± 2.4 which is only two percent above the target percent. The satisfactory calving pattern was achieved in part by a vigorous approach to calving induction with an average of 10.3 ± 2.3 percent of cows in these herds being induced to calve. The subsequent performance of this group is an important factor that could modify the herd outcome. The prospect that calving induction may not be possible for welfare and ethical reason in the future requires that the effects of not inducing are well understood. To some extent herd managers will choose to keep cows, knowing that calving induction is possible. The alternative to calving induction is more vigorous culling or an acceptance of reduced herd reproductive performance.

These herds were large with approximately 260 cows in the herd at the start of mating. Despite the adequate calving patterns, the 21 day submission rate was below target at 85.5 ± 2.1 percent. The calving pattern may have had a small effect on performance but would not explain all of this deficit in mating performance. Submission rates are low either because cows are not cycling or because heat detection is poor. The ratio of double to single cycles for these herds is 16 to 1 which suggests sensitive heat detection. Using the proportion of returns in the normal range and double cycle range gives an estimated mean heat detection rate of 92% using the formula described above. The low submission rates are therefore likely to be a consequence of a higher than expected number of anoestrous cows. This is supported by the slightly high proportion of short return intervals (14.7 ± 2.4 days). Although pregnancy rates did not achieve the industry targets, overall performance achieved 55.7 ± 2.7 percent of conceptions to first service and a rate for all services of 56.6 ± 2.5 percent. These figures are lower than commonly quoted performance levels for New Zealand, but the common use of non-return rates and measures of conception in elite herds may have provided optimistic measures of performance. The data collected and presented here should more closely reflect true performance. There may therefore be a significant opportunity to improve the reproductive performance of New Zealand herds through improvements in conception rates. The net effect of this performance was in-calf rates that were below target. The eight week calving rate was 80.7 ± 1.9 which is 5 percent below target. The empty rate was 10.7 ± 1.4 percent which is above the target of 7 percent. Again these figures are inferior to commonly quoted values, but should more accurately reflect true performance levels.

The herds using DairyMAN that did not pregnancy test had poorer overall performance for calving rates and submission rates. The pattern of return intervals was similar but the non-return rates and calculated in-calf rates were above target. These herds may have an inaccurate assessment of overall performance because pregnancy test results are not available

The herds sampled from the National Dairy Database (Table 10) showed calving rates and submission rates that were below industry targets. The calculated non-return rates are above target and the in-calf rates as measured have achieved the performance guidelines. The interpretation of these data depends on the accuracy of the non-return information.

Heat Recording

Information on heat detection was only available for herds using DairyMAN (Figure 4). Of 146 herds with data for 1993/94 season 54 recorded pre-mating heats for more than 20 percent of cows in the herd at the start of mating. Four herds recorded heats for only one or two cows but these were considered as non-heat recording herds. Although the heat detection rate will depend on the proportion of the herd that is cycling, some of these herds had less than 40 percent of cows showing heat before the herd PSM. Heat detection efficiency will further reduce the observed proportion, however it is likely that in some herds the data is incomplete.

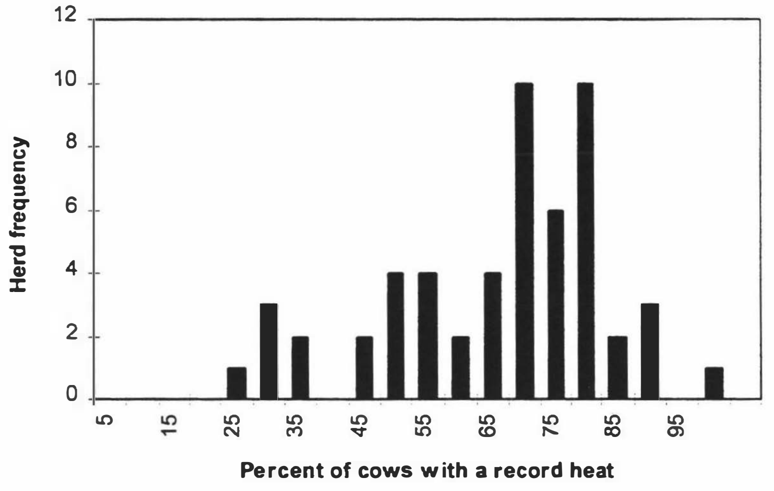

Figure 4. Frequency distribution of the proportion of a herd detected on heat for herds using DairyMAN in 1993

Table 8. Demographics and other descriptive statistics for the herds using DairyMAN

	Valid N	Mean	S.D.	Median	Minimum	Maximum	Lower Quartile	Upper Quartile	Range
Breeding Index	144	127.3 ± 0.5	3.3	127.8	115.1	133.7	126.0	129.7	18.7
Birth date	145	17/09/88 ± 28	169.9	25/09/88	5/06/87	9/04/90	23/05/88	29/12/88	-
Age (years)	144	4.3 ± 0.1	0.4	4.3	3.0	5.4	4.0	4.6	2.4
Cows > 7yrs (%)	144	25.6 ± 1.2	7.4	25.9	6.6	43.9	21.0	30.5	37.3
Two year olds (%)	144	21.0 ± 1.0	6.2	21.0	0.0	46	18	23	46
Heifer BI	138	130.5 ±0.6	3.6	131.3	115.0	136.1	129.3	132.8	21.1
No breed details (%)	145	3.8 ± 3.1	18.9	0.0	0.0	178.0	0.0	1.0	178.0
Friesian (%)	145	43.5 ± 5.0	30.7	44.9	0.0	100.0	13.8	70.1	100.0
Jersey (%)	145	13.8 ± 3.9	23.8	1.3	0.0	100.0	0.0	19.4	100.0
Crossbreed (%)	145	37.2 ± 3.9	23.7	34.1	0.0	100.0	18.5	53.9	100.0
Friesian pedigree (%)	145	1.8 ± 1.5	9.1	0.0	0.0	86.0	0.0	0.0	86.0
Jersey pedigree (%)	145	2.2 ± 1.7	10.5	0.0	0.0	96.4	0.0	0.0	96.4
Pre-mating heat detection rate (%)	54	63.9 ± 4.8	17.4	69.3	23.4	96.9	51.8	76.0	73.5
CIDRS (N) [a]	33	37.9 ± 16.0	45.2	23.0	1.0	198.0	9.0	40.0	197.0
Anoestrous cows (N) [b]	46	48.8 ± 13.9	46.8	41.5	1.0	207.0	15.0	63.0	206.0
Prostaglandin (N) [c]	14	18.4 ± 6.0	10.3	16.5	1.0	35.0	11.0	25.0	34.0
Days of mating	144	93.0 ± 3.8	23.2	94.0	31.0	144.0	80.5	110.0	113.0
Days of AI	144	42.7 ± 2.0	12.4	41.0	20.0	109.0	35.5	46.0	89.0
Days of bull	144	50.3 ± 4.0	24.5	51.0	0	102.0	38.5	70.5	1020

a The number of CIDR's (Controlled Intra-vaginal Drug Release devices) used in each herd for herds that recorded this data

b The number of anoestrous cows examined in herds that recorded this data at veterinary visits

c The number of anoestrous cows treated with prostaglandins in herds that recorded this information at veterinary visits

Table 9. Demographic and other descriptive statistics for the National Dairy Database herds

	Valid N	Mean	S.D.	Median	Minimum	Maximum	Lower Quartile	Upper Quartile	Range
Breeding Index	296	127.1 ± 0.3	2.4	127.1	115.1	132.8	125.5	128.8	17.7
Birth date	296	13/09/88 ± 27	233.7	11/10/88	29/07/86	7/09/90	1/05/88	2/02/89	-
Age (years)	296	4.3 ± 0.1	0.4	4.3	3.9	5.8	4.0	4.6	1.9
Cows >7 years old (%)	296	25.6 ± 1.1	9.3	24.7	0.6	54.8	19.9	30.5	54.2
Two year olds (%)	296	20.05 ± 2	8.4	20.0	0	64.7	16.9	23.2	64.7
Heifer BI	289	130.4 ± 0.3	2.7	130.9	115.8	136.0	128.5	132.3	20.2
No breed details (%)	295	1.5 ± 0.6	5.6	0.0	0.0	66.0	0.0	1.0	66.0
Friesian (%)	295	47.1 ± 3.6	31.2	50.0	0.0	--	17.7	75.2	--
Jersey (%)	295	17.3 ± 3.0	26.0	3.9	0.0	99.6	0.0	23.6	99.6
Crossbreed (%)	295	33.3 ± 2.6	22.4	30.0	0.0	--	17.4	45.8	--
Friesian pedigree (%)	295	0.7 ± 0.5	3.9	0.0	0.0	47.3	0.0	0.0	47.3
Jersey pedigree (%)	295	1.0 ± 0.8	6.6	0.0	0.0	79.6	0.0	0.0	79.6
Days of mating	296	74.7 ± 3.4	29.7	81.0	12.0	133.0	44.5	99.0	121.0
Days of AI	296	39.0 ± 1.6	14.2	37.0	13.0	101.0	31.0	43.0	88.0
Days of bull	296	35.7 ± 3.3	28.6	41.0	0	103.0	0.0	59.0	103.0

Table 10. Reproductive performance variables for 296 spring calving herds in 1993 from the National Dairy Database

	Mean	S.D.	Median	Min	Max	Lower Quartile	Upper Quartile	Range
Calving Performance								
Planned start of calving	29/07/93 ± 1.6	14.3	29/07/93	1/06/93	5/10/93	20/07/93	6/08/93	126 days
Cows to calve	184.7 ± 10.1	88.3	164.5	48	664	126	220	616
Cows calved	180.9 ± 10.0	87.5	160	44	630	122	218	586
Induction rate (% of cows calving)	5.5 ± 0.7	6.1	4	0	33	0	10	33
Four week calving rate (%)	62.7 ± 1.5	12.7	64	26	97	54	71	71
Eight week calving rate (%)	89.6 ± 1.0	8.6	92	58	100	87	96	42
Submission Rates								
Planned start of mating	20/10/93 ± 1.5	12.7	20/10/93	30/08/93	26/11/93	13/10/93	28/10/93	88 days
Cows to mate	169.3 ± 9.6	83.8	150	40	679	117	197	639
Percent 2 year olds	21.2 ± 0.9	8.2	21	0	65	18	24	65
Calved less than 40 days	15.7 ± 1.3	11.5	14	1	120	9	20	119
Reproductive disease rate (%)	-	-	-	-	-	-	-	-
21 day submissions rate (%)	78.9 ± 1.5	13.0	82	12	100	73	88	88
28 day submission rate (%)	84.8 ± 1.4	12.2	88	12	100	80	93	88
Return Intervals								
Return intervals 2-17days (%)	19.2 ± 2.0	17.3	15	0	100	8	24	100
Return intervals 18-24days (%)	61.7 ± 1.8	15.7	63	0	100	53	72	100
Return intervals 39-45days (%)	4.9 ± 0.6	5.2	5	0	50	0	7	50
Ratio of single to double cycles	13.8 ± 1.6	11.9	10	1	74	7	15	73
Conception Rates								
1st service 49 day non-return rate (%)	69.8 ± 1.2	10.5	70	24	100	63	76	76
All service 49 day non-return rate (%)	75.0 ± 0.9	8.0	74	45	100	69	80	55
In-Calf Rates								
Four week in-calf rate (%)	67.0 ± 1.4	12.3	68	14	97	61	74	83
Eight week in-calf rate (%)	86.2 ± 1.2	10.5	89	21	100	82	93	79
Empty rate (100 days after PSM) (%)	8.4 ± 1.4	12.0	5	0	95	2	10	95

Table 11. Reproductive performance variables for 48 spring calving herds using DairyMAN that pregnancy tested the entire herd for the 1993 season

	Mean	S.D.	Median	Min	Max	Lower Quartile	Upper Quartile	Range
Calving Performance								
Planned start of calving	31/07/93 ± 3.1	10.8	30/07/93	9/07/93	1/09/93	24/07/93	5/08/93	54 days
Cows to calve	265.6 ± 39.8	137.0	228	100	749	169	300	649
Cows calved	262.7 ± 39.1	134.8	228	100	737	167	297	637
Induction rate (% of cows calving)	10.3 ± 2.3	8.0	10	0	32	5	15	32
Four week calving rate (%)	67.5 ± 3.4	11.6	69	29	84	59	76	55
Eight week calving rate (%)	94.1 ± 1.5	5.1	96	81	100	91	98	19
Submission Rates								
Planned start of mating	22/10/93 ± 3.3	11.5	20/10/93	20/09/93	26/11/93	16/10/93	27/10/93	67 days
Cows to mate	257.0 ± 36.5	125.6	229	56	672	163	292	616
Percent 2 year olds	20.1 ± 2.4	8.2	19	0	44	17	23	44
Calved less than 40 days	11.8 ± 2.4	8.3	10	1	39	6	16	38
Reproductive disease rate (%)	0.5 ± 0.2	0.8	0	0	4	0	1	4
21 day submissions rate (%)	85.5 ± 2.1	7.3	87	68	97	80	91	29
28 day submission rate (%)	90.7 ± 1.9	6.5	91	71	98	88	96	27
Return Intervals								
Return intervals 2-17 days (%)	14.7 ± 2.4	8.3	14	3	40	8	19	37
Return intervals 18-24 days (%)	62.2 ± 3.1	10.8	62	38	90	55	70	52
Return intervals 39-45 days (%)	5.2 ± 0.8	2.9	5	0	12	4	6	12
Ratio of single to double cycles	16.1 ± 4.2	13.9	12	4	71	9	18	67
Conception Rates								
1st service 49 day non-return rate (%)	63.8 ± 2.8	9.5	64	40	86	60	70	46
All service 49 day non-return rate (%)	67.6 ± 2.3	7.9	67	48	88	61	73	40
1st service pregnancy rate (%)[1]	55.7 ± 2.7	9.3	57	35	78	50	63	43
All service pregnancy rate(%)[1]	56.6 ± 2.5	8.7	57	32	81	52	62	49
Serves per conception	1.8 ± 0.1	0.3	1.8	1.2	3.1	1.6	1.9	1.9
In-Calf Rates								
Four week in-calf rate (%)	60.1 ± 2.3	7.9	59	44	75	54	67	31
Eight week in-calf rate (%)	80.7 ± 1.9	6.5	80	66	96	76	85	30
Empty rate (100 days after PSM) (%)	10.7 ± 1.4	4.8	11	1	25	7	15	24

Table 12. Reproductive performance variables for 95 spring calving herds using DairyMAN that did not pregnancy test the entire herd for the 1993 season

	Mean	S.D.	Median	Min	Max	Lower Quartile	Upper Quartile	Range
Calving Performance								
Planned start of calving	29/07/93 ± 2.1	10.2	29/07/93	2/07/93	28/08/93	24/07/93	1/08/93	57 days
Cows to calve	235.5 ± 20.7	101.6	207	88	671	165	302	583
Cows calved	231.3 ± 20.1	98.7	203	88	671	163	290	583
Induction rate (% of cows calving)	7.6 ± 1.3	6.2	7	0	25	2	11	25
Four week calving rate (%)	66.8 ± 2.3	11.2	69	27	84	61	75	57
Eight week calving rate (%)	92.3 ± 1.5	7.3	94	64	100	90	97	36
Submission Rates								
Planned start of mating	19/10/93 ± 2.1	10.2	20/10/93	22/09/93	20/11/93	15/10/93	24/10/93	59 days
Cows to mate	229.2 ±21.3	104.6	200	84	668	154	297	584
Percent 2 year olds	21.7 ± 1.0	5.0	22	8	38	18	24	30
Calved less than 40 days	13.1 ± 1.9	9.4	10	0	44	7	16	44
Reproductive disease rate (%)	0.4 ± 0.3	1.6	0	0	13	0	0	13
21 day submissions rate (%)	84.6 ± 2.3	11.1	87	33	97	82	91	64
28 day submission rate (%)	89.5 ± 1.9	9.5	92	44	99	87	95	55
Return Intervals								
Return intervals 2-17days (%)	14.3 ± 2.0	9.8	12	0	52	7	18	52
Return intervals 18-24days (%)	64.9 ± 2.4	11.8	67	22	92	58	73	70
Return intervals 39-45days (%)	5.4 ± 0.8	3.9	5	0	25	3	7	25
Ratio of single to double cycles	17.7 ± 3.4	16.2	12	0	84	8	24	84
Conception Rates								
1st service 49 day non-return rate (%)	64.5 ± 1.6	8.0	64	41	98	60	69	57
All service 49 day non-return rate (%)	68.0 ± 1.4	6.7	67	52	98	64	72	46
In-Calf Rates								
Four week in-calf rate (%)	63.7 ± 2.0	9.6	66	24	89	59	70	65
Eight week in-calf rate (%)	85.6 ± 1.3	6.6	87	62	98	82	90	36
Empty rate (100 days after PSM) (%)	6.4 ± 0.9	4.5	5	0	22	3	8	22

Table 13. Reproductive performance variables for 99 spring calving herds using DairyMAN in 1992

	Mean	S.D.	Median	Min	Max	Lower Quartile	Upper Quartile	Range
Calving Performance								
Planned start of calving	30/07/92 ± 2.6	12.7	30/07/92	1/07/92	7/10/92	24/07/92	3/08/92	98 days
Cows to calve	237.1 ± 24.8	123.2	193	69	758	151	298	689
Cows calved	235.4 ± 24.7	123.5	193	69	758	149	296	689
Induction rate (% of cows calving)	6.3 ± 1.0	5.1	6	0	21	0	10	21
Four week calving rate (%)	68.2 ± 2.3	11.6	69	43	98	61	75	55
Eight week calving rate (%)	92.9 ± 1.2	6.3	95	71	100	90	97	29
Submission Rates								
Planned start of mating	21/10/92 ± 2.2	10.9	21/10/92	23/09/92	22/11/92	15/10/92	25/10/92	60 days
Cows to mate	230 ± 24.8	123.2	192	34	765	150	294	731
Percent 2 year olds	21.9 ± 1.3	6.2	22	6	43	18	25	37
Calved less than 40 days	13 ± 1.7	8.4	12	0	40	7	19	40
Reproductive disease rate (%)	1.1 ± 0.4	2.0	0	0	8	0	1	8
21 day submissions rate (%)	77 ± 3.0	14.6	82	32	96	69	87	64
28 day submission rate (%)	84.4 ± 2.7	13.1	88	37	100	78	93	63
Return Intervals								
Return intervals 2-17days (%)	16.2 ± 2.1	10.8	15	0	69	9	19	69
Return intervals 18-24days (%)	57.8 ± 2.9	14.3	62	12	79	49	69	67
Return intervals 39-45days (%)	4.9 ± 0.7	3.2	5	0	13	3	6	13
Ratio of single to double cycles	15.5 ± 3.3	16.1	11	0	87	7	17	87
Conception Rates								
1st service 49 day non-return rate (%)	63.7 ± 1.9	9.3	64	24	84	59	70	60
All service 49 day non-return rate (%)	66.9 ± 1.6	8.1	67	37	86	63	71	49
1st service pregnancy rate (%)[1]	51.2 ± 2.2	8.1	52	32	61	45	57	29
All service pregnancy rate(%)[1]	26 ± 7.5	7.8	52	32	64	45	58	32
Serves per conception	2.0 ± 0.1	0.4	1.9	1.6	3.1	1.7	2.2	1.5
In-Calf Rates								
Four week in-calf rate (%)	58.1 ± 2.5	12.6	60	20	90	49	67	70
Eight week in-calf rate (%)	80.4 ± 2.3	11.6	82	35	96	74	89	61
Empty rate (100 days after PSM) (%)	10.5 ± 2.1	10.3	9	0	65	3	13	65

Table 14. Reproductive performance variables for 30 spring calving herds using DairyMAN in 1991

	Mean	S.D.	Median	Min	Max	Lower Quartile	Upper Quartile	Range
Calving Performance								
Planned start of calving	28/07/91 ± 3.8	10.9	29/07/91	1/07/91	15/08/91	23/07/91	3/08/91	45 days
Cows to calve	224.3 ± 43.5	114.3	191	103	657	143	263	554
Cows calved	224.2 ± 43.4	114.3	191	103	657	143	263	554
Induction rate (% of cows calving)	6.8 ± 2.5	6.8	5	0	20	0	12	20
Four week calving rate (%)	63.9 ± 4.6	11.9	64	38	85	56	72	47
Eight week calving rate (%)	92.2 ± 2.6	6.9	95	70	100	88	98	30
Submission Rates								
Planned start of mating	19/10/91 ± 4.4	11.6	20/10/91	22/09/91	10/11/91	11/10/91	25/10/91	49 days
Cows to mate	218.5 ± 41.2	108.2	195	93	646	145	241	553
Percent 2 year olds	24.1 ± 3.3	8.7	21	11	48	18	27	37
Calved less than 40 days	14.2 ± 2.6	6.8	13	2	31	8	18	29
Reproductive disease rate (%)	0.3 ± 0.2	.6	0	0	2	0	0	2
21 day submissions rate (%)	75.9 ± 4.9	12.7	80	44	91	68	84	47
28 day submission rate (%)	82.3 ± 4.6	11.9	85	50	96	74	91	46
Return Intervals								
Return intervals 2-17days (%)	18.3 ± 3.6	9.3	18	3	43	10	22.5	40
Return intervals 18-24days (%)	58.9 ± 4.2	10.9	59	40	82	50	65.5	42
Return intervals 39-45days (%)	5.4 ± 1.4	3.5	5	0	14	2	8	14
Ratio of single to double cycles	11.9 ± 3.3	8.4	9	0	32	6.5	15.5	32
Conception Rates								
1st service 49 day non-return rate (%)	60.3 ± 4.1	10.8	63	29	82	54	67	53
All service 49 day non-return rate (%)	66.2 ± 3.3	8.6	67	44	83	60	72	39
1st service pregnancy rate (%)[1]	48.5 ± 3.6	5.0	48	41	56	44	53	15
All service pregnancy rate(%)[1]	51.5 ± 3.6	5.1	50	44	58	48	57	14
Serves per conception	2.0 ± 0.1	.2	2.0	1.7	2.3	1.8	2.1	.6
In-Calf Rates								
Four week in-calf rate (%)	53.7 ± 5.2	13.7	55	22	77	47	63	55
Eight week in-calf rate (%)	78.9 ± 3.9	10.2	81	53	95	70	85	42
Empty rate (100 days after PSM) (%)	10.7 ± 2.1	5.5	11	1	22	5	14	21

Establishing Performance Targets for Use in an Expert System

DairyMAN uses a set of predefined targets for each of the reproductive reports that have been derived from the known performance of New Zealand herds and the knowledge of experts. The chosen performance goals for use in the DairyFIX expert system are shown in Table 15. The targets have not been adjusted from those currently used in DairyMAN as they compare well with the observed herd performance. Warning and action levels represent inferior levels of performance and a more severe herd problem An operational system should allow for the modification of these targets. It would be reasonable to use the same set of targets for DairyMAN and the expert system and allow the user the option to modify these targets.

Table 15. A comparison of the reproductive performance of herds using DairyMAN and target performance values used in the development version of DairyFIX

	DairyMAN Not pregnancy tested		DairyMAN Pregnancy tested herds		National Database Herds		Performance goals		
Calving Performance	Mean	Upper Quartile	Mean	Upper Quartile	Mean	Upper Quartile	Target cut-off	Warning cut-off	Action cut-off
Induction rate	7.6 ± 1.3	11	10.3 ± 2.3	15	5.5 ± 0.7	10	10	15	20
Four week calving rate (%)	66.8 ± 2.3	75	67.5 ± 3.4	76	62.7 ± 1.5	71	67	60	50
Eight week calving rate (%)	92.3 ± 1.5	97	94.1 ± 1.5	98	89.6 ± 1.0	96	95	90	85
Submission Rates									
Percent 2 year olds	21.7 ± 1.0	24	20.1 ± 2.4	23	21.2 ± 0.9	24	25	35	40
Percent calved less than 40 days	13.1 ± 1.9	16	11.8 ± 2.4	16	15.7 ± 1.3	20	10	15	20
Reproductive disease rate (%)	0.4 ± 0.3	0	0.5 ± 0.2	1	-	-	20	25	30
21 day submissions rate (%)	84.6 ± 2.3	91	85.5 ± 2.1	91	78.9 ± 1.5	88	90	80	75
28 day submission rate (%)	89.5 ± 1.9	95	90.7 ± 1.9	96	84.8 ± 1.4	93	92	85	80
Return Intervals									
Return intervals 2-17days (%)	14.3 ± 2.0	18	14.7 ± 2.4	19	19.2 ± 2.0	24	13	20	30
Return intervals 18-24days (%)	64.9 ± 2.4	73	62.2 ± 3.1	70	61.7 ± 1.8	72	69	60	50
Return intervals 39-45days (%)	5.4 ± 0.8	7	5.2 ± 0.8	6	4.9 ± 0.6	7	7	12	15
Ratio of single to double cycles	17.7 ± 3.4	24	16.1 ± 4.2	18	13.8 ± 1.6	15	9	6	4
Conception Rates									
1st service 49 day non-return rate (%)	64.5 ± 1.6	69	63.8 ± 2.8	70	69.8 ± 1.2	76	62	55	50
All service 49 day non-return rate (%)	68.0 ± 1.4	72	67.6 ± 2.3	73	75.0 ± 0.9	80	62	55	50
1st service pregnancy rate (%)			55.7 ± 2.7	63			60	50	45
All service pregnancy rate (%)			56.6 ± 2.5	62			60	50	45
Serves per conception			1.8 ± 0.1	1.9			1.7	2.0	2.6
In-Calf Rates									
Four week in-calf rate (%)	63.7 ± 2.0	70	60.1 ± 2.3	67	67.0 ± 1.4	74	62	50	45
Eight week in-calf rate (%)	85.6 ± 1.3	90	80.7 ± 1.9	85	86.2 ± 1.2	93	86	75	65
Empty rate (100 days after PSM) (%)	6.4 ± 0.9	8	10.7 ± 1.4	15	8.4 ± 1.4	10	7	10	15
Abortions (%)							5	7	10

Demographics for DairyMAN User Herds

There were 34,623 cow records from 143 herds included in the final data-set for the analysis of individual cow reproductive performance. One thousand, eight hundred and twenty eight cows were excluded from within these herds because the calving dates were more than 40 days before the herd PSC or more than 160 days after the herd PSC. Four hundred and thirty two cows were further excluded because no calving date was recorded. Although some of these cases would have been true carryover cows from the previous season, it was not possible to validate the data. The 34,623 cows in the final data-set was used for all statistical analyses of cows in herds using DairyMAN and for the reporting of most descriptive statistics.

The number of animals sampled varied between regions (Table 16). There were only 689 cows in 3 herds from the Bay of Plenty (Region 3) which has the smallest population of the major dairying regions. It was however under-represented. All other regions were represented approximately in proportion to the population distribution and provided adequate sample numbers for the statistical analyses.

Table 16. The number and percentage of cows in each region

Region	N	%
Northland	2461	7.1
Waikato	14586	42.1
Bay of Plenty	689	2.0
Taranaki	6085	17.6
Wellington	5938	17.2
South Island	4863	14.0
Summary	34623	100

For the classification of lactation numbers into LACCAT the greatest proportion of cows was in LACCAT 5 with 10,161 cows (29.3%). However this combined all cows in Lactation 5 or greater into one class. The lactation one group was the largest single lactation category with 7,719 cows (22.3%). The numbers reduced with each lactation number. Figure 5 shows that there are significant losses from the dairy herd that begins from the first lactation. Although much of this culling may be voluntary, the losses in the early lactations are striking, considering that New Zealand cows are on a pasture-based system and that production does not peak until the fourth and fifth lactation (Table 18). Survival of cows is not a component of the present studies, but there is clearly a need to investigate these issues.

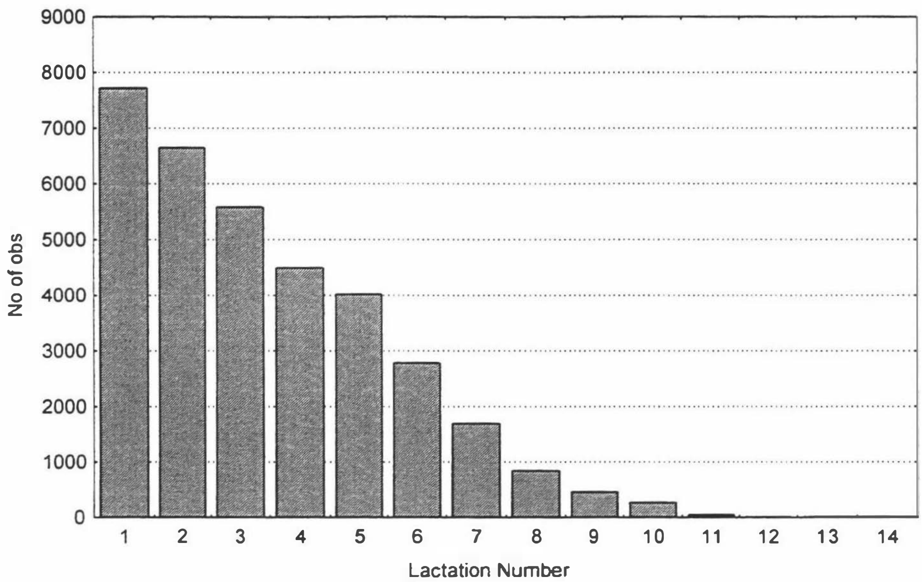

Figure 5. The number of cows for each lactation number in the sampled herds using DairyMAN

For the classification of cows into breed classes, the Friesian breed was the most common and represented close to half of all cows (Table 17). Only 13 percent of cows were Jersey with 36 percent of animals recorded as Cross-breeds. Pedigree animals represented less than 5 percent of cows. These animals were kept as separate classes because a preliminary analysis of the data suggested that their performance was very different from the commercial animals. An accurate assessment of the commercial cows was more likely if these animals were excluded, but the small numbers limited the power to accurately describe the performance of the pedigree Friesian and particularly the pedigree Jersey cows. Less than 1 percent of cases did not have a breed description recorded.

Table 17. The number and percentage of cows in each breed category for the herds using DairyMAN

Breed	N	%
Friesian Pedigree	455	1.31
Friesian	15621	45.12
Cross	12729	36.76
Jersey	4556	13.16
Jersey Pedigree	945	2.73
Missing	316	0.91
Total	34623	100

DairyMAN Herd Milk Production: Descriptive Statistics

Production statistics are shown in Table 18. Milk yields were greatest at the first herd production test which is generally two months after the herd planned start of calving (PSC). Not all herds recorded milk production test data and this accounts for most of the missing values. Some cows are not included in the first herd test as they had not yet calved and others were excluded in the latter part of the season as cows and herds are dried off.

Table 18. Milk production statistics for all cows included in the analyses at each of four herd tests during the season for the herds using DairyMAN

		Mean	-95%	+95%	Minimum	Maximum	S.D.
Herd Testl							
N=27397	Litres	20.5	20.4	20.5	0.0	43.1	5.6
	SCC	172.8	167.4	178.1	0.0	9999.0	455.7
	Milkfat (kg)	0.94	0.93	0.94	0.0	2.64	0.25
	Protein (kg)	0.74	0.74	0.75	0.0	1.83	0.19
	Milksolids (kg)	1.68	1.68	1.69	0.0	3.56	0.42
Herd Test2							
N=28800	Litres	18.4	18.3	18.4	0.0	72.3	5.0
	SCC	156.1	151.6	160.7	0.0	9167.0	394.0
	Milkfat (kg)	0.88	0.88	0.88	0.0	3.07	0.22
	Protein (kg)	0.68	0.67	0.68	0.0	2.20	0.16
	Milksolids (kg)	1.56	1.55	1.56	0.0	5.27	0.37
Herd Test3							
N=27942	Litres	15.2	15.1	15.2	0.0	33.2	3.9
	SCC	180.0	175.5	184.5	0.0	8179.0	386.2
	Milkfat (kg)	0.74	0.74	0.74	0.0	1.63	0.17
	Protein (kg)	0.55	0.55	0.55	0.0	1.26	0.13
	Milksolids (kg)	1.29	1.29	1.29	0.0	2.83	0.29
Herd Test4							
N=25841	Litres	11.1	11.0	11.1	0.8	33.8	3.6
	SCC	215.6	210.8	220.4	0.0	9999.0	393.8
	Milkfat (kg)	0.60	0.60	0.60	0.0	1.53	0.17
	Protein (kg)	0.43	0.43	0.44	0.0	1.05	0.12
	Milksolids (kg)	1.04	1.03	1.04	0.0	2.58	0.29
	Lactation Total Litres	3730.8	3719.1	3742.5	0.0	7525.0	961.9
BIINDEX N=34132		127.7	127.6	127.7	0.0	205.0	6.6

The milk production and Breeding Index for the major animal classes are shown in Table 19. These descriptive data suggest that the Breeding Index may reduce with increasing lactation number. The New Zealand Dairy Industry has a very active breeding programme that is controlled nationally and yearly gains in the Breeding Index have been reported (Livestock Improvement 1994). As previously discussed, the Breeding Index may be confounded by lactation number if the lactation number is not included in a statistical model of reproductive performance or interact with Breeding Index where both variables are included in a statistical model. The Breeding Index of different breeds may vary slightly as the variable cannot be strictly compared across breed (This was one of the reasons that the Breeding Index or BI was replaced, in New Zealand, with a new measure of genetic merit called the BW or Breeding Worth in 1996.). The Breeding Index would not be expected to vary with the number of days calved at the PSM for individual cows unless replacement animals have been reared from bull matings that generally occur late in the mating season. Such animals will be considerably younger at the start of mating as heifers and have been shown to have poor fertility (K.L. Macmillan 1996, personal communication). Consequently such animals may calve later as Lactation one animals into the adult herd. The practice of rearing this class of animals would be expected to be low in New Zealand.

The mean daily milk production values for different breeds and lactation number (LACCAT) are consistent with industry expectations (Table 19). Milk production ranged from 1.25 kilogram of Milksolids for LACCAT1 to 1.7 kilograms of Milksolids from LACCAT4 and greater. Because the number of days at the first herd production test varies with the PSMCAT there may be some variations in daily Milksolids consistent with an expected lactation curve. The data suggests that the measure of daily milk production may interact with PSMCAT in statistical models including both variables.

Table 19. The Breeding Index, daily milksolids per cow at the second herd test (MS2) and the lactation average daily milksolids per cow (MS) for each lactation category, days calved at PSM category (PSMCAT) and by breed category (BREEDCAT) in the herds using DairyMAN

Lactation	BIINDEX			MS2(kg/day)			MS (kg/day)		
number	N	Means	S.D.	N	Means	S.D.	N	Means	S.D.
1	7478	130.5	6.3	6358	1.25	0.27	5124	1.25	0.24
2	6498	129.1	6.4	5505	1.52	0.31	5030	1.44	0.37
3	5551	128.3	6.1	4786	1.64	0.33	4450	1.58	0.32
4	4479	126.7	6.2	3826	1.70	0.34	3676	1.66	0.26
>4	10126	124.7	5.8	8324	1.70	0.36	7561	1.66	0.27
Total	34132	127.7	6.5	28799	1.56	0.37	25841	1.52	0.33

PSMCAT	BIINDEX			MS2			MS		
	N	Means	S.D.	N	Means	S.D.	N	Means	S.D.
1	1023	126.4	7.5	819	1.63	0.47	696	1.56	0.35
2	3736	126.8	6.6	3088	1.63	0.38	2797	1.56	0.33
3	8956	127.3	6.5	7567	1.60	0.37	6960	1.54	0.35
4	16024	127.9	6.5	13512	1.55	0.35	12263	1.53	0.32
5	4394	128.8	6.3	3814	1.42	0.35	3125	1.41	0.32
Total	34133	127.7	6.5	28800	1.56	0.37	25841	1.52	0.33

Breed	BIINDEX			MS2			MS		
	N	Means	S.D.	N	Means	S.D.	N	Means	S.D.
Fr Ped	453	119.7	6.4	391	1.71	0.38	394	1.49	0.50
Fr	15471	127.9	6.1	12826	1.56	0.37	11267	1.52	0.34
Cross	12652	127.5	6.6	10752	1.58	0.38	9790	1.56	0.34
Jr	4491	128.6	5.9	3780	1.48	0.33	3378	1.47	0.26
Jr Ped	945	126.0	9.3	930	1.46	0.33	902	1.42	0.27
Total	34012	127.7	6.5	28679	1.56	0.37	25731	1.52	0.33

a Abbreviations are Fr Ped = Friesian pedigree, Fr = Friesian, Cross = crossbreeds, Jr = Jersey and Jr Ped = Jersey pedigree.

DairyMAN Herd Reproductive Performance: Descriptive Statistics

The reproductive performance of the different groups of animals is investigated in detail in later chapters. A summary of the performance statistics are reported here to identify areas of interest and to describe the reproductive performance of New Zealand dairy cows.

Continuous Measures of Reproductive Performance

Although the number of days from calving to the planned start of mating (CAL_PSM), from calving to service (CAL_SER), planned start of mating to service (PSM_SER) planned start of mating to non-return (PSM_NR) calving to conception (CAL_CONC) and planned start of mating to conception (PSM_CONC) are not considered in most of the statistical analyses of seasonal reproductive performance they are reported here (Table 20) as they are commonly used measures of herd reproductive performance in non-seasonal and some seasonal herds performance statistics. They are shown for the different lactation (LACCAT) breed (BREED) and days calved at PSM classifications (PSMCAT).

Table 20. The mean and standard deviation for the planned start of calving to calving (PSC_CAL), calving to planned start of mating (CAL_PSM), calving to service (CAL_SER), and planned start of mating to service (PSM_SER), in days for each lactation (LACCAT), breed (BREED) and the number of days calved at planned start of mating (PSMCAT) classifications.

	N	PSC_CAL		CAL_PSM		N	CAL_SER		PSM_SER	
		Mean	S.D.	Mean	S.D.		Mean	S.D.	Mean	S.D.
LACCAT										
1	7719	16.3	20.3	66.4	20.6	7269	80.2	20.9	13.6	13.3
2	6657	23.4	19.2	59.4	19.4	6406	72.4	19.5	12.8	12.2
3	5591	22.6	18.1	60.2	18.3	5440	72.1	18.2	11.8	10.5
4	4495	21.8	17.7	61.0	17.8	4344	72.7	17.9	11.6	9.7
>4	10161	21.8	17.8	61.0	18.0	9637	73.6	18.0	12.3	10.6
Total	34623	21.0	18.9	61.8	19.0	33096	74.5	19.3	12.5	11.4
PSMCAT										
<20	1041	72.3	12.7	9.2	11.8	928	38.5	17.2	28.8	19.8
20-39	3779	49.6	6.9	32.4	5.6	3554	48.8	14.0	16.4	13.5
40-59	9074	31.0	6.9	51.5	5.7	8686	64.2	12.3	12.7	11.4
60-79	16230	12.2	6.2	70.6	5.5	15632	81.7	11.0	11.1	9.7
>79	4500	-3.2	7.5	87.2	7.0	4297	97.6	11.3	10.5	9.3
Total	34624	21.0	18.9	61.8	19.0	33097	74.5	19.3	12.5	11.5
BREED[a]										
Fr Ped	455	25.7	22.1	60.1	21.5	422	74.9	21.9	15.1	14.8
Fr	15622	21.3	19.0	61.7	19.3	14901	74.7	19.6	12.7	11.9
Cross	12730	20.9	18.8	61.9	18.9	12221	74.4	18.9	12.3	11.2
Jr	4556	19.2	18.0	62.5	18.1	4386	74.2	18.6	11.6	10.0
Jr Ped	945	22.1	18.4	58.7	18.7	887	72.3	19.0	13.7	11.2
Total	34308	21.0	18.8	61.8	19.0	32817	74.5	19.2	12.5	11.4

a Abbreviations are Fr Ped = Friesian pedigree, Fr = Friesian, Cross = crossbreeds, Jr = Jersey and Jr Ped = Jersey pedigree.

Table 21. The mean and standard deviation for the planned start of calving to non-return (PSM_NR), calving to conception (CAL_CONC) and planned start of mating to conception (PSM_CONC), in days for each lactation (LACCAT), breed (BREED) and the number of days calved at planned start of mating (PSMCAT) classifications

	PSM_NR			CAL_CONC			PSM_CONC	
LACCAT	N	Means	S.D.	N	Means	S.D.	Means	S.D.
1	7287	26.4	23.5	2667	94.9	27.7	26.6	23.7
2	6415	24.9	22.0	2350	86.8	26.1	25.6	23.2
3	5444	23.4	20.9	2031	85.5	25.3	23.8	21.9
4	4351	23.4	20.7	1500	86.1	25.3	24.3	22.0
>4	9650	25.9	23.4	3544	88.6	25.2	25.9	22.8
Total	33147	21.5	22.4	12092	88.8	26.2	25.4	22.9

PSMCAT	PSM_NR			CAL_CONC			PSM_CONC	
	N	Means	S.D.	N	Means	S.D.	Means	S.D.
<20	930	45.9	25.3	260	58.9	23.5	48.8	24.6
20-39	3565	33.0	24.2	1184	67.0	25.2	34.3	24.9
40-59	8697	26.4	23.0	3098	78.7	23.7	27.0	23.5
60-79	15655	22.3	20.9	5794	93.7	21.7	22.9	21.3
>79	4301	21.2	20.3	1756	109.7	22.6	21.8	21.5
Total	33148	25.1	22.4	12092	88.8	26.2	25.4	22.9

BREED[a]	PSM_NR			CAL_CONC			PSM_CONC	
	N	Means	S.D.	N	Means	S.D.	Means	S.D.
Fr Ped	422	28.8	24.7	124	91.7	29.9	29.8	26.0
Fr	14901	24.5	21.4	6352	88.5	26.3	25.6	22.6
Cross	12221	25.2	22.8	4157	89.0	25.7	24.7	22.5
Jr	4386	25.0	22.9	1163	89.2	25.7	25.5	23.6
Jr Ped	887	31.3	28.2	245	88.2	28.8	27.2	26.2
Total	32868	25.1	22.4	12041	88.8	26.1	25.4	22.8

a Abbreviations are Fr Ped = Friesian pedigree, Fr = Friesian, Cross = crossbreeds, Jr = Jersey and Jr Ped = Jersey pedigree.

Measures of Reproductive Performance used in Seasonal Herds

The performance of the different lactations (LACCAT), days calved at PSM (PSMCAT) and breed (BREED) classes of cows in the DairyMAN data set using the commonly used measures of reproductive performance for seasonal herds (and those reported in DairyMAN) are shown in Table 24. The in-calf values (IN4NR and IN8NR) reported here are those calculated using the results of a 28 day return analysis for all recorded matings. Most users of DairyMAN do not pregnancy test the herd, so this is the more common method of determining the in-calf status of individual cows and the herd. (The DairyMAN programme will use pregnancy results for any individuals in the herd in preference to this calculation, where a pregnancy result has been recorded).

Calving Events and Description

A calving event has a number of descriptors that can be recorded on the National Dairy Database and in DairyMAN. The date, type of calving and details of the calf (ves) including the calf(ves) sex and fate can be recorded. Twin calves can also be documented. Health events other than induction are recorded as separate events in DairyMAN and are discussed in that section. Calving Induction accounted for 3026 (8.7%) of all calvings with less than 1 percent of calving being recorded as abortions or premature births (231 cows or 0.7%).

More than half of the calves with recorded sex details were bulls (52.6% male 47.4 female). The difference was statistically significant using a Chi square statistic comparing two proportions (P<.01). Four thousand and forty (11.7%) of all calving events did not include a record of calf sex. Care should however be taken in this simple comparison because the accuracy of recording calf sex may be confounded by the number of days from the Planned Start of Calving and the Fate of the calf. For example most herd managers only rear heifer calves born during the first six weeks and all other animals are either culled or reared for beef. Animals not required to be reared may not have the sex accurately recorded and may possibly be recorded as bull calves by default. The analyses described later in this chapter consider these interactions.

Twins were rarely recorded with 321 cases recorded. This represented less than 1 percent of all calving. Although this information is subject to missing values it is possible that the twinning rate is much lower in New Zealand than in some overseas dairy industries.

New Zealand seasonally calving dairy herds typically cull many males calves as new born animals and are referred to as "Bobby" calves (Table 22). Some heifer calves are also sold as new born animals if they are not to be kept for rearing into the dairy herd. Conversely some bull calves are reared for beef.

Table 22. The recorded fate of the first calf by sex for all calvings with recorded calf details

	Heifer Calf		Bull Calf		
	N	%	N	%	Totals
Reared	9381	87	1399	13	10780
Sold	1274	24	4028	76	5302
Died	1313	41	1851	59	3164
Bobbied	2241	22	7892	78	10133
Unknown	130	39	204	61	334
Totals	14339	48	15374	52	29713

Calving Pattern

The calving pattern for all cows in the herds using DairyMAN is shown in Figure 6. The mean PSC_CAL of 21 ± 0.2 is after the peak of calving as depicted in this graph. For herds that have not changed the PSM relative to the PSC in the season under investigation the PSM will be 83 days after the herd PSC. There is only a very small group of cows that have not yet calved at the PSM although there is a significant number that are calved less than forty days at the PSM. The numbers in each PSMCAT are shown in Table 23.

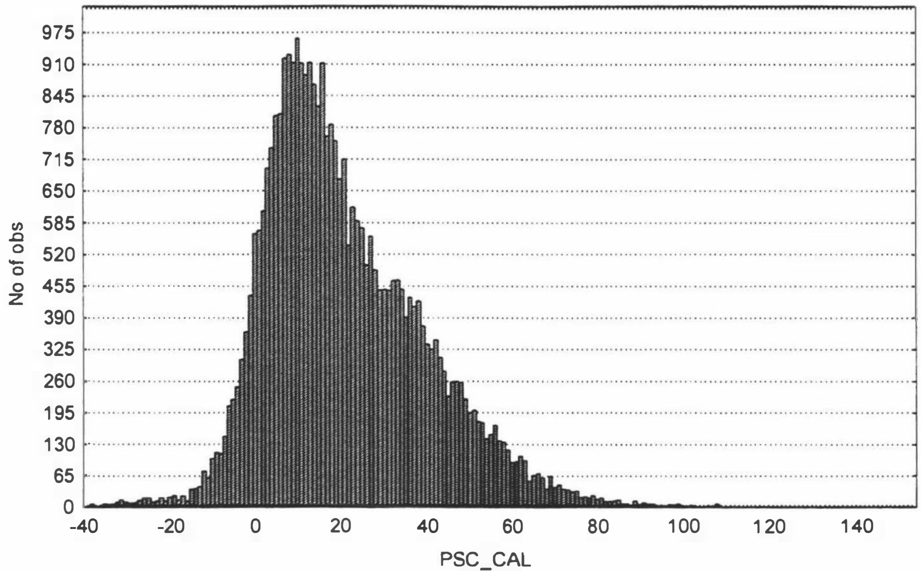

Figure 6. The calving pattern for all cows in herds using DairyMAN

Table 23. The number and percentage of cows in each category of days calved at the herd PSM.

PSMCAT	Range of Day Calved	N	%
1	0-19	1041	3.0
2	20-39	3779	10.9
3	40-59	9073	26.2
4	60-79	16229	46.9
5	>79	4501	13.0
Total		34623	100

Submission Rates

The proportion of the herd submitted in the first 21 days is generally used in New Zealand. The 28 day submission rate is in more common use in Australia.

Submission rates during the first three weeks of mating are not the same for each week. (Figure 7). The pattern of submissions is a function of the reproductive cycle of individual cows within a herd and the management strategies at the start of mating. There is a greater number of cows mated on Day 1 and this may be due to the inclusion of cows in oestrus during the previous day (or even longer if tail paint is the only indicator of oestrus). Some cows with an oestrus interval of greater than 21 days may not be submitted until the fourth week of mating. Conversely some cows will be have a short return interval and will therefore tend to be mated in the first week and a half of mating.

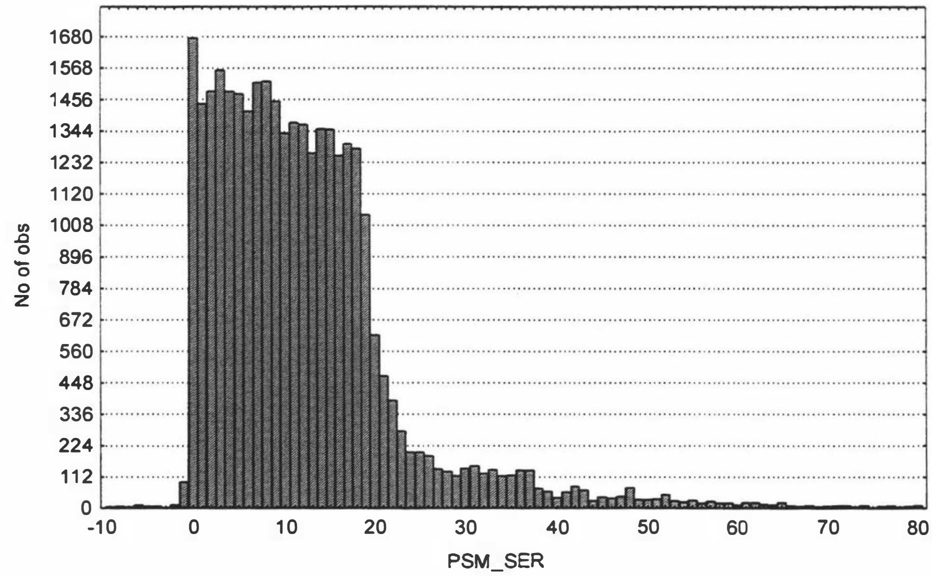

Figure 7. Daily submission (first service) frequencies for cows in herds using DairyMAN during 1993/94 season.

The use of anoestrus treatments may reduce some of the observed differences in submission rates, but this effect has not been quantified. Some of the increased submissions observed in the first days of the mating period may be due to unrecorded synchronisation or treatment of anoestrous cows prior to the start of mating.

The 21 day submission rates for all cows, by the number of days calved at the start of mating is shown in Figure 8. The graph suggests that submission rates of greater than 80 percent are usually achieved for cows calved greater than 40 days at the start of mating. Cows calved fewer days at the start of mating have a shorter period to begin cycling if they are to be submitted within the first 21 days of mating. Submission rates are however below accepted industry targets. Submission rates of greater than 90 percent are not achieved for any of the categories shown in Table 24. If we assume that approximately 6 percent of heats were missed (see below) in these herds then there is still a remaining group of non-cycling cows in these herds.

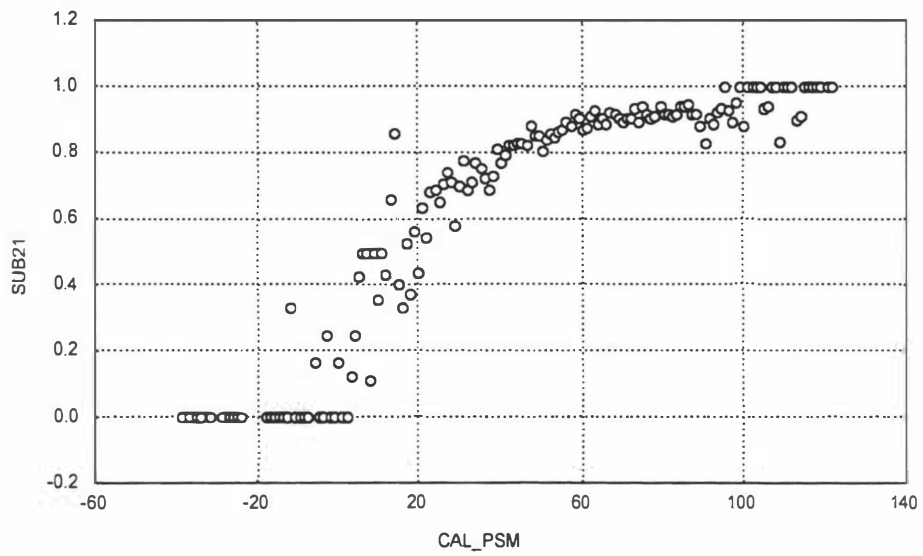

Figure 8. Twenty one day submission rates recorded in herds using DairyMAN by days calved at the herd planned start of mating

Heat Detection

The combined return interval distribution for herds using DairyMAN that recorded pre-mating heats is shown in Figure 9. A total of 15302 intervals were recorded with 62% in the normal range of 18 to 24 days. There were 15.9 percent of intervals less than 18 days and the ratio of double cycles to normal was 12.6 to 1. The average interval between heats was 23.7 days (single day returns were excluded from these calculations). The graphical representation of the return interval distribution illustrates the effects of missed heats with a small peak at 42 days and a peak of returns around day 11 due to short cycles. The number of long returns is significantly affected by the duration of heat detection during the mating season, however the ratio of double to normal cycles indicates satisfactory overall heat detection within these herds. Using the relationship for the heat detection rate (HDR)

$$HDR = \frac{(\%18-24)-(\%39-45)}{(\%18-24)} \times 100$$

gives an estimate of 94 percent of heats detected or 6 percent of heats missed. Heat detection often ceases or becomes variable when bulls are introduced to the herd at around the 6th week of mating.

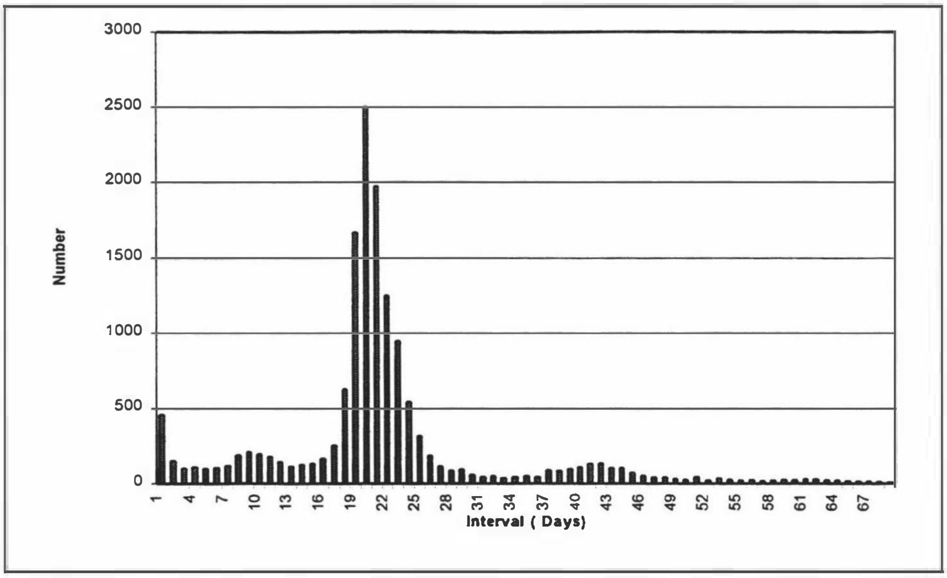

Figure 9. Distribution of return intervals for cows in herds using DairyMAN

Pregnancy Rates

Many of the causes of poor conception rates have been reported (Macmillan 1979, Macmillan 1985, Tranter 1985) Some observations are presented here.

Despite a decline in the number of submissions from week one to week three there is not a corresponding drop in the number of pregnancies (Figure 10). The pregnancy rate may therefore be increasing each week. This has been observed with non-return analyses for New Zealand herds (Burton 1996. personal communication) Pregnancy rates could increase as mating progresses for several reasons including

1. Improved accuracy of heat detection
2. Increasing days from calving
3. Improving technician skill

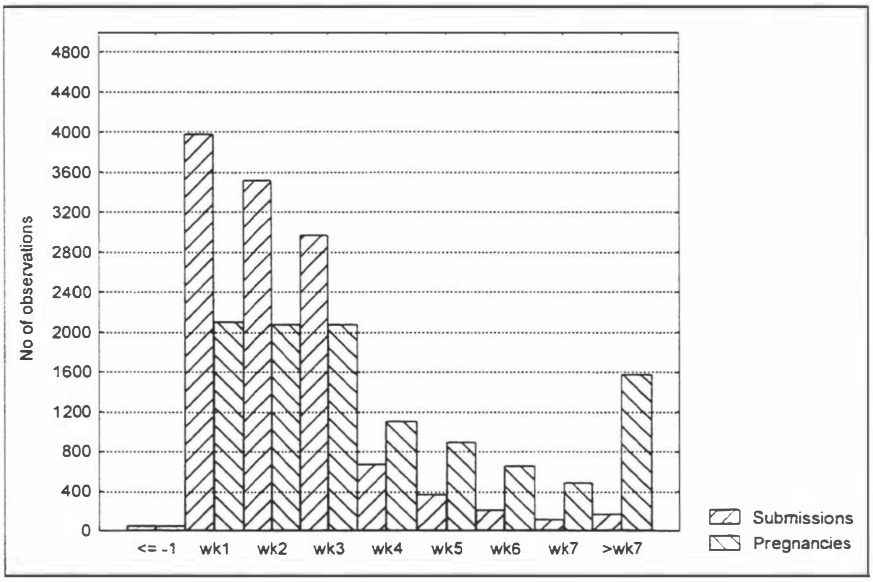

Figure 10. The number of submissions and pregnancies during each week after the start of mating for cows in the sampled herds using DairyMAN

The number of days since calving at mating is well recognised as a major influence on conception rates (Brightling et al. 1990). The proportion of cows calved less than 40 days is used to quantify the effect of poor calving pattern on submissions and conceptions. The relationship appears basically linear from approximately 30 to 80 days calved at the planned start of mating (Figure 11). Only 53 percent of cows calved less than 20 days at the planned start of mating are in-calf in the first 8 weeks of mating. This illustrates the large impact that the herd calving pattern and in particular the number of late calving cows has on a herd's reproductive performance.

Pregnancy rates are known to vary with lactation number. The performance of the first lactation animals if often lower than for the rest of the herd. The data suggests that both the young and aged stock classes may be subject to lower conception rates (Table 25).

The conception rates in New Zealand seasonally calving dairy herds are generally considered to increase with each subsequent service, primarily because the number of days from calving to service is increasing and long term reproductive pathology is not identified as a common problem. The conception rates shown in Table 25 are significantly lower for the third service compared to the first (P=0.01) using a chi square statistic comparing proportions. The first and second service conception rates were not statistically significantly different (P=0.3). This suggests that there is some suppression of conception rates due to chronic individual animal disease. If these observations are further classified by days calved at the planned start of mating (PSMCAT) two separate trends are apparent. For the cows calved less than 20 days at the PSM conception rates increase from 34 to 55 percent from the first to the third service. In contrast the conception rates for cows calved more than 80 days at the PSM reduce from 60 percent at the first service to less than 44 percent at the third service. Each of the observations is statistically significant using a chi square statistic comparing two proportions (P<0.05). This further supports the hypothesis that a (small) proportion of the reduced herd conception rates is due to individual animal disease.

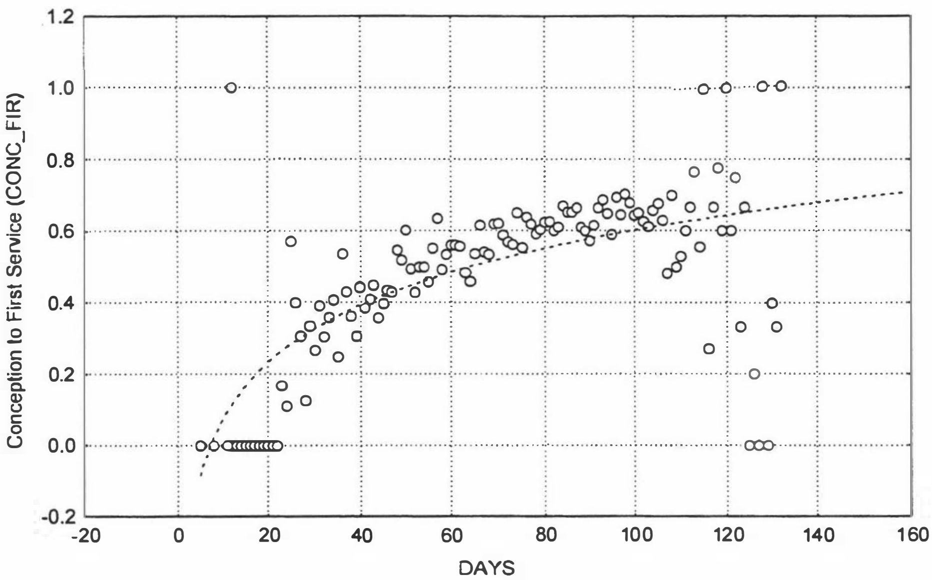

Figure 11. First service conception rates recorded in herds using DairyMAN that used whole herd pregnancy testing by days calved at the herd planned start of mating.

Table 24. The proportion of each cow class having a successful outcome for calving by 4 weeks after the PSC, calving by 8 weeks after the PSC, Mating within 21 days of the PSM, non-return (by 28 days) to the first service and in-calf by 4 and 8 weeks after the PSM using a non-return criteria in the herds using DairyMAN. The classes reported are lactation number (LACCAT), days calved at the PSM (PSMCAT) and breed (BREED)

	Calving and Submission				Non-return		In-calf		
		CAL4	CAL8	SUB21		NR28		IC4NR	IC8NR
LACCAT	N	%	%	%	N	%	N	%	%
1	7719	78.2	95.1	80.0	7269	68.7	7312	62.7	85.4
2	6657	64.3	94.3	84.0	6406	69.1	6398	65.4	87.4
3	5591	66.6	95.4	87.7	5440	69.9	5410	68.8	88.7
4	4495	68.3	95.8	87.7	4344	69.1	4331	68.6	89.5
>4	10161	69.6	95.5	84.5	9637	67.8	9618	64.2	85.7
Total	34623	69.8	95.2	84.3	33096	68.8	33069	65.4	86.9
PSMCAT									
<20	1041	0.0	5.1	38.6	928	57.8	940	25.7	64.8
20-39	3779	0.0	82.3	70.8	3554	60.6	3573	49.1	79.7
40-59	9074	39.0	100.0	83.7	8686	66.8	8669	63.1	86.1
60-79	16230	99.4	100.0	89.4	15632	71.4	15597	71.1	89.7
>79	4500	100.0	100.0	89.4	4297	72.3	4290	72.1	89.7
	34624	69.8	95.2	84.3	33097	68.8	33069	65.4	86.9
BREED									
Fr Ped	455	61.5	89.7	72.7	422	67.1	424	59.4	83.5
Fr	15622	68.6	95.2	83.1	14901	69.6	14906	65.1	86.7
Cross	12730	70.5	95.2	85.6	12221	68.7	12198	66.0	87.4
Jr	4556	74.2	96.1	87.9	4386	67.6	4334	67.1	88.0
Jr Ped	945	67.9	96.3	79.5	887	63.0	926	59.2	83.5
Total	34308	69.9	95.2	84.4	32817	68.8	32788	65.5	87.0

Table 25. The proportion of each cow class having a successful outcome for conception to first service (CONC_FIR) second service (CONC_SEC) and third service (CONC3RD). Also In-calf at 4 weeks (INCALFP4) and 8 weeks (INCALFP8) after the planned start of mating and empty at the end of mating (EMPTY) for cows in the herds using DairyMAN. The classes reported are lactation number (LACCAT), days calved at the PSM (PSMCAT) and breed (BREED) The in-calf and empty outcomes are calculated from the staging of gestation at manual pregnancy diagnosis.(Cows without a recorded pregnancy test are excluded).

	Conception By Pregnancy Examination						In-calf by Pregnancy Examination			
	CONC_FIR		CONC_SEC		CONC3RD			INCALF P4	INCALF P8	EMPTY
LACCAT	N	%	N	%	N	%	N	%	%	%
1	2877	53.7	1173	55.2	385	51.2	2954	58.2	79.5	10.5
2	2507	55.9	990	56.4	338	54.1	2540	61.8	81.9	8.2
3	2154	57.9	830	60.2	251	54.2	2166	66.2	84.2	6.7
4	1585	57.9	617	55.8	205	59.5	1602	64.4	83.8	6.7
>4	3860	54.8	1574	55.1	498	48.8	3907	59.6	80.6	9.9
Total	12983	55.6	5184	56.3	1677	52.5	13169	61.4	81.6	8.8
PSMCAT	N	%	N	%	N	%	N	%	%	%
<20	308	34.1	161	46.6	66	54.5	333	17.4	52.9	22.5
20-39	1319	43.2	652	53.5	227	48.9	1360	44.2	71.0	14.1
40-59	3358	52.4	1442	55.8	470	51.5	3395	58.2	80.4	9.5
60-79	6118	59.8	2255	58.2	689	57.2	6180	67.4	85.3	6.7
>79	1880	60.3	674	55.8	225	43.6	1901	67.5	84.2	8.2
Total	12983	55.6	5184	56.3	1677	52.5	13169	61.4	81.6	8.8
BREED CAT	N	%	N	%	N	%	N	%	%	%
Fr Ped	129	51.9	56	62.5	18	50.0	132	57.6	81.8	7.6
Fr	6834	54.7	2711	58.1	796	52.9	6953	60.2	81.1	9.3
Cross	4424	57.1	1756	54.5	615	52.8	4483	63.6	82.9	7.9
Jr	1265	56.4	520	54.2	189	52.9	1268	61.9	81.3	8.4
Jr Ped	269	56.9	114	48.2	50	44.0	270	62.2	78.9	9.3
Total	12921	55.7	5157	56.3	1668	52.6	13106	61.5	81.7	8.8

Removal Reasons Recorded In DairyMAN User Herds

Caution must be used in the interpretation of these data because the investigation was retrospective and the level and type of recording varied between farms.

Fate of Animals and Reasons for Removal

The data shown in Table 26 is from the 48 herds that pregnancy tested most of the herd. In many of these herds, a significant number of cows were culled or sold to other dairy herds in January before the herd pregnancy test date. It is possible that many of the culled animals were considered empty by the herd (by non-return status) owner, but such an assumption may not always be true. The animals sold for dairying are more likely to have been considered pregnant by non-return but a specific analysis of this has not been done.

The calculated total culling rate for these herds is 15.0 percent. This suggests that approximately 25 percent of culls have not been recorded if a 20 percent true culling rate is assumed. DairyMAN users can create their own definition of removal reasons. Up to three removal reasons can be recorded. The data presented are a summary of the first or primary removal reasons. Approximately 5.6 percent of removals are recorded for reproductive reasons.

Table 26. Principal reasons for removal recorded in the DairyMAN pregnancy test herds and the number of unknown pregnancy status, pregnant and empty cows within each removal group from a total of 12983 cows

	N	% of all cows	% of culled cows	Unknown fertility status	Empty	Pregnant
Reproductive disease	733	5.6	37.6	187	418	128
Other reasons	300	2.3	15.4	168	0	132
Low Production	392	3.0	20.1	192	12	218
Dairy	147	1.1	7.6	16	0	131
Mastitis	54	0.4	2.8	42	1	11
Unknown	321	2.5	16.5	119	17	185
	1947	15.0	100	724	448	805

Health Events Recorded In DairyMAN and the National Dairy Database Herds

Calving Descriptions

Inductions

The mean induction rate for herds using DairyMAN in 1993/94 was 10.3 percent of cows due to calve in each herd. This is at the upper limit of an industry acceptable target. Twenty two herds (15%) did not record any calving inductions. The induction rate for the National Dairy Database herds was 5.5 percent. Inductions are well recorded on the national database, however it is still possible that the distributions underestimate actual induction rates because of incomplete data recording.

Abortions and Premature Calving

Most DairyMAN herds (100) did not record any abortions starting a new lactation. For the 46 herds that did record at least one event the recorded abortion rate was 90 cases from 12027 cows (0.8%). Only eleven herds recorded 3 of more cases. These herds also recorded a smaller proportion of premature calving (0.3%).

Sixty-four DairyMAN herds recorded at least one premature calving. The premature calving rate was 1.2 % and the recorded abortion rate within these herds was 0.3%.

Although many of the abortions may not be recorded this data is consistent with the view that in most New Zealand herds, abortions do not have a significant impact on herd reproductive performance.

These data also indicate that the recording accuracy for these events varies considerably with herd. The data systems only include abortions that start a new lactation and may therefore be underestimating abortion incidence, independent of recording efficiency.

Lameness

Eighty seven of the 145 herds in the DairyMAN sample recorded at least one lameness event for the 1993 season, however the recorded mean prevalence within herd of 4.2 ± 1.4 cases per 100 cows is low and not similar to that reported for New Zealand herds (Tranter 1992). This suggests that herds do not accurately record lameness, because of the low recorded disease prevalence. The level of recording is likely to vary considerably between these herds.

Lameness event records can include information on the affected leg and type of lameness in DairyMAN. The leg description is not modifiable, however users can create their own lameness descriptions. The hind legs are more commonly affected than forelimbs (Table 27) which is consistent with previous descriptions (Tranter 1992).

Table 27. Affected limb for lame cows recorded in DairyMAN from a population of 35731 cows in 145herds during the 1993/94 season.

	Front Leg		Rear Leg		Total
	Left	Right	Left	Right	
N	71	68	236	243	618
Percentage	0.2	0.2	0.7	0.7	1.7

Mastitis

Clinical mastitis cases were recorded in 78 of the 146 DairyMAN herds. The mean number of cows affected at least once during the season for herds that recorded mastitis cases was 8.4 ± 1.5 cases per 100 cows.

The front quarters were not recorded with clinical mastitis as commonly as the rear two quarters (Table 28). This has been documented in many previous studies. The mean number of cases recorded and the distribution by herd suggests that this health event is reasonably well recorded.

Table 28. Affected quarters for cows recorded with mastitis in DairyMAN from a population of 35731 cows in 145 herds during the 1993/94 season.

	Front Quarters		Rear Quarters		Total
	Left	Right	Left	Right	
N	268	242	553	596	1659
Percentage	0.8	0.7	1.5	1.7	1.2

Other Health Events

The recording of other diseases was very low. Retained foetal membranes were recorded for 362 cows (3 percent) from 12,272 cows in 49 herds. Metabolic diseases such as milk fever and grass tetany (hypomagnesaemia) were recorded for 295 of 15,181 cows (1.9 percent) in 63 herds that recorded these events. Assisted calving was recorded for 702 of 20,293 cows (3.5 percent) in 73 herds. Of 48 herds containing 12,657 cows only 159 cows (1.3 percent) were recorded with at least one other type of disease event.

Conclusions

This chapter describes the performance of New Zealand seasonally calving dairy herds. It has covered as much of the reproductive, health and demographic data that is available in DairyMAN herds in sufficient numbers to accurately quantify performance. Some aspects including those specifically relevant to the development of the DairyFIX expert system are examined in more detail at herd and individual cow level in the following chapters. The tables of performance in this chapter are intended as a source of data to describe the typical performance of New Zealand herds. Although the reproductive performance of these herds is good by international standards there is still an opportunity to improve herd results and some aspects such as conception rates are lower than commonly reported performance levels. The high culling rates shown in Figure 5 may also indicate that there are some longer term opportunities, but a more though understanding of the reasons for culling dairy cattle must first be obtained. The temporal pattern of conception rates may also warrant a more detailed investigation. The data in this chapter also shows that there are significant gaps in the recording of information in dairy herds. The reasons for culling and health events are the most obvious examples of this.

Chapter 3

Path Analysis of Herd Reproductive Performance Indices

Path Analysis of Herd Reproductive Performance Indices

Introduction

The in-calf and empty rates achieved by the manager of a dairy herd depend on the additive effects of the herd conception rates and submission rates. Both of these are modified by the calving pattern because cows that calve late have insufficient time to commence cycling or if they cycle to achieve optimal conception rates. Each of these key indicators of performance are affected by many variables. Some, such as the age profile of the herd can be directly measured and this information can be made available to an expert system such as DairyFIX. Other factors including herd nutrition and heat detection may be less easily measured and veterinarians often use indirect methods of assessing performance. Milk production per cow, for example, is one or the more common variables that has been used when investigating herd nutrition. Heat detection is measured using a variety of methods and measures of conception may also be approximated using non-return criteria. For these indirect measures and approximations of performance to be useful an understanding of their relationship to other performance indicators is essential. Proper interpretation is not otherwise possible. In contrast other variables may be shown to have little association with herd performance and cannot therefore be used in an expert system for assessing performance.

The purpose of these investigations is to identify the relationship between the various diagnostic and performance indicators of herd reproductive performance. Some of the important relationships were then incorporated into the DairyFIX expert system which is described in later chapters. The effect of reduced performance for a herd in a given area can be quantified in terms of the effect on final in-calf and empty rates. The path models provide a useful method of visually depicting the complex relationships between reproductive performance indicators and the impact of other management indicators such as milk production have on reproductive performance.

In many cases this investigation is confirming previously recognised effects that various factors and calculated performance indicators have on the reproductive performance of seasonally calving dairy herds. The methods of recording data and the calculation methods can vary so valid paths that link factors can exist although they do not represent true biological effects. These effects must be understood if a veterinarian, farmer or an expert system is to adequately investigate performance. For example if non-return is used as the measure of pregnancy rates then Friesian herds may be expected to have higher calculated performance because Friesian cows are not as easily detected on heat (and may become nutritionally anoestrus more commonly). Similarly the number of weeks of heat detection may have considerable effect on the calculated herd in-calf rates. For these reasons the path models may vary for the different classes of herds available for investigation and separate models were investigated for each group of herds. Separate models were also used for the different herd classes because the diagnostic and performance variables are available in herds within each group are different. The null models described below represent the hypotheses tested in the path models.

Path Analysis Techniques

Path analysis is a statistical method for studying the causal relationships between a selected group of variables. The technique aids the interpretation of statistical information because prior knowledge, causation and implied logic are initially applied to develop a structure for the data that is to be statistically tested. It is often useful to construct a two dimensional "path" diagram of all variables to be investigated. Lines with arrows are drawn from causes to effects. In this way a diagrammatic model of the biological effects based on previous information can be drawn with some intermediate variables having paths leading to and from them. The technique does not prove cause, but can provide support (or otherwise) for a suggested model hypothesis. Path analysis requires a temporal association between variables to be valid. That is, a particular factor cannot be a cause of something unless it occurs before the result.

The conceptual framework or path diagram is statistically tested for each factor and a final structure validated. Standard linear regression techniques are commonly used for continuous outcome variables and logistic regression for binary outcome variables. Standardised regression coefficients provide a measure of the magnitude or weight of a particular path. Only statistically significant (valid) "paths" are retained in the final model. Paths that may be statistically significant but are practically of little or no significance are often removed from the final model, particularly if the structure is complex.

The technique has been applied in several studies of bovine disease (Curtis et al. 1988), and the interactions between disease, milk yield and reproductive performance of individual dairy cows (Dohoo et al. 1984, Etherington et al. 1988, Mellado and Reyes 1994). Models investigating reproductive performance have generally examined individual cow factors with few investigating herd performance. Although there are several studies that examine the effect of herd level factors on seasonal herd reproductive performance (Brightling et al. 1990) and the interpretation of herd statistics including DairyMAN data (Tranter 1991) there are no studies that have applied the path model concepts to this area of investigation.

Causal Links in Path Modelling

The arrows linking variables within a path model imply causation and associate two variables directly or via other variables in the model. The direction of these associations are validated from the literature, inherent logic, or an hypothesis that may require subsequent evaluation in other prospective studies. The links in a path model are categorised as;

Direct (independent) There is an arrow directly linking both variables thus indicating a direct association.

Indirect (mediated). The effect is mediated by an intermediate variable

Spurious (common cause). Two variables have an association mediated by a third variable that is considered to influence both variables.

Exogenous variables are those whose variability is determined by causes not included in the model and the model therefore does not provide any causal explanation for these observations. Endogenous variables however have a causal association with other variables in the model and their variability is at least partially explained by the paths in the model. Endogenous variables or effects (dependent variables) have arrows leading to them from causes (independent variables).

Methods and Data

The herd data collected and previously described in Chapter 2 was used for this evaluation of several path models investigating the association between measured herd factors, reproductive performance measures, diagnostic indicators and mating outcome. Performance measures from DairyMAN were used in this analysis. Milk production was measured as the mean daily production for the lactation at cow level. The herd average milk production was calculated from the individual cow lactation daily production values using the number of cows in milk at the start of mating as the denominator. Some herd demographic information was calculated from the individual cow information recorded in DairyMAN.

All outcome variables were assumed to be measured on a continuous scale. Some categorical variables were included as causal factors in the models. Standard multiple linear regression using Proc REG in SAS for windows was used in a backward stepwise process. All variables included in the respective null hypothesis model were initially offered for analysis of each endogenous dependent variable. Each variable was regressed on all preceding variables that had direct arrows leading to them. The criterion for removal from the model was $P>0.05$.

Many of the variables evaluated in these path models are proportions and could have violated assumptions of linearity and normality. Various authors have recommended an arcsine transformation of binomial proportions (Snedecor and Cochran 1992). It is also recommended that where $n<50$ the zero proportions should be counted as $1/4n$ and a 100% proportion as $(n-1/4)/n$ before transforming into angles. For most of this investigation n was greater than 50. The arcsine transformation does not account for any inequalities in variance due to different values of n within groups and is not likely to have a significant effect if most of the proportions lie within the 30 to 70 percent range. Although a few variables had proportions close to zero (Inductions) each of the models was tested using this arcsine transformation, but there were no significant changes to the path models. The original values are therefore retained in the results to aid interpretation.

The data was analysed in four separate path models. A path model of National Dairy Database herds was evaluated as this data is considered representative of the population of New Zealand herds. This herd data however did not contain some important information including pregnancy test data and heat records before the start of mating. If there is no pregnancy data the in-calf rates are calculated in DairyMAN as a direct mathematical result of non-return rates and submissions rates. The association between these variables must therefore exist. This also means however that the "outcome" is not necessarily the true in-calf rate but an evaluation or expected in-calf rate that is dependent on a number of herd and management factors. These include the accuracy and extent of heat detection and the rate of post service anoestrum. Some measures of herd data recording including the number of days of recorded matings were included in this model to identify some factors that significantly modify the calculated outcome, but would not be affecting the actual (unmeasured) outcome. If non-return rates and in-calf rates calculated from non-return rate data are to be used in the investigation of herd performance an understanding of these effects is essential. The measured performance of pregnancy test herds may vary from those using non-return rate data for two reasons:

A cow can be pregnant without a recorded mating.

A herd that pregnancy tested could (theoretically) achieve an in-calf result that is greater that expected from recorded matings and submissions because there have been unrecorded matings from bulls that have resulted in pregnancy.

Cows that have been mated and fail to return to oestrus may not be pregnant.

> These cows are considered pregnant using the non-return criteria, but may have stopped cycling or failed to be detected on heat because of poor heat detection or cessation of heat detection at the end of AB mating.

This second effect may mean that the herd non-return rates are higher than pregnancy rates and result in an overestimate of herd in-calf rates and artificially low empty rates.

Separate models were also evaluated for herds that used DairyMAN and the combination of DairyMAN and National Dairy Database herds to determine if DairyMAN had a main effect on the intermediate and outcome variables in the path model. Another model for the subset of these herds that had conception rate information was also investigated to identify factors that affect herd conception rates and the influence of conception rates on herd in-calf rates. Pregnancy testing results were used as the measure of conception. The model for the National Dairy Database herds included 294 available data sets. There were 142 DairyMAN data sets and 45 herds that recorded pregnancy test data. The statistical power to detect associations was different for each model. The power of the model with only pregnancy tested herds was low and the path model may be incomplete because there were only 45 herds available for analysis.

Seasonal Reproductive Performance Indicators

The important seasonal reproductive performance measures used in New Zealand have been well documented and have been described in the literature review (Chapter 1). The need to development seasonal specific indices was recognised by (MacMillan 1984) and(Jolly 1986). The seasonal reproductive, production and demographic variables used in these path models are defined in Table 29.

The Null Hypothesis Model: DairyMAN Pregnancy Test Herds

Variables included in the null hypothesis path model for herds using DairyMAN that use whole herd pregnancy testing are described in this section. The hypothesised direction of the association is explained and potential confounding discussed were appropriate.

Factors that Modify Calving Rates

Calving performance for an individual herd is a function of the reproductive performance in the previous season, culling and stock purchases, heifer mating management, abortions and calving inductions. Not all of these variables are available for investigation from data including only one year's records.

Inductions

The use of calving induction should result in an improved calving rate because the induced cows should be calving earlier than if allowed to calve after a normal gestation length. The magnitude of this effect will depend on a number of herd management factors including the timing of induction relative to the herd planned start of calving, the number of cows induced, the predicted calving pattern and confounding due to possible differences in performance of herds that induce compared with herds that do not induce cows. Reproductive reports from DairyMAN record the proportion of calvings induced but more specific reports are required to evaluate the pattern of induced calvings. Induction could therefore modify the four week calving rate or the four to eight week calving rate depending on individual herd management. Both paths were included in the null hypothesis model.

Table 29. Abbreviations, descriptions and the definition of all variables included in the path model investigations of herd reproductive performance

Abbreviation	Description	Definition
Breed		
Fr	Friesian	Greater than 15/16th Friesian or Holstein but excluding pedigree
Jer	Jersey	Greater than 15/16th Jersey but excluding pedigree
Cross	Cross	Any combination of Jersey and Friesian
Herd Size		
Herd 100	small herds	Less than 101 cows at end of calving in herd
Herd 101-249	average herds	From 101 to 249 cows in herd at the end of calving
Herd 250-449	large herds	From 250 to 449 cows in herd at the end of calving
Herd >449	very large herds	Herds larger than 449 cows in herd at the end of calving
Genetics		
BI	Breeding Index	New Zealand database genetic production index
Calving Performance		
PSC	Planned start of calving	Date cows are planned to start calving ie 282 days after last start of mating
Induce	Calving Induction	Cows that were induced to calve
Calved(4)	Four week calving rate	Cows calved by the end of the 4th week after planned calving start
Calved(4-8)	Four to eight week calving rate	Cows calved from end of 4th week to the end of the 8th week after the planned calving start
Age Profiles		
Lac1	lactation one cows	Number of lactation one animals in the herd
Old	Lactation 7plus	Number of cows of lactation 7 or greater in herd.
Mating		
PSM	Planned start of mating	The date seasonal mating starts
Calved<40	Cows calved < 40 days at start of mating (PSM)	Number of cows calved less than forty days at the start of mating (PSM)
PSC-PSM		The number of days between the PSC and PSM. If mating has been unchanged relative to other years then this is 83 days
Sub21	Submissions	The proportion of cows receiving a first mating in the 21 days after the PSM
Days mate	days of mating	The number of days from the first breeding to the last recorded mating to a bull or Artificial insemination
Heat Detection		
Heats 2-17	Short cycles	Proportion of return intervals that were from 2 to 17 days
Heats 18-24	normal cycles	Proportion of return intervals in the normal oestrus interval of 18 to 24 days
Heats 39-45	double cycles	Proportion of return intervals that are twice the normal oestrus interval (39-45 days)
Conception		
NR49	Non-return 49 days	Proportion of first matings not followed by a return to oestrus in the next 49 days
Conc_fir	Pregnancy	Proportion of first matings that resulted in conception based on pregnancy diagnosis
Incalf 4	Four week in-calf rate	The percentage of cows becoming pregnant in the first four weeks of mating
Other		
Pregtest	Pregnancy test	Herds that pregnancy test all cows
Reprodis	Reproductive disease	Clinical diagnoses of reproductive pathology except anoestrum
MS	Milksolids	Average daily lactation production of fat plus protein (kg)

Breed

There are no significant differences in gestation length between breeds in New Zealand (MacMillan 1982) although gestation length has been reported as having a high heritability. Friesians have been shown to have reduced reproductive performance, including increased anoestrum and lower pregnancy rates (Grosshans 1996). Reproductive performance varies between breeds so there may be some variation in a subsequent calving pattern that is due to breed differences.

Herd Size

The effect of herd size on herd performance is not well understood. Larger herds may have reduced performance due to the work demands of managing large numbers of cows and disease such as lameness may be a greater problem. Owners of large herds, however, may have very different management styles and be more progressive and more efficient herd operators.

Breeding Index

The herd breeding index (BI) is the average of the BI for all cows in the herd. It is a measure of the herd's genetic capacity for milk, fat and protein yield. Many reports have demonstrated a negative association between a high genetic index for milk production and reproductive performance. The average index for a herd may however be confounded by several factors including farm management skills.

Heifers

It is common practice to mate heifers before the adult herd in New Zealand. The proportion of heifers in a herd may therefore be directly associated with improved calving performance. The proportion of heifers is also an indirect measure of the average age of cows in a herd.

Abortions and other Factors

Information on the rate of abortions and premature calvings was not available for many herds and was therefore not included in this analysis. Other variables including calf sex and twinning are not evaluated in DairyMAN at herd level.

Submission Rates

Calving Rates

Improved four and eight week calving rates have been shown to improve subsequent submission rates.

Days from PSC to PSM

Some herds alter the PSM relative to the PSC to bring calving forward or delay calving in subsequent seasons. Improved utilisation of pasture during the winter and early spring, alternative feed sources during the same period or the availability of grazing land during the winter may allow herd owners to advance the PSM and hence PSC in the next season in order to increase lactation length and milk yield. The transition year will, however, reduce the number of days from calving to the PSM for all cows in the herd. Reduced reproductive performance may result from this effect.

Breed

Jersey cows tend to have greater visual oestrous activity and reduced anoestrum than Friesians. Herds with a high proportion of Friesian cows may in contrast have higher rates of anoestrum and lower submission rates.

Milk Yield

Many authors have demonstrated a negative correlation between milk yield and fertility including recent studies in New Zealand (Grosshans 1996). This path model investigation of herd performance cannot differentiate between phenotypic and genetic effects. Milk production may have a strong positive relationship to the nutritional status of the herd. There may be a negative genetic association, although the phenotypic effects may be of a greater magnitude in a New Zealand pasture fed dairy herd. Milk yield was measured by the variable "Milksolids" which is the sum of Fat and Protein yields on a per cow per day basis.

Reproductive Disease

A significant proportion of reproductive disease in a dairy herd is likely to affect reproductive performance because individual cows with disease of the reproductive tract or a history of reproductive disease have a reduced chance of conception and lower submission rates.

Pre-Mating Heats

If a high proportion of cows are cycling at the start of mating the submission rates would be greater than in a herd where few cows are cycling at the start of mating.

Return Intervals

A high proportion of normal oestrus cycles within a herd may indicate accurate heat detection with few heats being missed. Submission rates will be modified by the ability of the herd manager to detect cows on heat. Alternative measures of heat detection efficiency including the ratio of normal to double cycles was not used in these analyses because of the limited period of mating in many herds. The proportion of normal cycles is in part affected by the proportion of short returns. A high proportion of short returns may result in a small increase in submissions because some cows are being mated before their true oestrus within the mating period. Previous work has indicated that this effect is small (Brightling et al. 1990). The path for this effect was not included in the null models.

Veterinary Herds

These were herds that have significant veterinary involvement that may have improved performance although this may be confounded by a number of factors. For example the veterinarians providing data in this study were providing expert consultant advise in a range of management areas and herd milk production. Advice was not restricted to reproductive performance. In other cases veterinarians may be working with a herd because there is poor performance.

Drug Treatments and Synchrony Programs.

Synchrony programmes and the use of associated drugs could be expected to improve submission rates. There were, however, no herds in this study that utilised such programs. The variable could therefore not be included in the analyses.

Conception rates

Calving Pattern

A superior calving performance is expected to be associated with higher conception rates because a greater proportion of the herd has a sufficient number of days between calving and mating to allow for optimum conception rates.

Return intervals

The return interval analysis records the proportion of cows showing normal, short or long return intervals during the pre-mating and mating periods. A high proportion of short intervals should be associated with lower conception rates because either a larger proportion of cows are being mated to their first oestrus after calving or matings are being recorded when cows are not in oestrus (Macmillan and Watson 1971). The conception rate to first oestrus is lower than for subsequent oestrus cycles and will be zero for cows not in oestrus.

Milk Yield

Milk yield is included in that part of the null path model having conception as the endogenous outcome for the same reasons discussed above under submission rates. Since milk yield is considered to be correlated to herd nutrition, the suggested path is via the proportion of short return intervals and the affect this has on conception rates.

In-Calf Rates

The herd in-calf rates are a direct mathematical consequence of conception rates (recorded and unrecorded) and submission rates achieved in a herd (recorded and unrecorded). The 21 day submission rate and first service conception rate are only a part of the overall herd performance. Any variable that affects these outcome variables may also have a direct effect on in-calf rates in addition to an indirect effect. Direct effects for such variables were therefore retained in the path model if there was a significant explanatory indirect effect.

The Null Hypothesis Model: All Herds Using DairyMAN, the Combined DairyMAN, National Dairy Database Herds and the National Dairy Database Herds

The conception rate to first service was replaced with the non-return rate for these analyses. The number of weeks of recorded mating was included in the models as a independent variable for the return intervals, non-return rates and in-calf rates. For the combined analysis of DairyMAN and National Dairy Database herds the use or otherwise of the DairyMAN information system by the herd manager was included as a independent binomial variable for calving rates, submission rates, non-return rates and in-calf rates. Otherwise the null models were similar to that for DairyMAN pregnancy tested herds. The in-calf rates were the values calculated in DairyMAN for each herd. In all cases the DairyMAN defaults were set to calculate the in-calf rates based on pregnancy test outcome for each cow, but to also use non-return criteria for cows that were not examined for pregnancy status after the end of mating.

Results and Discussion

Path Model for Pregnancy Tested Herds Using DairyMAN

The completed model is shown in Figure 17 and the decomposition of effects in Table 30. Only those paths that were not statistically significant were removed from the models.

Calving Rates

Induction, BI, heifer percent and breed were significant effects for the four week calving rate. A high proportion of Friesian cows was linked to a lower four week calving rate (standardized coefficient = -0.34), which is consistent with previously reported performance of Friesian cows (Grosshans 1996). A high BI was associated with improved performance (standardized coefficient = 0.43). This may not be a genetic effect but the consequence of improved management practices in some herds that lead to improved reproductive performance, greater genetic gain and other positive herd attributes. The association between the proportion of heifers and the four week calving rate was negative (standardized coefficient = -.31). This is unexpected as heifers generally calve before the rest of a herd and will therefore increase an individual herd's calving rate when compared to the calving rate for lactation 2 and greater cows. A high proportion of heifers, if maintained over several years, implies a high culling rate within the herd and a low average herd age. In most cases, this trend in herd age profiles would tend to reduce calving rates (and overall reproductive performance of the herd) even though the heifers may calve significantly earlier than the rest of the herd. This is because the proportion of 3rd and 4th lactation animals that have superior reproductive performance will have been reduced. The analysis of individual animal records identifies a strong relationship between lactation number and reproductive performance including calving rates (see page 143).

Inductions were negatively associated with the four week calving rate (standardized coefficient = -.43). This was the opposite effect to that considered in the null model. It is not possible for an increasing induction rate to "cause" a reduced calving rate. Rather it may be that herds with a poor actual or predicted calving performance elect to induce a higher proportion of the herd. In other words an alternative null model could have considered inductions as a consequence of low calving rates. This alternative model is shown in Figure 21 and is a more appropriate model given the unexpected association between the calving rate variables and the proportional incidence of induction within herd. In this alternative model the proportion of the herd calving as heifers had a negative link with calving induction rates (standardized coefficient = -0.47). This is plausible as heifers are rarely induced to calve as the initiation and maintenance of lactation tends to be poor. Also heifers are mated before the rest of the dairy herd and calve earlier. The requirement for induction is therefore less in this group. This alternative model remains unchanged in all other aspects.

Large herds were associated with an increase in the proportion of the herd calving late (standardized coefficient = 0.12). This suggests that these herds have an inferior calving pattern although the early calving pattern is similar.

The calving pattern as measured by the four week (standardized coefficient = -.77) and four to eight week calving rates (standardized coefficient = -0.59), had a large effect on the proportion of the herd calved less than 40 days at the start of mating. The only other factor that had a direct influence on this variable was a change in the number of days from the planned start of calving to the planned start of mating (standardized coefficient = -0.48). Advancing the PSM date in a season reduces the average number of days calved at the start of mating. This will have a similar effect to a reduced calving performance.

Submission Rates

Only the path from the proportion of cows calved less than 40 days was significant for 21 day submission rates (standardized coefficient = -0.37). As the herd proportion calved less than 40 days increased the submission rate decreased.

Conception Rates

Induction (standardized coefficient = -0.38), and short returns (standardized coefficient = -0.48), had significant direct paths to pregnancy rates. Milksolids had a positive indirect effect (standardized coefficient = 0.14) on pregnancy rates (Figure 12), the path being via the proportion of short cycles. Average daily milk yield is a consequence of herd nutrition and the genetic capacity for milk production. A high genetic capacity for milk production has been associated with reduced reproductive performance. In this particular analysis the variation in milk yield may mostly be due to the environmental effects of feed intake. It is suggested that the low milk solids is correlated with poor nutrition. Nutritional anoestrus is a direct consequence of inadequate nutrition and in particular reduced energy intake and will result in a higher proportion of short cycles during the mating period. The fertility of these first cycles may be inferior to subsequent normal cycles. In these models there was however no significant path (direct or indirect) between milksolids and submission rates.

The assumption of a linear relationship between milksolids and conception rates may not be valid for the range of production levels in these herds (Figure 12). A more detailed investigation with a larger sample size could identify these effects by classifying herds into production categories.

The effect of inductions on reproductive performance is examined in more detail in Chapter 5 (see page 118)

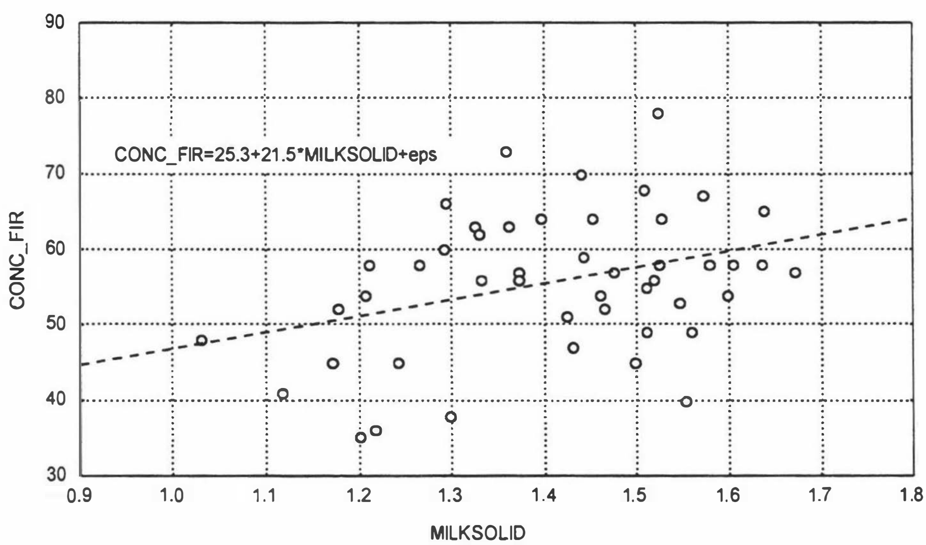

Figure 12. Scatter plot of the first service conception rates for pregnancy tested herds as a function of the herd average daily milksolids/cow(kg). The line is the least squares linear regression line.

In-Calf Rates

The in-calf rates are primarily determined by the herd submission (Figure 13) and conception rates (Figure 14). Other factors influence the in-calf rates indirectly by modifying the chance of conception or the rate of submissions. The decomposition of effects is shown in Table 30. Factors with standardised effects greater than 0.1 include the proportion of short cycles, cows calved less than 40 days, inductions and both measures of calving rate. The overall indirect effect of large herds on in-calf rates is too small to be of practical significance. The other exogenous variables had small but statistically significant indirect effects on the herd in-calf rate.

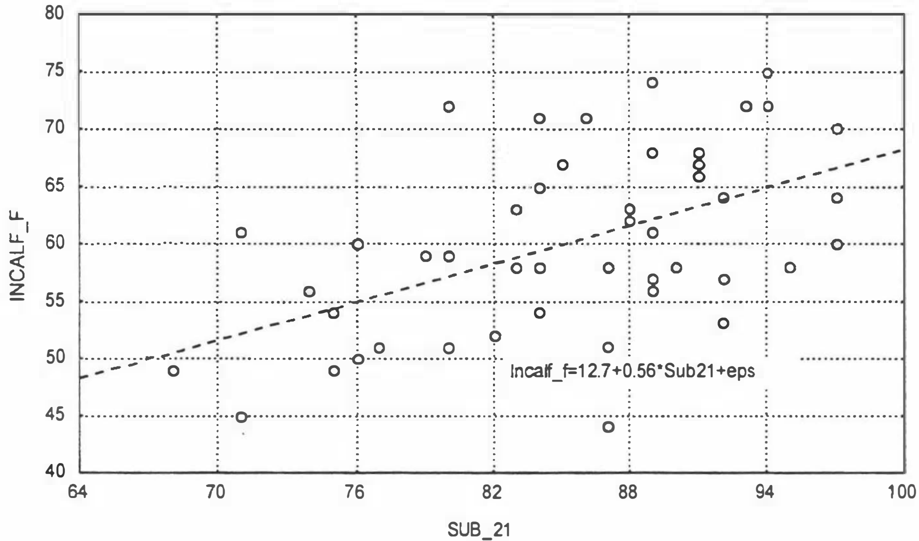

Figure 13. Scatter plot of the four week in-calf rates (INCALF_F) for each herd as a function of the herd twenty one day submission rates (SUB_21). The line is the least square linear regression. This illustrates the importance of achieving good submission rates for a herd to achieve optimal in-calf rates

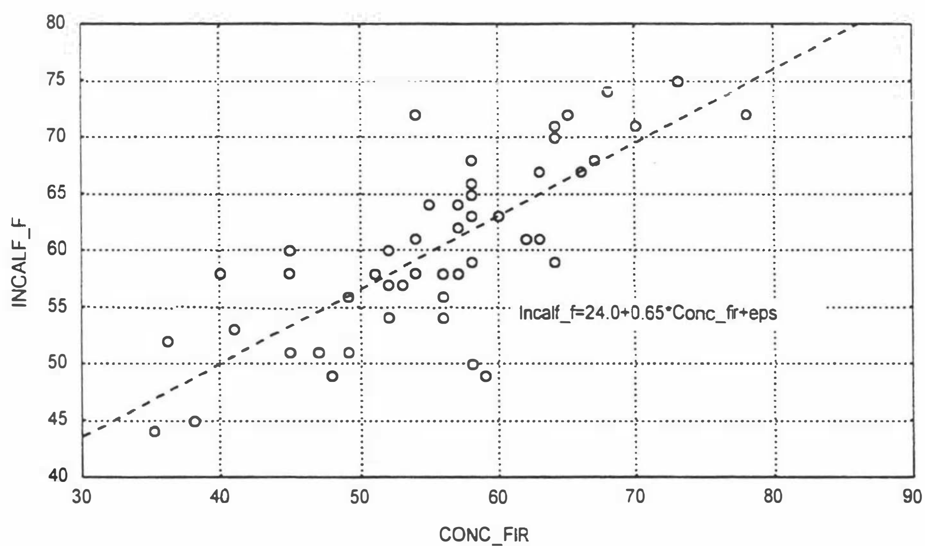

Figure 14. Scatter plot of herd four week in-calf rates (INCALF_F) as a function of the first service conception rates (CONC_FIR) for herds that used whole herd pregnancy testing. The line is the least square linear regression and illustrates the strong relationship between conception rates and achieved four week in-calf rates

Herds using DairyMAN

The model including all herds using DairyMAN retained more of the null hypothesis paths than in the previous model. This may be due to an increased power to detect statistically significant differences as the number of herds included is larger. This influence is apparent in each of the following models. The path model for all herds using DairyMAN is shown in Figure 18 and the decomposition of direct and indirect effects in Table 31.

Induction was negatively associated with the four week calving rate (standardized coefficient = -0.25) but had a positive association with the 4 to 8 week calving rate. In other words herds that induce cows tend to be those with poorer calving patterns. Small herds had improved four week calving rates and BI was again included in statistically significant path.

Herd submission rates were dependent on the proportion of the herd calved less than forty days (standardized coefficient = -0.53) and positively associated with the herd average daily milk production per cow (standardized coefficient = 0.15).

The herd non-return rates were directly affected by the proportion of the herd calved less than forty days, the days of recorded mating and the proportion of short cycles. The derivation of non-return rates implies that some of these paths must be interpreted with caution. The days of recorded mating is a significant direct path (standardized coefficient = -0.29) because an increased period of heat detection gives a greater period to detect returns to oestrus and a more accurate assessment of true conception rates. In contrast those herds that cease detection at the end of artificial breeding will have overestimates of non-return rates if the DairyMAN update date was more than 49 days after the majority of matings. The update date is the program's estimate of the date that herd information is accurate to and is determined from the last data event date. The proportion of short returns reduces as the number of days of recorded matings increase (standardized coefficient = -0.18) because an increasing proportion of long returns will be detected. Short cycles are again negatively associated with the measure of conception rates (standardized coefficient = -0.3).

Submission and non-return rates had significant direct effects on the herd four week in-calf rate (standardized coefficient 0.74 and 0.54 respectively). Herds that pregnancy tested were associated with a reduction in the calculated four week in-calf rate (standardized coefficient = -0.22) because these herds have a more accurate indication of performance compared with non-return calculations which fail to identify a proportion of empty cows.

National Dairy Database Herds

The path model for all National Dairy Database herds is shown in Figure 19 and the decomposition of direct and indirect effects in Table 32. The model is similar to those previously discussed except that there was no pregnancy test data for these herds so this path could not be included in the null model. Breed effect paths are significant in this model. Jerseys and cross-breeds are associated with improved four week calving rates as a direct effect (standardized coefficient = 0.22 and 0.17 respectively) and Cross-breeds had a direct effect on herd twenty one day submission rates (standardized coefficient = 0.11). Friesians were associated with superior calculated non-return rates (standardized coefficient = 0.13). This effect may be due to a reduced chance of Friesians being detected to return to oestrus either from reduced behavioural signs of oestrus or increased non-cycling rates. Friesian cows have been associated with lower conception rates (Grosshans 1996). The superior calving rates for Jerseys and cross-breeds is supportive of improved reproductive performance in these groups. Inductions had a negative effect on calving rates because induction was a direct positive effect on an increased late calving rate (Calved 4-8) (standardized coefficient = 0.23). Induction also had a direct negative effect on the in-calf rate but this was small and not of practical significance. The direct and indirect effects of the proportion of short returns as discussed for the previous model are also evident in this path model. Milksolids was associated with increased submission rates (standardized coefficient = 0.11) and also had a direct negative path to the proportion of short cycles. The indirect effect of Milksolids on the calculated in-calf rates was therefore negative (Table 32). The total effect of Milksolids on in-calf rates was positive but small (standardized coefficient = 0.04). Again the indirect paths mediated by the proportion of short returns must be interpreted with caution because the calculated in-calf rates are inherently dependent on the heat detection efficiency of the particular herd.

Combined DairyMAN National Dairy Database Model.

The path model for all National Dairy Database herds is shown in Figure 20 and the decomposition of direct and indirect effects in Table 33. The model is again similar to those previously discussed, however the increased sample size has increased the power to detect statistically significant effects with a resulting increase in valid paths. The effect of DairyMAN was included in this model. DairyMAN had a direct positive path to the four week calving rate (standardized coefficient = 0.14) and also to the twenty one day submission rates (standardized coefficient = 0.13). DairyMAN had a positive combined indirect effect on herd in-calf rates (standardized coefficient total = 0.13). Pregnancy testing had a negative effect on the in-calf rates (standardized coefficient = -0.15). These herds are likely to have a more accurate and realistic assessment of herd reproductive performance than for those herds that rely on non-return rates that tend to over estimate performance. The breed effects were again seen in this model. Friesians were associated with improved non-return rates (standardized coefficient = 0.09), but this may be a failure to have or detect returns. Increasing herd proportions of Jersey (standardized coefficient = 0.18) and Cross-breeds (standardized coefficient = 0.14) were directly linked to a superior four week calving rate. The proportion of Jersey and Cross-breeds also had a direct effect on herd submission rates (standardized coefficient = 0.11 for each). The complex effects of short cycles and normal cycle proportions are also evident in this model. A high proportion of normal cycles was directly associated with improved non-return rates (standardized coefficient = 0.14) and herd submission rates (standardized coefficient = 0.16). The proportion of normal returns had a total direct and indirect effect on in-calf rates of 0.28 (Table 33).

The bi-variate association between the proportion of cows calved less than forty days and herd submission rates is shown in Figure 15. The magnitude of this effect is large and supports the hypothesis that the herd calving pattern is a critical determinant of herd reproductive performance. The total direct and indirect effect of the proportion of cows calved less than forty days was large (standardized coefficient = -0.39).

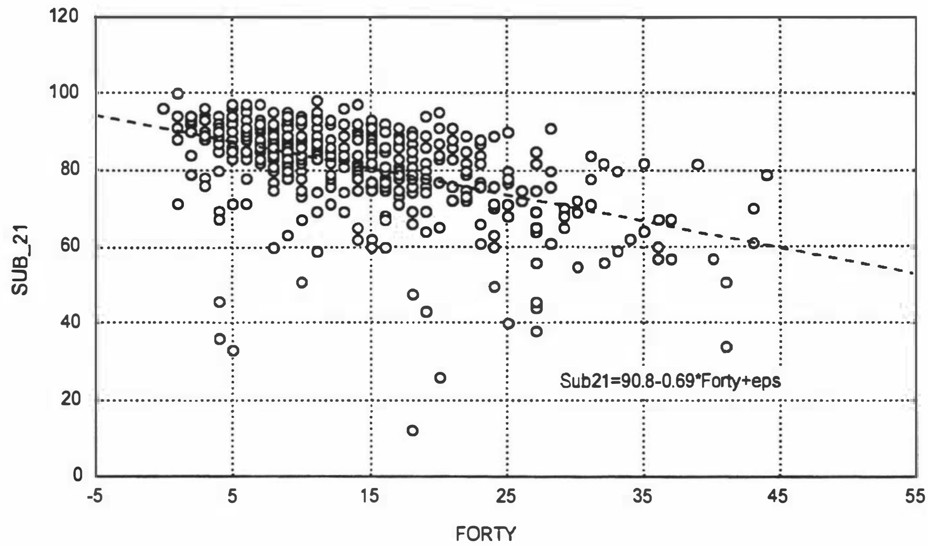

Figure 15. Scatter plot of herd twenty one day submission rates (SUB_21) as a function of the proportion of a herd calved less than forty days at the start of mating (FORTY). The line is the least square linear regression line. The proportion of the herd calved less than forty days at the start of mating is an important determinant of herd submission rates and therefore herd in-calf rates

The effect of the Jersey breed on the four week calving rate is graphically depicted Figure 16. A similar effect was evident with an increasing proportion of cross-breed cows.

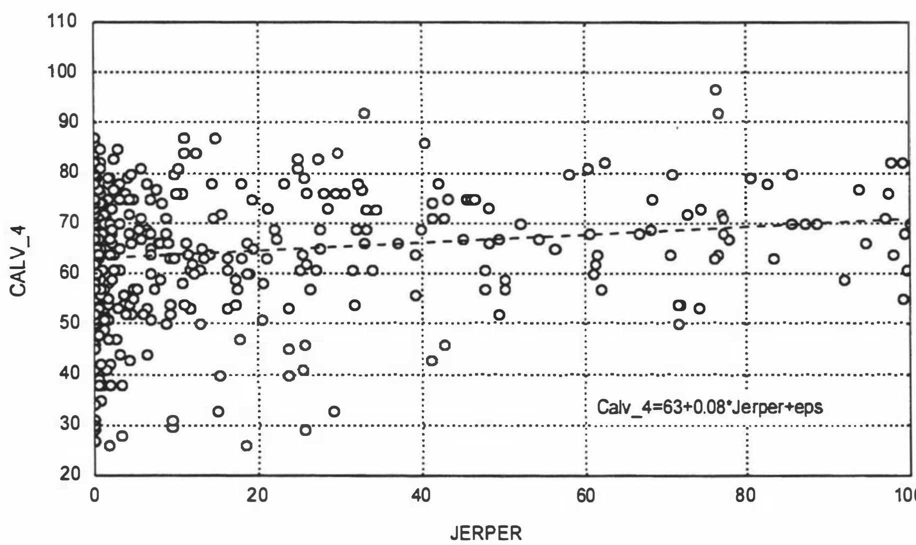

Figure 16. Scatter plot of the herd four week calving rates as a function of the proportion of Jersey cows in a herd. The line is the least squares linear regression line. The reasons why herds with a high proportion of jersey cows have improved calving rates requires further investigation.

Summary

These path models confirm that calving rates within herd are an important determinant of subsequent reproductive performance. A number of factors are associated with variations in calving rates, but the causes, including the previous seasons reproductive performance, culling, stock purchases and the management of young stock are not considered in these models. Given a known reproductive outcome for a season, DairyMAN can provide an expected calving pattern for a subsequent year. The intention of these models and the individual cow models detailed in the following chapters is to determine the effect this known calving pattern has on the herds subsequent reproductive outcome. With this information it is possible for an expert system to predict performance given certain changes in herd management or to determine the relative importance of calving pattern and other factors on a known outcome for a mating season.

It is interesting to observe that herds with a high rate of calving induction do not have superior calving rates. It may be that calving induction has been implemented as a consequence of an expected poor performance as discussed above. It does however raise some concern about the effectiveness of calving induction within the overall management of dairy herds. It must certainly be true that calving induction improves the calving pattern for a herd (compared with not inducing) however it may create unachievable expectations if the subsequent fertility of these induced cows is reduced. It may be that these herds are prepared to accept a lower reproductive performance because inductions can be used, but the effect of such inductions may be insufficient to achieve acceptable performance. This is discussed in more detail in Chapter 5. Additional studies are required to determine the effect of calving induction on the reproductive performance of New Zealand dairy herds.

Herds with a high proportion of Jersey or Cross-breeds have superior calving performance. Again the reasons for this path effect is not explained by these models. It is possible that these herds either have improved mating performance in the preceding year of more vigorous culling strategies when considering the predicted calving date of potential cull cows.

Twenty one day submission rates and first service conception rates are important predictors of herd in-calf rates. This is a mathematical relationship and does not require a statistical proof. However the models do quantify the magnitude of these associations which will vary depending on the specific variable used to measure performance and determines the association where imperfect measures of performance are used.

Increasing herd average per cow milk yield is associated with improved conception rates and submission rates. The association between milk production and reproductive performance is complex and there have been numerous studies that identify a negative association between milk yield and fertility. These path models however show that under New Zealand management conditions milk yield is positively associated with conception rates and submission rates. Higher nutrition is likely to be an exogenous common cause of both a greater milk yield and superior submission rates and conception rates. This knowledge is used in DairyFIX to assess the effect that nutrition may be having on poor herd performance by using milk production as an indirect measure of nutrition in a dairy herd.

Non return rates are significantly modified by the recording of heats and the period of heat detection. It is therefore essential that this information be considered when assessing non-return rates and in-calf rates calculated from non-return rates. Pregnancy testing may give a more accurate (but lower) estimate of conception rates and therefore different targets and expectations are appropriate when determining if poor performance exists in a herd before attempting to identify causes.

These path models show that DairyMAN is associated with superior performance. This is discussed in more detail in Chapter 4.

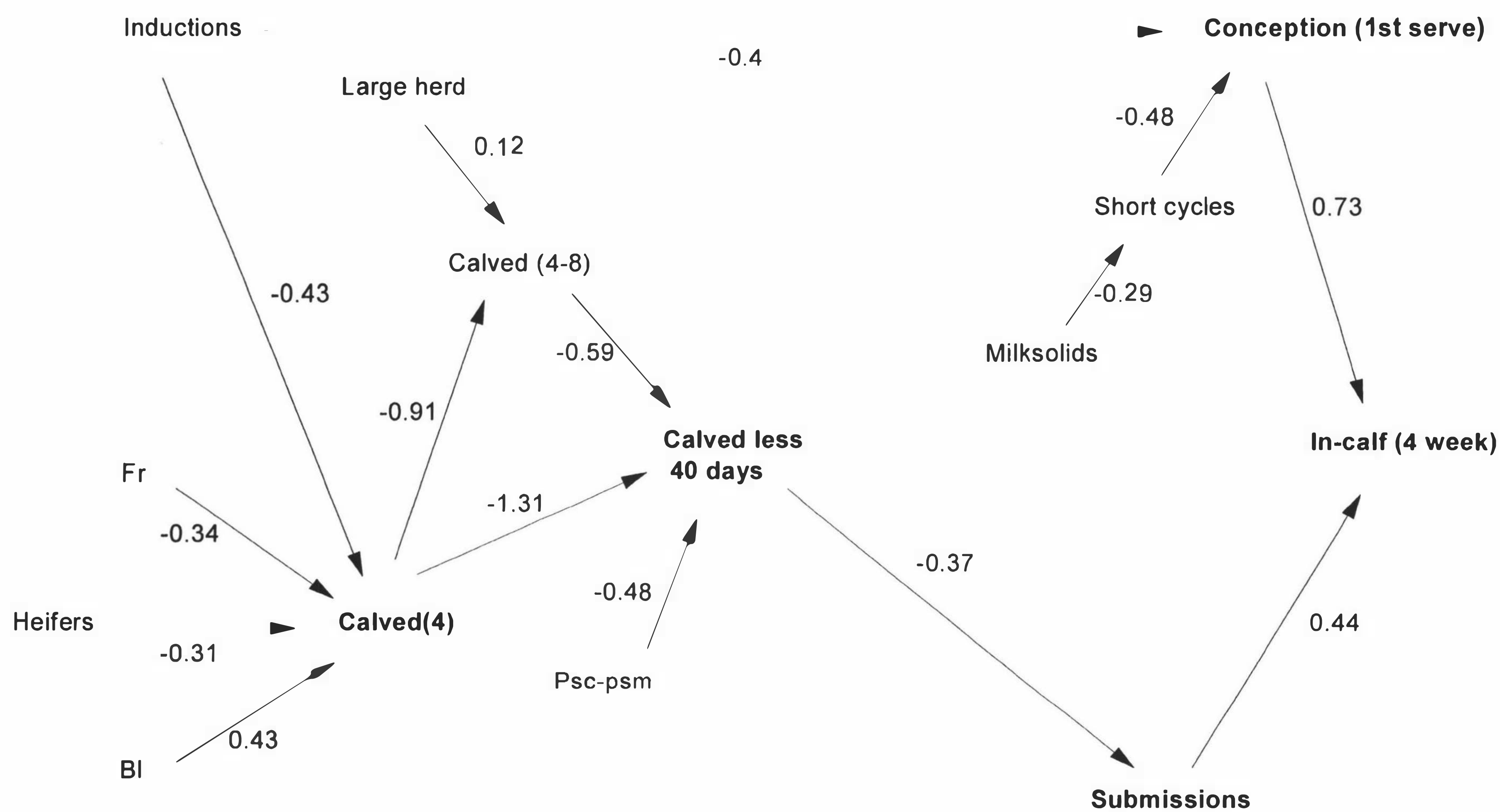

Figure 17. Final path model for reproductive performance indices of herds using DairyMAN that recorded whole herd pregnancy test data. Arrow weights = standardised partial regression coefficients

Table 30. Decomposition of direct and indirect effects for DairyMAN pregnancy test herds. The indirect effect is the sum of all indirect paths between the two variables excluding common cause paths and the total effect is the sum of the indirect and direct effects. Spurious or common cause effects are not shown in this table. Arrow weights used in the calculations were the standardised regression coefficients

		Direct	Indirect	Total
Calved 4	Induction	-0.43		-0.43
	Friesian	-0.34		-0.34
	Heifers	-0.31		-0.31
	BI	0.43		0.43
Calved 4-8	Large Herd	0.12		0.12
	Calved4	-0.91		-0.91
	Induction		0.39	0.39
	Friesian		0.31	0.31
	Heifers		0.28	0.28
	BI		-0.39	-0.39
Calved less 40	Calved4	-1.31	0.54	-0.77
	Calved4-8	-0.59		-0.59
	PSC_PSM	-0.48		-0.48
	Large Herd		-0.07	-0.07
	Induction		0.33	0.33
	Friesian		0.26	0.26
	Heifers		0.24	0.24
	BI		-0.33	-0.33
Submissions	Calved less 40 days	-0.37		-0.37
	PSC_PSM		0.18	0.18
	Calved4-8		0.22	0.22
	Large Herd		0.03	0.03
	Calved4		0.29	0.29
	Induction		-0.12	-0.12
	Friesian		-0.10	-0.10
	Heifers		-0.09	-0.09
	BI		0.05	0.05
Conception	Inductions	-0.38		-0.38
	Short Cycles	-0.48		-0.48
	Milksolids		0.14	0.14
In-calf 4 weeks	Submissions	0.44		0.44
	Conceptions	0.73		0.73
	Inductions		-0.35	-0.35
	Short Cycles		-0.35	-0.35
	Milksolids		0.10	0.10
	Calved less 40 days		-0.16	-0.16
	PSC_PSM		0.08	0.08
	Calved4-8		0.10	0.10
	Large Herd		0.01	0.01
	Calved4		0.13	0.13
	Friesian		-0.04	-0.04
	Heifers		-0.04	-0.04
	BI		0.05	0.05

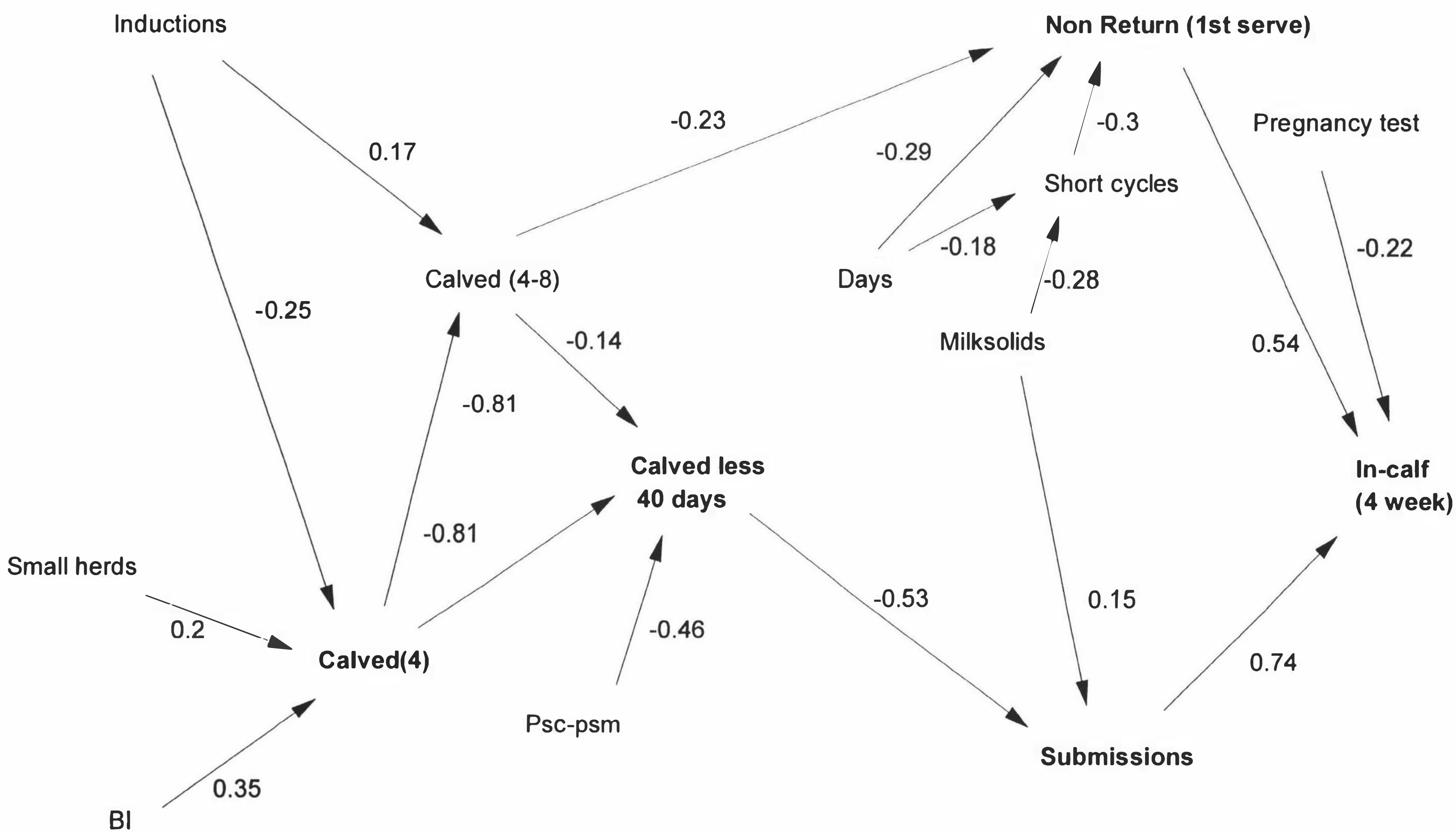

Figure 18. Final path model of reproductive performance indices for herds using DairyMAN. Arrow weights = standardised partial regression coefficients

Table 31. Decomposition of direct and indirect effects for all herds using DairyMAN. The indirect effect is the sum of all indirect paths between the two variables excluding common cause paths and the total effect is the sum of the indirect and direct effects. Spurious or common cause effects are not shown in this table. Arrow weights used in the calculations were the standardised regression coefficients

		Direct	Indirect	Total
Calved 4 weeks	Inductions	-0.25		-0.25
	Small herd	0.20		0.2
	BI	0.35		0.35
Calved 4to8	Calved 4 weeks	-0.66		-0.66
	Inductions	0.17	0.17	0.34
	Small herd		-0.13	-0.13
	BI		-0.23	-0.23
Calved less than 40 days	Calved 4to8	-0.14		-0.14
	Calved 4 weeks	-0.81	0.09	-0.72
	Inductions		0.16	0.16
	Small herd		-0.14	-0.14
	BI		-0.25	-0.25
	Psc_psm	-0.46		-0.46
Submission Rates	Calved less 40 days	-0.53		-0.53
	Calved 4to8		0.07	0.07
	Calved 4 weeks		0.43	0.43
	Inductions		-0.08	-0.08
	Small herd		0.08	0.08
	BI		0.13	0.13
	Psc_psm		0.24	0.24
Non-Return	Calved less 40 days	-0.23		-0.23
	Calved 4to8		0.03	0.03
	Calved 4 weeks		0.17	0.17
	Inductions		-0.04	-0.04
	Small herd		0.03	0.03
	BI		0.06	0.06
	Psc_psm		0.11	0.11
	Days	-0.29		-0.29
	Short Cycles	-0.30		-0.3
	Milksolids		0.08	0.08
In-calf	Submission	0.74		0.74
	Non-Return	0.54		0.54
	Pregnancy test	-0.22		-0.22
	Calved less 40 days		-0.52	-0.52
	Calved 4to8		0.07	0.07
	Calved 4 weeks		0.37	0.37
	Inductions		-0.08	-0.08
	Small herd		0.07	0.07
	BI		0.13	0.13
	Psc_psm		0.24	0.24
	Days		-0.13	-0.13
	Short Cycles		-0.16	-0.16
	Milksolids		0.05	0.05

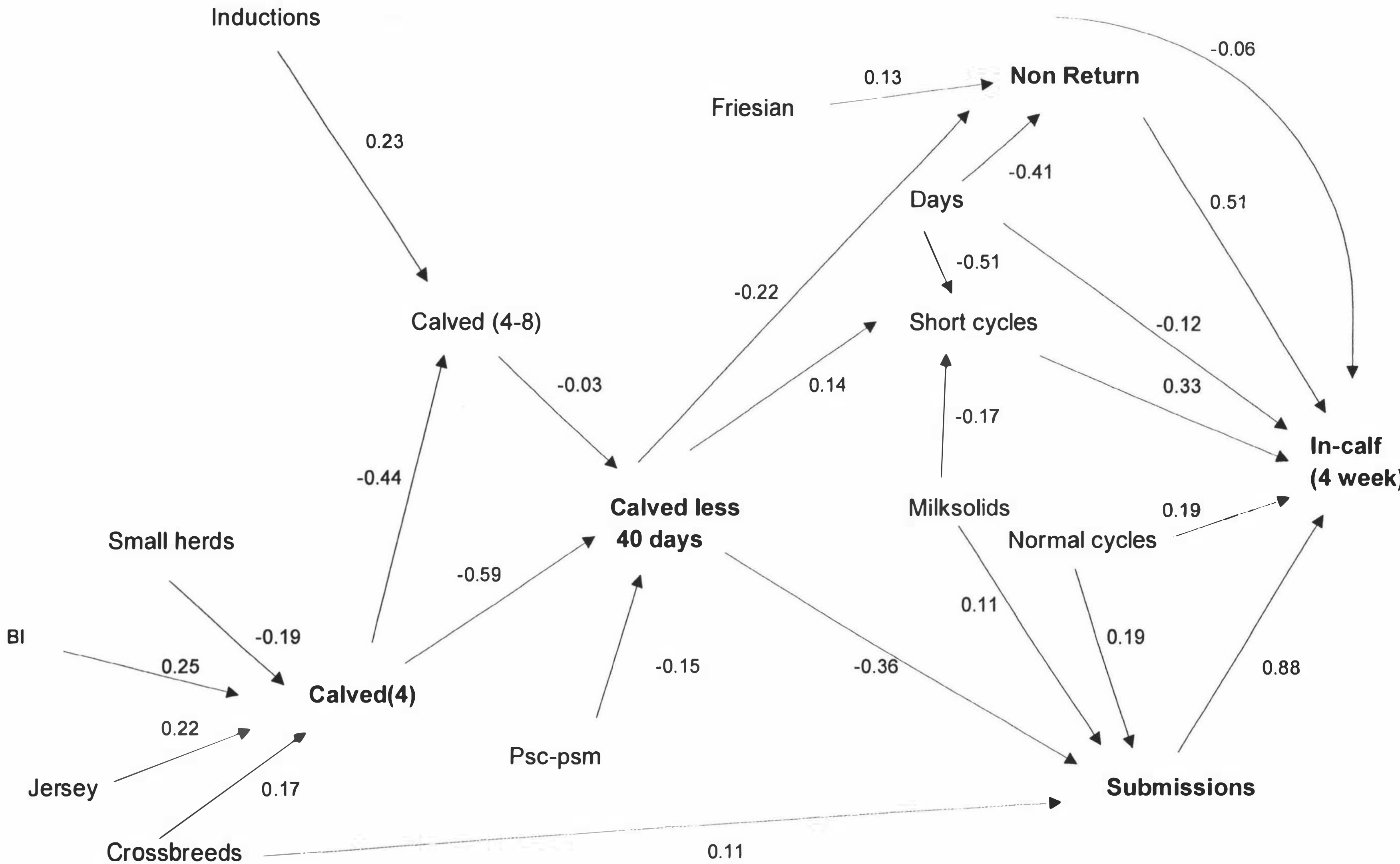

Figure 19. Final path model of reproductive performance indices for National Dairy Database. Arrow weights = standardised partial regression coefficients

Table 32. Decomposition of direct and indirect effects for all National Dairy Database herds. The indirect effect is the sum of all indirect paths between the two variables excluding common cause paths and the total effect is the sum of the indirect and direct effects. Spurious or common cause effects are not shown in this table. Arrow weights used in the calculations were the standardised regression coefficients

		Direct	Indirect	Total
Calved 4 weeks	Small herd	-0.19		-0.19
	BI	0.25		0.25
	Jersey	0.22		0.22
	Crossbreeds	0.17		0.17
	Calved 4 weeks	-0.44		-0.44
Calved 4to8	Inductions	0.23		0.23
	Small herd		0.08	0.08
	BI		-0.11	-0.11
	Jersey		-0.10	-0.10
	Crossbreeds		-0.07	-0.07
Calved less 40 days	Calved 4to8	-0.03		-0.03
	Calved 4 weeks	-0.59	0.01	-0.58
	Inductions		-0.07	-0.01
	Small herd		0.11	0.11
	BI		-0.14	-0.14
	psc_psm	-0.15		-0.15
	Jersey		-0.13	-0.13
	Crossbreeds		-0.10	-0.10
Submission Rates	Calved less 40 days	-0.36		-0.36
	Calved 4to8		0.01	0.01
	Calved 4 weeks		0.21	0.21
	Inductions		0.00	0.00
	Small herd		-0.04	-0.04
	BI		0.05	0.05
	psc_psm		0.05	0.05
	Jersey		0.05	0.05
	Crossbreeds	0.11	0.04	0.15
	Milksolids	0.11		0.11
	Normal Cycles	0.19		0.19
Non-Return	Calved less 40 days	-0.22		-0.22
	Calved 4to8		0.01	0.01
	Calved 4 weeks		0.13	0.13
	Inductions		0.00	0.00
	Small herd		-0.02	-0.02
	BI		0.03	0.03
	psc_psm		0.03	0.03
	Jersey		0.03	0.03
	Crossbreeds		0.02	0.02
	Friesian	0.13		0.13
	Days	-0.41		-0.41
	Submissions	0.88		0.88
In-calf	Non-Return	0.51		0.51
	Calved less 40 days		-0.38	-0.38
	Calved 4to8		0.01	0.01
	Calved 4 weeks		0.22	0.22
	Inductions	-0.06	0.00	-0.06
	Small herd		-0.05	-0.05
	BI		0.06	0.06
	psc_psm		0.06	0.06
	Jersey		0.05	0.05
	Crossbreeds		0.14	0.14
	Friesian		0.07	0.07
	Days	-0.12	-0.38	-0.50
	Short Cycles	0.33		0.33
	Normal Cycles	0.19	0.17	0.36
	Milksolids		0.04	0.04

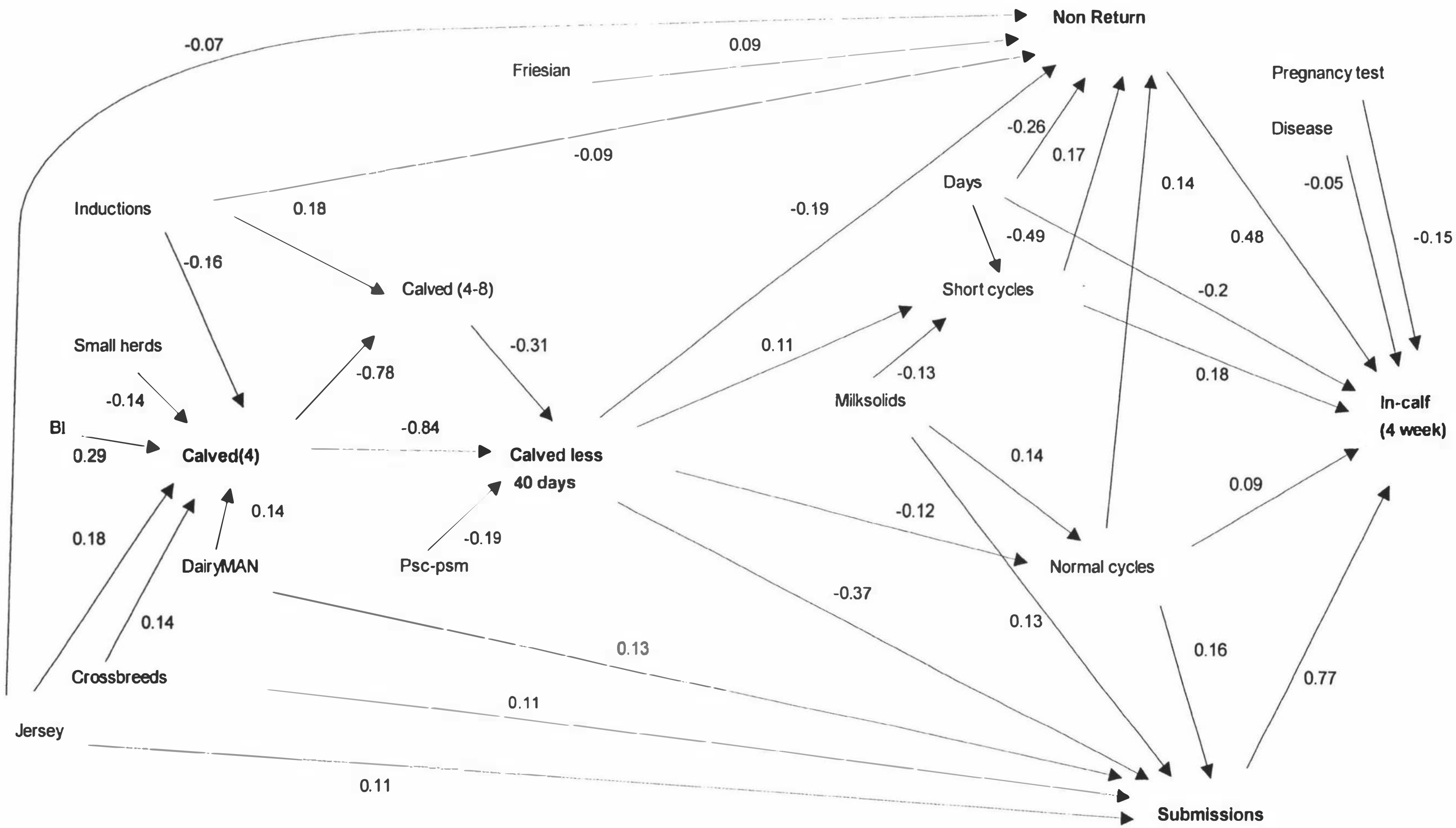

Figure 20. Final path model of herd reproductive performance indices. Arrow weights = standardised partial regression coefficients

Table 33. Decomposition of direct and indirect effects for the path model including both DairyMAN and National Dairy Database herds. The indirect effect is the sum of all indirect paths between the two variables excluding common cause paths and the total effect is the sum of the indirect and direct effects. Spurious or common cause effects are not shown. Arrow weights were the standardised regression coefficients

		Direct	Indirect	Total
Calved 4 weeks	Inductions	-0.16		-0.16
	Small herd	-0.14		-0.14
	BI	0.29		0.29
	Jersey	0.18		0.18
	Crossbreeds	0.14		0.14
	DairyMAN	0.14		0.14
Calved 4to8 weeks	Calved 4 weeks	-0.78		-0.78
	Inductions	0.18		0.18
	Small herd		0.11	0.11
	BI		-0.23	-0.23
	Jersey		-0.14	-0.14
	Crossbreeds		-0.11	-0.11
	DairyMAN		-0.11	-0.11
Calved less than 40 days	Calved 4to8	-0.31		-0.31
	Calved 4 weeks	-0.84	0.24	-0.60
	Inductions		0.04	0.04
	Small herd		0.08	0.08
	BI		-0.17	-0.17
	psc_psm	-0.19		-0.19
	Jersey		-0.11	-0.11
	Crossbreeds		-0.08	-0.08
	DairyMAN		-0.12	-0.12
Submission Rates	Calved less than 40 days	-0.37	-0.02	-0.39
	Calved 4to8		0.11	0.11
	Calved 4 weeks		0.23	0.23
	Inductions		-0.02	-0.02
	Small herd		-0.03	-0.03
	BI		0.07	0.07
	psc_psm		0.07	0.07
	Jersey	0.11	0.04	0.15
	Crossbreeds	0.11	0.03	0.14
	Milksolids	0.13	0.02	0.15
	Normal Cycles	0.16		0.16
	DairyMAN	0.13	0.03	0.16
Non-Return	Calved less than 40 days	-0.19	0.02	-0.17
	Calved 4to8		0.05	0.05
	Calved 4 weeks		0.10	0.10
	Inductions	-0.09	-0.01	-0.10
	Small herd		-0.01	-0.01
	BI		0.03	0.03
	psc_psm		0.03	0.03
	Jersey	-0.07	0.02	-0.05
	Crossbreeds		0.01	0.01
	Friesian	0.09		0.09
	Days	-0.26	-0.08	-0.34
	Short Cycles	0.17		0.17
	Normal Cycles	0.14		0.14
	Milksolids		0.00	0.00
	DairyMAN		0.01	0.01
In-calf	Submissions	0.77		0.77
	Non-Return	0.48		0.48
	Pregnancy test	-0.15		-0.15
	Disease	-0.05		-0.05
	Calved less than 40 days		-0.40	-0.40
	Calved 4to8		0.12	0.12
	Calved 4 weeks		0.24	0.24
	Inductions		-0.06	-0.06
	Small herd		-0.03	-0.03
	BI		0.07	0.07
	psc_psm		0.08	0.08
	Jersey		0.01	0.01
	Crossbreeds		0.12	0.12
	Friesian		0.04	0.04
	Days	-0.2	-0.25	-0.45
	Short Cycles	0.18	0.08	0.26
	Normal Cycles	0.09	0.19	0.28
	Milksolids		0.11	0.11
	DairyMAN		0.13	0.13

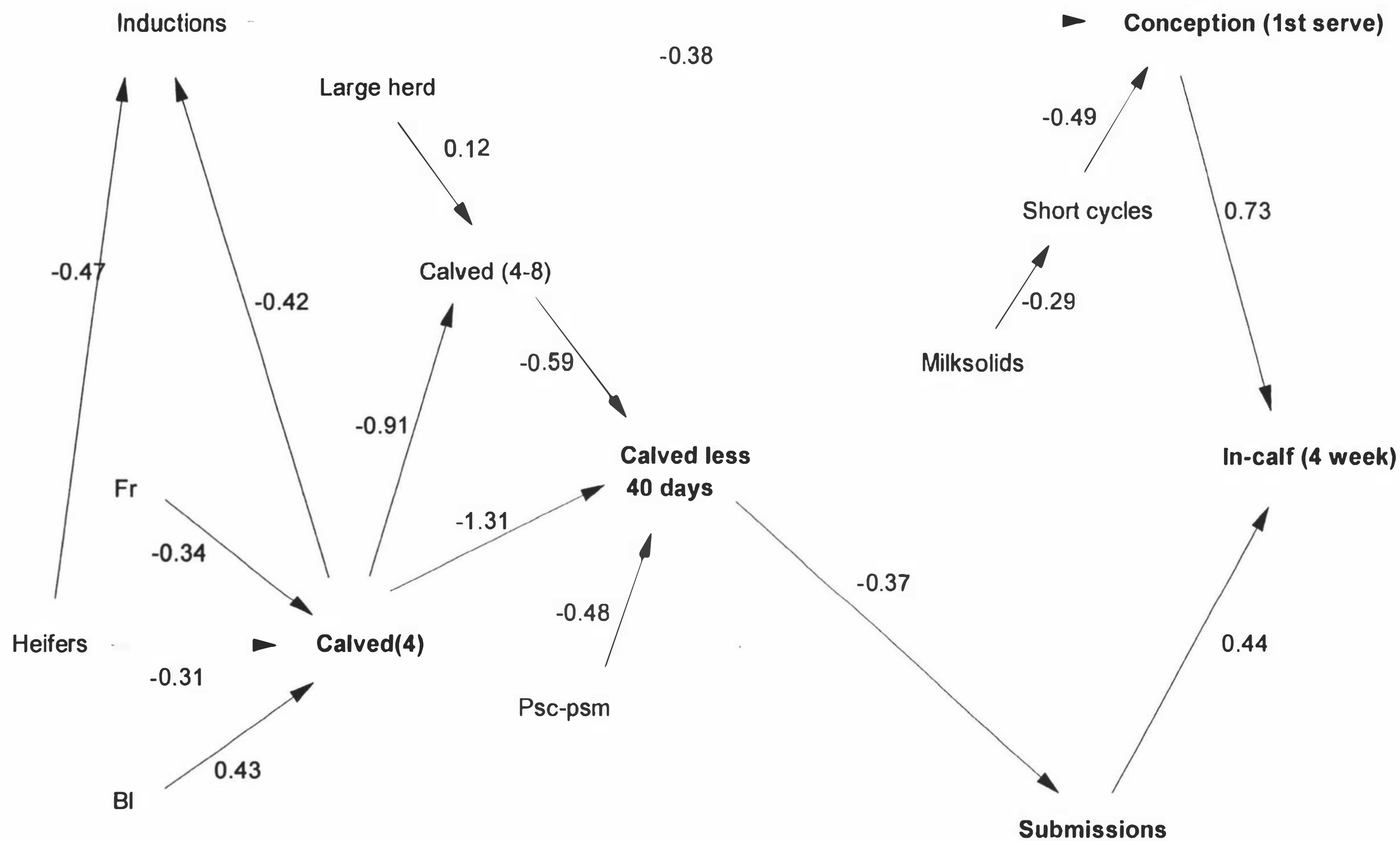

Figure 21. Alternative path model for reproductive performance indices of herds using DairyMAN that recorded whole herd pregnancy test data. Arrow weights = standardised partial regression coefficient

Chapter 4

Production and Reproductive Response to Use of DairyMAN: A Management Information System for Dairy Herds.

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Production and Reproductive Response to Use of DairyMAN: A Management Information System for Dairy Herds.

Abstract

In order to assess the benefits of on-farm use of a computerised management information system (DairyMAN) on New Zealand seasonally calving herds, data for 141 herds using this system were compared with a stratified random sample of 300 herds using only the national centralised dairy database system during the 1993/94 season. Demographic, reproductive performance and milk yield indices were compared.

DairyMAN user herds had superior reproductive outcomes measured as a higher percentage (+8.4%) of cows calving during the desired seasonal period (critical in this very seasonal system), and a higher percentage of cows (+9.7%) mated at the optimal time to achieve a concentrated calving in the following year. Multiple analysis of covariance was used to differentiate effects. The superior performance was not associated with differences in some of the more commonly used reproductive indices (heat detection efficiency, first service non-return rate, pregnancy rate), which tend to be biased between the two groups, and do not so accurately reflect true performance. Herds using DairyMAN had more information on mating performance because pregnancy data was recorded and matings were recorded for a greater proportion of the seasonal mating period.

Herds using DairyMAN produced 1.2 litres per cow per day more milk averaged over the lactation compared with herds using only the centralised database. Genetic merit did not differ between the groups, nor did breed types, so DairyMAN users were able to produce more milk with animals of equivalent genetic merit, indicating that users achieved better management of the herd through improved attention to managerial details. This was associated with their adoption of DairyMAN, but not shown by this study to be a direct consequence of it. DairyMAN user herds were larger (245 cows) than non-user herds (181 cows), but this difference did not statistically significantly affect the various outcomes measured.

(key words: Information-systems, computers, DairyMAN, Milk-production, reproduction)

Introduction

Herd management information systems (MIS) can potentially enhance the management, organisational and analytical skills of a farm operator (Lazarus et al. 1990), so that a herd is more productive than would otherwise be the case, with the same physical resources. DairyMAN is a computer program that is operated as an on-farm MIS by herd managers and veterinarians to monitor production, health and reproductive performance of New Zealand dairy herds (Tranter 1991, McKay 1991).

The benefits of herd health programs and the adoption of associated management information systems have been extensively reported (Williamson 1982, Blood 1980). Some studies have demonstrated production and economic benefits from the incorporation of these programs into dairy farming systems (Williamson 1980). Morris (1978) showed the implementation of herd health programs was associated with improvements in several herd reproductive performance variables and similar results have been demonstrated in New Zealand seasonally calving herds (McKay 1986). Some studies have examined the effect of information systems separately from veterinary involvement (Verstegen et al. 1995). A longitudinal study (Verstegen et al. 1994) of pig herds showed that those managers who adopted herd management information software improved performance indices relative to contemporaries who did not adopt such systems, as a specific effect of the MIS. A limited cross sectional study of dairy farmers in New Zealand found that DairyMAN users had higher milk yield per hectare (Ward and McQueen 1994) than non-users.

The aim of this study was to determine if the use of the on-farm management information system "DairyMAN" by veterinarians and dairy farmers is associated with superior productivity and reproductive performance.

Methods

The study covered one complete milking year, and was limited to spring calving seasonal herds, typical of the New Zealand dairy industry. Such herds are managed so that all cows calve on a synchronous annual cycle as close as possible to the "ideal" calving date in that location. A typical aim is to have calvings spread over 6 to 8 weeks with a narrow spread being strongly favoured. Data were obtained from dairy farmers licensed to use DairyMAN for the 1993/94 spring season and from a stratified random sample of herds which were recorded on the New Zealand national herd data base during the same period, but did not use DairyMAN. The information was collected at the end of the 1993/94 season. DairyMAN data came from the farmer's files, while comparison herd data came from the National Dairy Database.

Sample Size Required

There were approximately 350 registered DairyMAN users during the 1993/94 season and a population of 14597 herds recorded on the National Dairy Database (Livestock Improvement 1994). The response rate of DairyMAN users could potentially have limited the study's power. A sample size for DairyMAN herds that would detect significant biological and economic differences was determined by power analysis using the statistical software Pass (Hintze 1992) and a fixed sample of 300 National Dairy Database herds. A sample of eighty two DairyMAN herds had a power of 0.8 of detecting a 5 percent difference in pregnancy rates at $P<0.05$ using an expected population SD of 14. Other reproductive measures required less than 120 herds per group to achieve the required power. For an estimated population mean daily per cow milk yield of 18 litres and a SD of 3 litres a sample of 98 herds was required to detect a difference of 1 litre. It was concluded that a survey of the population of DairyMAN users would provide an adequate sample size providing the response rate exceeded 35 percent.

Sampling Techniques

DairyMAN herds

All DairyMAN users were sent a letter in early May 1994 requesting a copy of their herd's data on floppy disk. The reason for requesting the data was outlined and computer software prizes were offered as incentives. Non-respondents were sent a second letter three weeks later.

National Dairy Database herds.

Greater than 90 percent of New Zealand herds record cow information on the national data base (Livestock Improvement 1994). The data set of individual cow records for a single herd is called the Animal Register for that herd. To ensure that the sample distribution approximated the New Zealand herd population the sampling used a random, stratified proportionate technique using four herd size groups. The strata were 0-100, 101-250, 251-450 and greater than 450 cows in the herd at the start of mating. To exclude herds that used computerised management information systems, all herd data sets that had computer readable electronic Animal Register file were excluded from the population of herds to be sampled. Herds that had not production-tested or updated the cow records on the animal register in the four months prior to May 1994 were also excluded. To eliminate herds that would not have complete AI mating records, only herds that used a national artificial breeding service (Livestock Improvement, Hamilton NZ) were included in the data set. Using these criteria 300 herds were randomly selected and the data extracted from the national data base.

Data Management

All data sets were loaded into DairyMAN and checked for integrity. Most dairy herds in New Zealand are seasonal spring calving herds. Those that did not demonstrate a spring calving pattern were excluded at this stage. The herd planned start of calving (PSC) date defines the planned beginning of this optimal period of calving and the planned start of mating (PSM) the first day of mating that must be used to achieve the desired calving pattern. The PSC therefore is usually 83 days before PSM in a given season. Some cows calve before the PSC because of variation in gestation length, abortions and calving induction. Reproductive indices were measured relative to the PSC and PSM dates.

Reproductive performance including calving rates, rates of submission to AI, pregnancy rates, non-return rates and weekly conceptions (pregnancy rates) were calculated using standard DairyMAN reports. Calving rate and submission rate are herd variables used in seasonally mated herds. The calving rate indicates the cumulative proportion of the herd that has calved over a given period since the herd PSC. The submission rate indicates the cumulative proportion of cows submitted to a mating over a given period of time since the PSM for the herd. Non-return rates are an indirect estimate of pregnancy rates where a non-return to service is the failure to record a subsequent heat or mating within a specified time period. Calving, submission, non-return and in-calf rate reports and oestrus return interval analyses were evaluated for data validity and errors. Performance outliers were checked and corrections made if data entry errors or incorrect PSC or PSM dates were identified. Outliers were otherwise not excluded from the analysis. Cows calving after the PSM were excluded from the submission rate analysis because DairyMAN was not able to accurately calculate these data.

Statistical Analysis

Herd reproductive variables for each herd were taken from the DairyMAN reports. Individual cow records were exported from DairyMAN and stored in an Access database (MS Access, Microsoft Corporation). These data were used to calculate herd production and breed demographics. The lactation-to-date milk production was divided by the number of days in lactation at the last test date to give a lactation average daily milk yield per cow. The herd mean of this value for litres of milk, kg of fat and kg of protein was included in the statistical analysis of herd performance.

The effects of DairyMAN and of herd size were analysed using multivariate analysis of variance techniques (Manova and Mancova). Separate models for reproductive, production and demographic variables were evaluated. First order interactions between DairyMAN and herd size were included in the models. Herds were assigned to the same four herd size categories used for the animal register sampling. The specific effect of DairyMAN was then evaluated for each dependent variable where there was a significant main effect. Where it was appropriate to investigate effects "post hoc", multiple comparison of means was done using the Bonferroni technique (SAS Institute Inc 1991).

The effect of DairyMAN on reproductive performance was further evaluated using individual cow records where there was a significant effect using bulk herd data. A mixed linear model blocked by herd (SAS Institute Inc 1993) was used, with PSC to actual calving date as the dependent variable. The null model included breed, lactation, DairyMAN and calving induction as independent variables. Breed was categorised as Jersey, Friesian or crossbred. Animals not in these groups were excluded. Submission to service in the first 21 days after PSM was evaluated using logistic regression blocked by herd, using a general mixed linear model in SAS (SAS Institute Inc 1993). It included the same independent variables as well as milk yield and PSC to calving. First order interactions were included in each model.

The length of the period of artificial and natural matings in each herd may influence the calculation of non-return rates and in-calf rates. This is because non-return rate calculations and consequently in-calf rates (if cows are not pregnancy tested) are dependent on the observation of returns to oestrus within a herd. For this reason the length of the mating period for each herd was defined as the last recorded mating date less the PSM date and was included as a covariate in the model for reproductive variables. The proportion of short, normal and long return intervals will also be modified by this variable.

Pregnancy test information was not available for the animal register herds. Forty-nine DairyMAN herds pregnancy tested all cows and most pregnancy tested at least some cows in this study. Pregnancy results are used in the calculation of in-calf rates, but non-return to service is used if there is no pregnancy data. Pregnancy testing has been shown to reduce calculated in-calf rates because non-return rates are significantly higher than pregnancy rates (Morris 1976). The effect of this factor for DairyMAN herds was analysed in a separate Manova model.

Mancova models including DairyMAN and herd size as factors and litres of milk, kg of milkfat, kg of protein and somatic cell count as dependent variables, also included the herd breeding index (BI), the proportion of Friesian, Jersey and Cross-breed cows within herd and the number of days from the herd PSC to the last production test date as covariates. These variables could modify daily milk yield measurements. Mean herd somatic cell counts were log transformed for analysis but untransformed values are reported for clarity.

Results

Survey and Data Collection.

There were 165 DairyMAN respondents. Four herds were excluded because they were non-seasonal and 17 data sets were corrupt, damaged or missing. Of the 300 National Dairy Database herds 4 herds were excluded because the calving pattern was non-seasonal and 2 data sets were corrupt. The proportions of herds in each herd size category were similar between groups Table 34.

Table 34. Distribution of "representative" sampled animal register, DairyMAN user and New Zealand herds.

Herd size category	National database herds sampled		DairyMAN respondents		New Zealand herds	
	N	%	N	%	N	%
1-100	47	16	4	3	2380	16
101-250	205	68	89	61	10428	68
251-430	43	14	45	31	2199	14
> 450	5	2	7	5	243	2
Total	300		145		15250	

Demographics

DairyMAN use (Rao's $R_{10, 421}$ = 1.99, P= 0.032), and herd size (Rao's $R_{30, 1236}$=1.6, P= 0.018), were significant as main effects for the demographic variables, but the interaction was not significant (Rao's $R_{30, 1236}$=0.75, P=0.83).

For the specific effect of DairyMAN (Table 35) the PSC and PSM did not differ significantly, but DairyMAN herds were larger. There was no significant difference in the breeding index (BI), proportion of two year olds, older cows or each breed type. DairyMAN herds recorded bull matings for a significantly longer period, but the period of AI was not significantly different.

Table 35. Demographic variables for herds using only the national database and those also using DairyMAN [a].

	National database	DairyMAN	$F_{1,430}$	P
PSC [b]	30/7/94 ± 2.1	29/7/93 ± 1.8	1.13	0.3
PSM c	21/10/93 ± 1.9	20/10/93 ± 1.8	0.97	0.3
Cows in herd	185 ± 12.9	246 ± 19.8	38.3	< 0.001
Cows >6 years old (%)	25.4 ± 1.4	25.0 ± 1.3	0.48	0.5
Two year olds (%)	21.4 ± 1.2	21.7 ± 1.1	1.34	0.3
Friesian (%)	45.3 ± 4.5	43.5 ± 5.3	2.21	0.1
Jersey (%)	18.8 ± 3.7	11.4 ± 4.1	0.22	0.6
Crossbreed (%)	32.4 ± 3.3	38.3 ± 4.0	1.74	0.2
Days artificial breeding	39.4 ± 2.1	43.3 ± 2.1	1.23	0.3
Days bull mating	33.3 ± 4.2	49.3 ± 4.2	7.21	0.008
Breeding Index	127.0± 0.4	127.0 ± 0.6	0.13	0.7

[a] Values within each row not sharing the same superscript are significantly different (P<0.01)
[b] Planned Start of Calving
[c] Planned Start of Mating
[d] At the planned start of mating

Reproductive Performance

Variables included in the Mancova model are listed in Table 36. DairyMAN (Rao's $R_{12, 415}$ = 3.4, P< 0.0001), was significant as a main effect. Herd size (Rao's $R_{36, 1226}$= 1.24, P= 0.16), and the interaction (Rao's $R_{36, 1226}$= 1.28, P= 0.12) were not significant.

DairyMAN herds had significantly superior four and eight week calving rates, although the proportion of induced cows was not significantly different (Table 36). The proportion of cows calved less than forty days at the PSM was significantly lower for DairyMAN herds (Table 36). Submission rates at 21 and 28 days were significantly greater for DairyMAN herds (Table 36).

Table 36. Reproductive performance for herd using only the national database and those also using DairyMAN. (least square means ± 95 percent confidence intervals).

	National database	DairyMAN	$F_{1,426}$	P
Induced (%)	5.9 ± 0.5	7.8 ± 0.6	1.54	0.2
Four week calving rate (%)	60.8 ± 1.0	68.4 ± 1.0	8.32	0.004
Eight week calving rate (%)	88.3 ± 0.6	93.7 ± 0.6	9.78	0.002
Calved less than 40 days (%)	17.8 ± 0.9	11.3 ± 0.8	8.01	0.005
Submissions 21 days (%)	76.3 ± 1.0	86.0 ± 0.9	13.58	< 0.001
Submissions 28 days (%)	81.6 ± 0.9	91.3 ± 0.7	16.01	< 0.001
Short Intervals 2-17 days (%)	18.7 ± 1.3	13.2 ± 0.8	0.04	0.8
Normal cycles 18-24 days (%)	61.0 ± 1.2	63.6 ± 1.0	0.84	0.4
Double cycles 39-45 days (%)	4.8 ± 0.4	5.8 ± 0.3	0.15	0.7
Non-return (49 day, 1st service)	69.4 ± 0.8	64.5 ± 0.7	1.93	0.2
Four week in-calf rate (%)	60.9 ± 0.6	63.5 ± 0.8	1.11	0.3
Eight week in-calf rate (%)	81.8 ± 0.6	85.0 ± 0.6	0.27	0.6
Not in-calf (Empty) rate (%) [a]	9.3 ± 0.4	7.1 ± 0.4	0.32	0.6

a the proportion of a herd that is not confirmed in-calf after the end of the mating period.

For the analysis of individual cow data, the least squares mean of the PSC to Calving was 26.8 days for DairyMAN cows and 31.8 days for National Dairy Database cows. The difference between groups was statistically significant ($F_{1,84492}$=35.0, P< 0.0001). Breed, ($F_{1,84492}$=14.7, P< 0.0001), Induction ($F_{1,84492}$=3082, P< 0.0001), and Lactation ($F_{1,84492}$=155.0, P< 0.0001) were also significant effects. There was a significant interaction between DairyMAN use and induction ($F_{1,84492}$=87.4, P< 0.0001). For the non-induced category, DairyMAN cows had a mean PSC to calving of 2.5 days shorter than animal register cows, but for induced cows the difference was 7.4 days (Table 37). There was no significant interaction effect between DairyMAN and lactation ($F_{1,84492}$=1.2, P=0.33), or DairyMAN and breed ($F_{1,86492}$=14.7, P=0.15).

Table 37. Comparison of the mean planned start of calving (PSC) to actual calving for different classes of cows in national database and DairyMAN herds [a].

	PSC to Calving	
	National database	DairyMAN
All cows	31.8 ± 1.0	26.8 ± 1.3
Induced	40.2 ± 1.2	32.8 ± 1.4
Non-induced	23.3 ± 0.9	20.8 ± 1.3
Lactation 1	28.1 ± 1.2	22.5 ± 1.4
Friesian	32.3 ± 1.0	27.5 ± 1.3
Cross-breed	31.2 ± 1.0	26.8 ± 1.3
Jersey	31.7 ± 1.1	26.6 ± 1.5

[a] In all cases the difference between representative NZ and DairyMAN cows was statistically significant (P<0.002)

The twenty one day submission rate was significantly greater for DairyMAN users ($F_{1,84035}$=20.8, P<0.0001) (table5). PSC to calving ($F_{1,84035}$=3758.9, P<0.0001), Breed, ($F_{2,84035}$=21.8, P<0.0001), and lactation number($F_{6,84035}$=112.8 P<0.0001) were also significant effects for twenty one day submission rate. There was a significant interaction effect between DairyMAN and lactation number ($F_{6,84035}$=4.9, P=0.0001). Although DairyMAN was significant for all cows it was not statistically significant for lactation 1 cows (). DairyMAN and PSC to calving ($F_{1,84035}$=5.5, P=0.019) and DairyMAN and induction ($F_{1,84035}$=8.4, P=0.0038) were also significant interaction effects, although the main effect of induction ($F_{1,84035}$=0.19, P< 0.7) was not significant. The effect of DairyMAN was greater for non-induced cows. The interaction between breed and DairyMAN was not significant ($F_{2,84035}$=1.7, P= 0.17).

Herd pregnancy testing had a significant main effect on calculated in-calf and empty rates for DairyMAN herds (Rao's $R_{3,139}$= 2.79, P= 0.042) with pregnancy testing had significantly lower in-calf rates and higher empty rates

Table 38. Comparison of 21 day submission rates for different classes of cows in national database and DairyMAN herds.

	Submission by 21 days from PSM		
	National database	DairyMAN	P
All cows	0.83 ± 0.01	0.87 ± 0.013	< 0.001
Induced	0.84 ± 0.02	0.87 ± 0.02	0.03
Non-induced	0.82 ± 0.01	0.88 ± 0.01	< 0.001
Lactation 1	0.78 ± 0.02	0.80 ± 0.02	0.1
Friesian	0.83 ± 0.01	0.87 ± 0.02	< 0.001
Cross-breed	0.85 ± 0.01	0.89 ± 0.01	< 0.001
Jersey	0.82 ± 0.02	0.88 ± 0.02	< 0.001

Table 39. Comparison of herd in-calf rates and empty (non-pregnant) rates calculated using DairyMAN, for pregnancy tested and non-pregnancy tested herds.

	Pregnancy test n=46	Not pregnancy tested n=97	$F_{1,141}$	P
Four week in-calf rate	60.9 ± 1.2	63.5 ± 1.6	2.6	0.1
Eight week in-calf rate	81.8 ± 1.1	85.0 ± 1.1	7.3	0.01
Empty rate	9.3 ± 0.9	7.1 ± 0.8	6.1	0.02

Milk Production

DairyMAN use was significant as a main effect (Rao's $R_{4,409}$=3.98, P= 0.004), but there was no significant main effect for herd size (Rao's $R_{12,1082}$=1.44, P=0.14) or interaction between herd size and DairyMAN use(Rao's $R_{12,1082}$= 1.06, P= 0.39). Daily milk yield, milkfat and protein were all significantly different (Table 40). Somatic cell counts were not significantly different between groups (Table 40), but this data was only available for the final herd test.

Table 40. Comparison of national database and DairyMAN herds for milk production [a].

	National database	DairyMAN	$F_{1,412}$	P
daily litres	15.2 ± 0.4	16.4 ± 0.4	11.3	< 0.001
daily fat (kg)	0.74 ± 0.02	0.82 ± 0.01	15.1	< 0.001
daily protein (kg)	0.56 ± 0.01	0.63 ± 0.01	15.5	< 0.001
Somatic cell count [b]	254 ± 19	220 ± 12	0.93	0.3

[a] daily production calculated from lactation totals divided by days in-milk
[b] Somatic cell counts were log transformed for the analysis, but actual means are shown

Discussion

Herds using DairyMAN as part of a MIS showed superior calving performance that was not the result of increased herd calving induction rates. These herds did however induce cows earlier in the calving period and this reduced the mean calving date. The significant, although smaller difference for non-induced cows indicates that some of the improvement was independent of calving induction patterns. The superior performance of DairyMAN herds was a consequence of improvements in both heifer and herd management for the previous season because group differences were similar for lactation 1 and all lactations. Calving performance is modified by the reproductive performance for the milking herd and heifers during the previous season, differences in culling and stock replacement rates prior to calving and factors causing premature calving. While breed did affect calving date there was no interaction with DairyMAN and this does not account for differences between these groups.

The lower percentage of cows calved less than 40 days at the start of mating in DairyMAN herds is a consequence of the more concentrated calving pattern because there is no significant difference in either the PSC or PSM dates for the two groups. A reduction in the number of late calving cows is likely to improve submission rates (Brightling et al. 1990) and this was confirmed in the model of individual cow submissions. DairyMAN cows, however showed improved submissions rates that were independent of this effect, which suggests that other management effects are involved.

Calving performance, submission rates and conception rates determine the outcome of a mating season, as measured by in-calf rates (Brightling et al. 1990). The comparison of non-return rates and therefore in-calf rates may be confounded by the intensity of oestrus detection within a herd, and may not be adequately controlled by including the length of oestrus detection in the model. This is because non-return rates increase as the efficiency of detecting returns to oestrus decreases. Pregnancy data is also a confounding factor because most DairyMAN herds included at least some pregnancy information and this will reduce calculated in-calf rates compared with herds which simply assume that mated cows are pregnant. The lack of significant differences in return intervals suggest that heat detection efficiency and accuracy were not different for DairyMAN herds.

It is possible that DairyMAN herds had a more realistic assessment of herd reproductive performance because of the pregnancy test information and the longer heat recording period.

The improved per cow milk yield is consistent with previous work that showed an association between increased per hectare milk production and the use of DairyMAN (Ward and McQueen 1994). Breeding Index is a measure of the genetic ability to produce milk. DairyMAN herds had the same Breeding Index as the National Dairy Database herds and so the improved performance associated with the use of this MIS cannot be attributed to differences in herd genetics. This suggests that DairyMAN use is a causal factor for improving herd milk production. If the association was the reverse, that is, that high producing herds tended to adopt DairyMAN then it would be expected that DairyMAN users would also have a significantly higher breeding index.

The adoption of management information systems in association with veterinary health programs has been slow and limited (Tranter 1982, Blood and Brightling 1988), although recent advances in computer technology and increased availability of specialised software has increased adoption. This study demonstrates that despite some of these trends, a significant positive association between the on-farm use of a MIS and herd performance variables exists.

A 1993 survey of New Zealand dairy farmers showed that 16 percent used computers to assist with dairy farm management, but only 39 percent of this group used any type of animal management software. There could be potential for considerable improvements in overall productivity of dairy farms if these technologies are adopted more generally.

Chapter 5

Regional Differences in Reproductive Performance

Regional Differences in Reproductive Performance

Objectives and Methods

Some preliminary analyses (Hayes et al, 1996) and regional summaries of herd performance recorded on the National Database (Burton, personal communication 1995) have indicated that there are differences in herd reproductive performance by regional classification in New Zealand. Since this project collected a large body of data for each of the six regions in New Zealand it was considered appropriate to use the data to further refine any observed regional differences. Although the findings of this analysis were not intended for use in an Expert System this may have been necessary if large and consistent performance differences were identified.

The effects of region on herd reproductive performance were evaluated using DairyMAN and National Dairy Database herd records. The methods of data collection and management have been previously described. The effect of region is also considered in the analysis of individual cow data in Chapter 6.

Multi-variate analysis of variance techniques (Manova and Mancova) were used to investigate differences between regions in New Zealand. Separate models for reproductive, production and demographic variables were evaluated similarly to that described for DairyMAN and herd size on page 100. DairyMAN and the interaction between DairyMAN and region were also included as dependent factors. The specific effect of Region was then evaluated for each dependent variable where there was a significant main effect. Where it was appropriate to investigate effects "post hoc", multiple comparison of means was done using the Tukey honest significant difference test for unequal sample sizes.

There are six primary regions defined by the New Zealand Dairy Industry. They are Northland, Waikato, Bay of Plenty, Taranaki, Wellington and the South Island and are numbered 1 to 6 in the order listed (Livestock Improvement 1994). A map of these regions and a summary of the districts within each region is shown in the appendix.

The number of sampled DairyMAN and National Dairy Database herds are shown in Table 5 on page 42 for each region. Because the number of herds varied by region the power of the statistical analyses to detect specific regional differences varied. Where there are no demonstrated significant differences between specific regions, the data must be interpreted with caution because type II error must be considered. This is particularly true for the Bay of Plenty region but may effect other specific regional contrasts. The purpose of this investigation was to identify differences rather than quantify performance. The DairyMAN and National Dairy Database herds were therefore included in the analysis to increase the statistical power. The reported mean regional performance for each variable cannot however be assumed to be indicative of the population of New Zealand herds.

Results and Discussion

Demographics

Region (Rao's $R_{55, 1929} = 4.74$, $P < 0.0001$), and DairyMAN (Rao's $R_{11, 416} = 4.8$, $P<0.0001$), were significant as main effects for the demographic variables, but the interaction was not significant (Rao's $R_{55, 1929} = 1.22$, $P=0.13$).

The herd Planned Start of Calving (PSC) and the herd Planned Start of Mating (PSM) dates differed significantly between regions and the differences are consistent with a later PSC and PSM as latitude increased. Northland herds had a mean start of mating date of the 10th of October and South Island herds had the latest mean PSM date of the 6th of November.

The breeding index (BI) varied significantly between regions. The was no statistically significant difference in herd size, two year olds, older cows, breed type or mating periods between regions as a main effect. The reason for the lower breeding index in the South Island herds cannot be determined from this data, but the size and number of herds was increasing at a greater rate in that region during the period of investigation (Burton, 1996. personal communication). The demand for dairy stock is under these circumstances is likely to reduce the average BI as the genetically inferior animals will tend to be retained (or purchased) for a longer period to allow herd expansion.

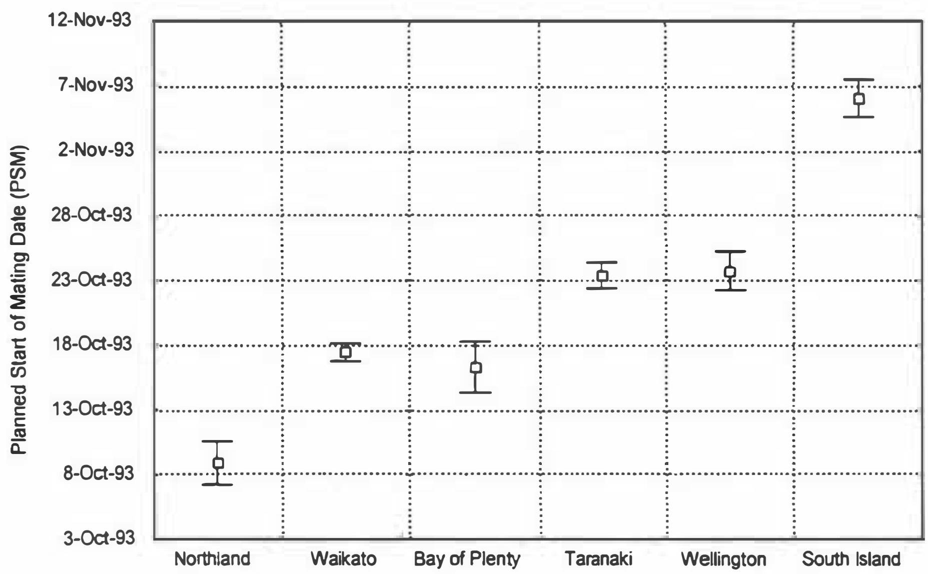

Figure 22. Mean herd planned start of mating date for each region (error bars are plus/minus the standard error)

Reproductive Performance

Region (Rao's $R_{70, 1956} = 1.5$, $P < 0.003$), and DairyMAN (Rao's $R_{14, 420} = 7.1$, $P< 0.0001$), were significant as a main effect. The interaction effect was not significant (Rao's $R_{70, 1956}= 0.79$, $P= 0.9$).

Calving rates ($F_{5,322} = 9.6$, $P <0.0001$) and the proportion of cows calved less than 40 days at the PSM differed significantly between regions as a main effect. There was a tendency for differences in submission rates ($F_{5,423} = 2.1$, $P =0.06$). The four week in-calf rates were significantly different as a main effect ($F_{5,322} = 2.8$, $P = 0.02$), but eight week in-calf rates were not statistically significantly different between regions.

There was no significant difference in induction, short, normal or double cycles, non-return rates to 1st service or all services and empty rates ($P>0.1$).

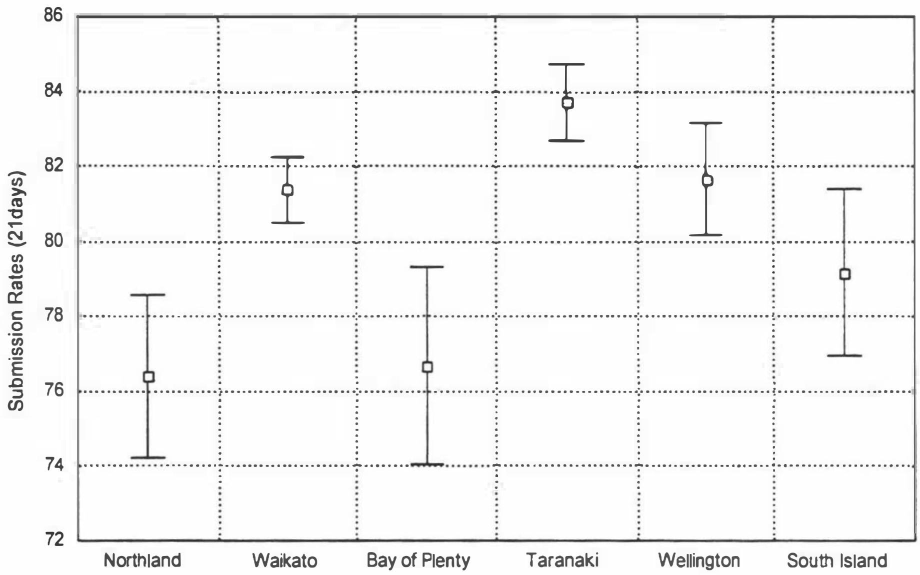

Figure 23. Mean herd twenty-one day submission rates for each region (error bars are plus/minus the standard error)

Although region is significant as a main effect for reproductive performance variables there are few significant post hoc differences (Table 41). Northland had the poorest performance with lower calving rates, submission rates and in-calf rates compared with most other regions. The Tukey honest significant difference for unequal sample sizes is a rigorous statistic that excludes many differences detected using simple anova or manova technique that may be subject to increased alpha errors due to multiple post hoc comparisons.

Pregnancy Rates

Information on herd pregnancy rates was only available for a small subset of the DairyMAN data. A separate model including only herds that used whole herd pregnancy testing was evaluated with Region as the independent factor. A pre-planned comparison of first service pregnancy rates between Waikato and Taranaki and Wellington was considered. This comparison was chosen because Wellington has been reported as having reduced first service non-return rates (Burton, 1995. personal communication). The first service pregnancy rate was included as the single dependent variable in the simple analysis of variance model (Anova).

Although Northland demonstrated poor performance in other areas and the South Island is demographically distinct, a comparison of the pregnancy rates for these regions was not possible because an insufficient number of herds in these regions used whole herd pregnancy testing.

The Wellington region had statistically significantly lower first service conception rates compared with Waikato and Taranaki. ($F_{1, 36} = 4.9$, $P < 0.03$). The first service pregnancy rate in Wellington herds was 51.7 ± 8.8 and for Waikato and Taranaki 58.5 ± 8.5.

Milk Yield

Region was significant as a main effect (Rao's $R_{20, 1344}$=4.19, P< 0.001) for a model including daily milk yield (Litres), milkfat (kg), protein (kg) and somatic cell count. DairyMAN was also significant (Rao's $R_{4, 405}$=2.71, P=0.03). The interaction between the two factors was not statistically significant (Rao's $R_{20, 1344}$= 1.54, P= 0.06).

Milkfat production was significantly different between Northland and Taranaki and between Northland and the South Island (Table 42). Protein was only different between Northland and the South Island. Milk yield and somatic cell counts were not significantly different between regions. The regional differences in milk production are not large. Only the lower production from Northland herds is of significance.

Summary

The purpose of this section was to identify any regional differences in reproductive performance. This was not intended to be used within the DairyFIX system, but rather was a separate investigation as part of the first objective of this thesis. That is, to describe the reproductive performance of New Zealand dairy herds.

The planned start of mating (PSM) varies with region. The pasture growth rate curves changes with latitude. As the latitude for a herd increases there is generally a longer and colder winter that reduces overall growth rates and delays the onset of spring pasture growth. To adequately match the herd's nutritional requirement it is necessary to delay the start of calving relative to more northerly herds. Consequently the PSM is later at more southerly latitudes.

The were few detected variations in herd reproductive performance by region although Northland herds had poorer overall performance. Of particular interest is the inferior conception rates achieved in the Wellington region. This region has been known to have poorer performance measured using non-return rates over several years (Burton personnel communication 1996). Management of technicians used for artificial breeding was different in this region and considered to be one cause of reduced performance in previous years. The effects however are still present and this study has confirmed that pregnancy rates as lower. The causes of poorer performance have not been identified but a more detailed study of nutrition, trace elements and soil types may be one avenue of investigation to consider.

Milk production did not vary greatly between regions. South Island herds had similar production although the herd average breeding index was lower. These large south island herds tend to have a lower breeding index as cows are retained to allow for rapid expansion that has occurred in recent years.

The results do not suggest that there are regional differences of a magnitude that would require inclusion in the final DairyFIX Expert System. Further efforts are required to more accurately quantify and identify factors associated with these regional effects.

Table 41. Variables included in the Mancova model of demographic and those included in the Mancova model of reproductive performance with herd size and region as factors

	Northland	Waikato	Bay of Plenty	Taranaki	Wellington	Southland	F (df1,2) 5,426	p-level
Demographics								
Region number	1	2	3	4	5	6		
Planned start of Calving	19/7/93 ± 9^{1234}	27/7/93 ± 12^{15}	26/7/93 ± 7^{6}	1/8/93 ± 9^{27}	1/8/93 ± 9^{38}	11/8/93 ± 18^{45678}	18.7	0.000
Cows_calved	215.2 ± 110	208.7 ± 94	192.9 ± 66	216.7 ± 99	222.8 ± 146	200.2 ± 94	0.37	0.6
Planned start of mating	10/10/93 ± 10^{1234}	17/10/93 ± 10^{15}	17/10/93 ± 11^{6}	22/10/93 ± 9^{27}	23/10/93 ± 9^{38}	6/11/93 ± 10^{45678}	39.4	0.000
old percent	26.8 ± 11.0	26.7 ± 8.1	24.2 ± 11.1	25.2 ± 6.8	23.3 ± 9.8	24.9 ± 9.1	1.38	.2
Percent 2 year olds	21.1 ± 8.4	20.7 ± 7.3	23.1 ± 10.3	21.0 ± 5.7	21.7 ± 6.0	21.8 ± 10.2	0.411	0.9
Days of recorded AI	41.0 ± 11.1	39.6 ± 13.3	40.0 ± 15.2	40.3 ± 14.1	45.3 ± 13.1	42.0 ± 15.5	1.26	.3
Days of bull matings	44.2 ± 29.2	43.1 ± 29.0	33.3 ± 29.3	50.9 ± 26.5	36.0 ± 24.7	40.4 ± 25.9	2.09	.07
Breeding Index (payment)	126.9 ± 3.1	127.4 ± 2.5^{1}	126.7 ± 2.0	128.1 ± 2.4^{2}	127.4 ± 2.5^{3}	125.6 ± 3.8^{123}	5.53	0.000
Friesian percent	49.6 ± 28.5	48.1 ± 30.5	44.8 ± 28.6	36.5 ± 29.3	45.3 ± 34.3	41.9 ± 33.7	1.53	0.2
Jersey percent	10.6 ± 14.4	13.6 ± 24.9	8.8 ± 22.5	22.2 ± 25.0	19.7 ± 32.9	17.6 ± 27.2	1.90	0.1
Cross-breeds percent	35.2 ± 24.2	35.4 ± 22.3	35.7 ± 21.1	39.9 ± 20.7	31.5 ± 25.6	32.3 ± 25.1	1.11	0.4
Calving Performance								
Region number	1	2	3	4	5	6		
Induced (% calved)	8.9 ± 7.8	6.8 ± 6.2	5.4 ± 8.4	6.1± 5.3	6.3 ± 6.2	7.9 ± 7.7	1.125	.3
Four week calving rate	50.22 ± 14.9^{12345}	64.5 ± 11.6^{1}	66.3 ± 13.0^{2}	62.9 ± 10.5^{3}	63.5 ± 10.7^{4}	60.2 ± 13.8^{5}	10.3	.000
Eight week calving rate	80.0 ± 11.7^{12345}	87.9 ± 7.4^{1}	90.8 ± 7.9^{2}	87.1 ± 6.2^{3}	87.1 ± 7.3^{4}	86.5 ± 9.5^{5}	8.1	.000
Mating Performance	1	2	3	4	5	6		
Cows calved < 40 days	23.8 ± 13.2^{12345}	13.5 ± 11.4^{1}	12.2 ± 14.2^{2}	12.2 ± 7.3^{3}	12.6 ± 8.4^{4}	13.0 ± 8.2^{5}	6.173	.000
Submissions 21 days	77.7 ± 12.7^{1}	83.5 ± 11.9	82.4 ± 14.8	84.5 ± 9.4	82.2 ± 9.51^{1}	79.3 ± 16.0	2.016	.06
Submissions 28 days	84.2 ± 11.4^{1}	88.9 ± 10.7	87.4 ± 12.7	89.8 ± 8.7	87.5 ± 8.1^{1}	84.6 ±15.8	1.888	.07
In-Calf Performance	1	2	3	4	5	6		
Four week In calf rate	61.1 ± 11.3^{1}	66.2 ± 10.6	68.9 ± 14.7^{1}	66.6 ± 10.1	62.3 ± 9.2	62.9 ± 14.3	2.78	.02
Eight week in calf rate	84.1 ± 8.8	86.1 ± 8.7	86.4 ± 10.5	86.7 ± 7.7	84.7 ± 8.6	82.24 ± 12.6	1.8	.11
Not in-calf rate	8.5 ± 7.2	7.8 ± 10.9	9.2 ± 10.9	6.1 ± 6.3	7.8 ± 7.1	10.30 ± 13.3	1.03	0.4

a Means sharing the same superscript within each row are significantly different (Tukey honest significant difference for unequal N. P<0.05)

Table 42. Mean herd average daily production by region for Milk yield kilograms of milkfat and kilograms of protein and the mean herd average somatic cell count at the last herd production test [a]

	Northland	Waikato	Bay of Plenty	Taranaki	Wellington	South Island	F (df1,2) 5,408	p-level
N	33	185	30	84	41	47		
Litres	15.2 ± 2.8	15.9 ± 2.6	15.2 ± 2.9	15.3 ± 2.4	15.8 ± 2.7	16.7 ± 3.7	1.77	0.1
Fat (kg)	070 ± 0.12[1,2]	076 ± 0.10	073 ± 0.11	080 ± 0.10 [1]	078 ± 0.09	079 ± 0.14 [2]	3.55	0.004
Protein(kg)	054 ± 0.09[1]	058 ± 0.08	056 ± 0.09	060 ± 0.07	059 ± 0.07	061 ± 0.11[1]	2.66	0.02
Somatic cell count b	262 ± 142	240 ± 115	217 ± 118	224 ± 124	235 ± 89	223 ± 109	0.64	0.6

a Means sharing the same superscript within each row are significantly different (Tukey honest significant difference for unequal N. $P<0.05$)

b The model included the mean log SCC but actual means are reported for clarity

Chapter 6

The Effect of Induced Parturition on Subsequent Reproductive Performance and Milk Production of Cows in New Zealand Seasonally Calving Dairy Herds

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The Effect of Induced Parturition on Subsequent Reproductive Performance and Milk Production of Cows in New Zealand Seasonally Calving Dairy Herds

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Abstract

Some effects of calving induction were investigated in 38 seasonally calving dairy herds for the 1993 spring calving season. Herds from the North Island of New Zealand with pregnancy test data for all cows were included in the study. Cows with an induced parturition were compared with non-induced cows that calved at about the same time. Calving induction had a direct negative effect on milk production (-9.3%), particularly in early lactation. The mean difference in total lactation milk yield was 341 litres. The effects on milkfat and protein yield were less (-7% and -6.1%) because the milk from induced cows had higher percentages of milkfat (+3.0%) and protein (+3.1%) for the lactation. Cows induced to calve within the first 4 weeks after a herd's "planned start of calving" date had the greatest production deficit. A difference in 21-day submission rates between groups was not observed, but induced cows had reduced chances of pregnancy, to first service or during the entire mating programme.

Introduction

The termination of pregnancy by injecting hormones is a common practice in New Zealand seasonally calving dairy herds. Cows are induced to calve because there are potential production gains and reproductive benefits. Lactations are usually terminated within a herd at a common date in the autumn, so an earlier calving date after either a normal or induced parturition increases the duration of lactation. This has been described as the indirect effect which induction has on milk yield (Morton and Butler 1995) and is well documented (Malmo 1991). The total benefits for a herd will also depend on other factors, including pasture growth rates and herd management practices.

The induction procedure may initially have direct negative effects on daily milk production per cow (Malmo 1991), but a positive response will result if total production for the lactation is increased because of the extra lactation days (Malmo 1991). A recent prospective study demonstrated a direct negative association between induction and daily milk production (Morton and Butler 1995).

Seasonally calving dairy herds commence mating at a herd dependent date termed the "planned start of mating" (PSM). Cows are mated during the following 6 - 12 weeks. The PSM determines the planned start of calving (PSC) for the following season and the pattern of calving in any year is determined primarily by the reproductive performance in the previous season (Macmillan 1984). Culling, replacements, abortions and induction will modify the calving pattern. Various measures have been used to evaluate performance (Macmillan et al. 1990) because the calving pattern is not distributed normally, but rather skewed toward the PSC. The proportion of cows calving up to the end of the fourth week after the PSC is commonly used (McKay 1986). A cow is deemed to have been submitted when served, generally by artificial insemination, for the first time during a mating period. Herd managers aim to have 90 percent of cows submitted in the first 21 days (Tranter 1991).

The submission rate, ie, the proportion of cows submitted in the first 21 days of mating, is a key reproductive indicator in seasonal herds (Macmillan and Moller 1977).

The reproductive benefits from inducing a premature calving result from an increase in the number of days from calving to the herd PSM and therefore calving to first service. The PSM imposes a voluntary waiting period that is herd dependent and varies inversely with calving date. This voluntary wait period has been shown to significantly affect the reproductive performance of seasonal herds (Brightling et al. 1990). Induction of calving has been shown to increase the incidences of retained foetal membranes and endometritis, with both having deleterious effects on subsequent mating performance (Dohoo et al. 1984, Erb et al. 1985, Mellado and Reyes 1994, Morris 1976, Peeler et al. 1994). Induction of calving has been shown to have some negative effects on subsequent reproductive performance in New Zealand herds (Moller and MacDiarmid 1981), and an Australian study showed a tendency towards lower pregnancy rates for induced cows when compared with a control group calving normally (Morton and Butler 1995).

The purpose of this study was to identify any direct association between the induction of calving and subsequent individual milk production and reproductive performance. The changes in production and reproductive performance that result from changes in lactation length and an increase in the number of days from calving to the start of mating were not investigated.

Methods

Data from a retrospective study of the reproductive performance and milk production of herds using the DairyMAN (Tranter 1991) management information system for the 1993-94 season was used for this investigation. Users of this computer program were asked to provide copies of their herd data. There were 145 respondents from about 400 users distributed throughout New Zealand. This study was restricted to the Waikato, Taranaki and Wellington regions because insufficient data was available from other smaller regions. The study only included herds that used whole-herd pregnancy testing. These herds had superior reproductive performance when compared with a stratified random sample of New Zealand herds, but induced a similar number of cows (Hayes and Morris 1996). Information was not available for individual herds on induction methods used or special management applied to induced cows.

Cows were commonly induced in one or two groups for each herd. Non-induced cows that calved within the same date range as a group of induced cows within each herd were used as control cows for production and reproductive comparisons. Non-induced cows that commenced the lactation by either a premature calving or an abortion were excluded. Herds were excluded in cases where control cows did not exist because induced cows calved after most other cows in the herd.

Statistical Techniques

The sample size was limited by the number of herds that used whole-herd pregnancy diagnosis. Power analysis was used to determine if a sample size of about 900 induced cows and 2000 herd mates with normal parturition was adequate. These numbers gave a estimated power of 0.88 to detect a 3 % difference in submission rates and 0.80 to detect a 5 % difference in pregnancy rates. For 560 induced cows and 1500 normally calved cows that had complete production records, there was an estimated power of 0.8 to detect a 1.0 litre per day difference in milk production. This study was therefore considered to have ample power to detect reproductive and production differences of management significance.

Statistical analyses were performed using SAS for Windows (SAS Institute Inc 1988) and Statistica for Windows (Statsoft Inc 1993). The effect of induction on continuous production variables was analysed using mixed linear model techniques, blocked by herd (SAS Institute Inc 1993). The lactation milk yield variables, litres of milk, kilograms of milkfat and kilograms of protein, and lactation average percentage by volume of milkfat and protein were included as dependent variables in separate models. The variable "4 week calving" categorised cows into those that calved up to 28 days after the herd PSC and all cows calving after 28 days from the PSC. Induction, breed, lactation number, breeding index, 4 week calving, region and first order interactions between induction and the other independent variables were included as fixed effects in each model.

Individual milk yield was measured for each herd 4 times at about 2 month intervals from September 1993 at herd tests. To investigate the interactions between induction and yield at each herd test, milk yield by volume (litres) was included in a repeated measures mixed linear model, again blocked by herd with the number of days from calving to first production test included as a covariate.

Lactation persistency of induced and normally calved cows was evaluated using logistic regression blocked by herd, with the outcome being the recording or otherwise of production details at each production test date.

The effects of induction on submission rates, first service pregnancy rates and pregnancy status at the end of mating was analysed using logistic regression, with herd included as a random effect. Induction was initially included in separate analyses for each outcome variable. If there was a significant effect of induction, then breed, lactation number, and 4 week calving were evaluated in separate models. The three week submission rate was also evaluated for the models with pregnancy outcome as the dependent variable. All effects that were significant ($p \leq 0.05$) in these models were then offered as independent variables in a backward stepwise regression technique. Main effects with $p > 0.05$ for the maximum likelihood Chi-squared were removed singly from the model. This step-down process was continued until all effects were evaluated. Interaction terms were then offered to the model individually using a forward selection technique.

Results

Thirty eight herds from the Waikato, Taranaki and Wellington regions were included in the investigation. The mean herd size was 268 cows is larger than the New Zealand average of 195 cows (Livestock Improvement 1994). They included 10172 cows which calved during the spring of 1993, of which 8.8% were recorded as having calved after an induction treatment. Seven herds (18%) did not induce cows and a further two herds each induced only one cow. These were not included in analyses. The proportional incidence of calving induction was similar for all parities, except heifers calving into the first lactation (Table 43).

Table 43. Distribution of calvings and the incidence of calving induction by lactation number among cows in 38 herds.

	Lactation Number							
	1	2	3	4	5	6	>6	Total
Cows Calved	1914	1907	1779	1339	1192	901	1140	10172
Induced (%)	0.8	11.6	12.8	10.2	9.8	8.2	10.0	8.9

The mean calving date for all cows calving at term was 18.4 days after the PSC. The equivalent date for induced cows of 26.3 days was significantly later ($t = 12.5$, df 10 170 $p < 0.0001$). Induced calvings therefore represented a distinct population of cows that calved late in the calving period. Some herds had more than one distinct group of induced cows. For these reasons, only cows calving within the date ranges of each induction group were included in the analysis of production and reproduction. There were 878 induced cows and 2169 normally calving herd mates that met these criteria and were included in the production and reproductive analyses.

The 10 172 cows included 54% classified as Friesian, 33% as Friesian Jersey and 10% as Jersey. Another 3% were pedigree Friesian or Jersey. The induction rate within each breed type only varied from 6.9 % (Jersey) to 9.3% (Friesian).

Milk Production

The number of cows presented at each production test was not statistically different between induced and non-induced herd mates ($p > 0.05$) for all test dates.

Induction was significant as a main effect for all lactation yield and composition variables (Table 44). Induced cows produced a less milk and fewer kilograms of milksolids for the lactation. The lactation average percentages of milkfat and protein components were higher for the induced cows (Table 44). There was a significant interaction between induction and 4 week calving for milkfat ($p = 0.05$) and protein ($p = 0.05$). There was a tendency for an interaction between 4 week calving and litres but no interaction for fat percentage ($p = 0.4$) or protein percentage ($p = 0.6$). This means induction had a greater negative effect on total lactation production of milkfat and protein for cows calving in the first 4 weeks of calving compared to later calving cows.

Table 44. Least square means for total lactation total litres of milk, kilograms of milkfat and kilograms of protein and average lactation fat and protein percentage [a].

	Induced	Non-Induced
n	591	1536
Litres	3554 ± 0.96	3858 ± 0.95
Fat	176.0 ± 4.3	187.0 ± 4.2
Protein	138.1 ± 3.2	145.0 ± 3.1
Fat %	5.05 ± 0.08	4.95 ± 0.08
Protein %	3.92 ± 0.05	3.81 ± 0.05

[a] In every case, production for induced cows was significantly different from non-induced cows within each calving group ($p < 0.0001$)

Breed, lactation number, and 4 week calving had a significant main effect on all lactation production variables ($p < 0.0001$). Breeding index was significant for litres ($p < 0.0001$), fat ($p < 0.0001$) and protein ($p = 0.0002$), but not for milkfat and protein percentage ($p > 0.1$).

There were no significant first order interaction involving induction with breed, lactation number or breeding index ($p > 0.05$),ie. breed, lactation number and breeding index did not modify the effect induction had on milk solids.

The repeated measures analysis of herd test production, included 507 induced and 1383 non-induced cows. There were fewer cases in this analysis because cows without complete production records were excluded. Induction had a significant negative effect on daily production ($F_{1,31}$=16.7, $p = 0.0003$). There was a significant interaction between induction status and test number ($F_{93,5409}$=15.7, $p < 0.0001$). The difference in mean production at the first herd test was 2.49 litres/day, but this difference diminished to 0.60 litres per day at the fourth test date (Figure 24).

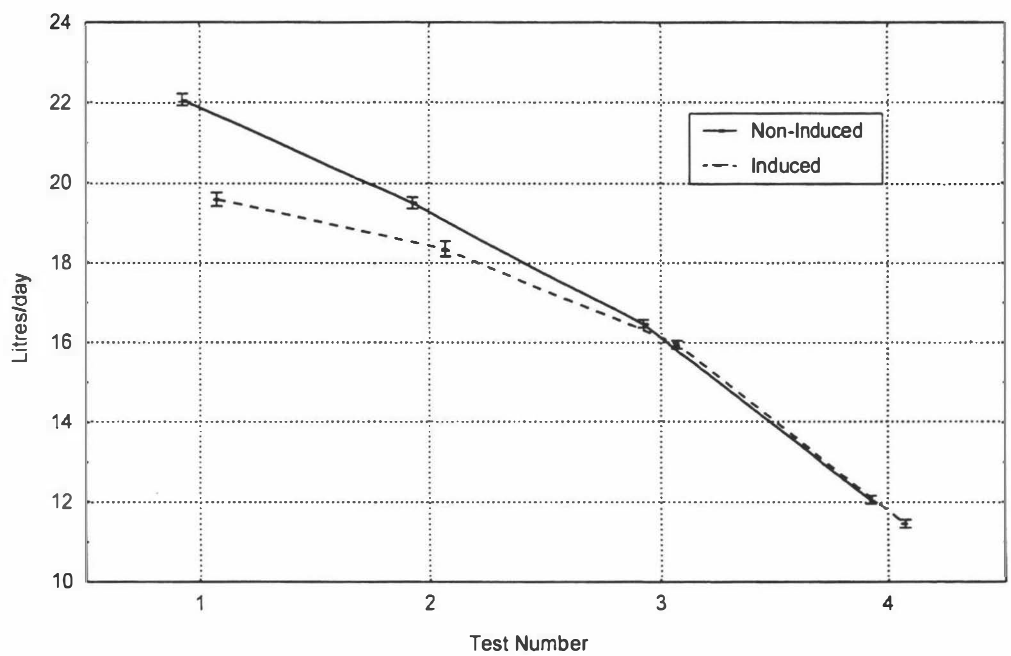

Figure 24. Mean daily milk production in litres for cows with induced and non-induced calvings for each herd production test during the 1993/94 production season. (Error bars show plus/minus one standard error)

Reproduction

Reproductive performance variables for the induced and non-induced cows are shown in Table 45.

Table 45. Descriptive reproductive statistics for induced and non-induced cows

	Induced	Non-Induced
n	878	2169
Submission rate (21 day)	0.88 ± 0.09	0.88 ± 0.08
Conception rate to 1st serve	0.56 ± 0.15	0.60 ± 0.10
Pregnant at end of mating	0.90 ± 0.09	0.94 ± 0.06

Submission Rates

In a logistic regression model blocked by herd, induction did not have a significant effect on the 3-week submission rate (df1, Wald $\chi^2 = 0.012$, $p = 0.9$).

Pregnancy Rates

The final model for significant effects on the first service pregnancy rates included induction, 4 week calving and the Waikato region. The odds ratio for pregnancy to first service for induced cows was 0.8 compared with non-induced cows (Table 46). Submission rates, breed, breeding index and lactation number did not have significant effects on pregnancy outcome to first service ($p > 0.05$) and were removed from the model. No first order interaction terms were significant.

Table 46. Final logistic regression model for first service conception. The covariate "herd" was included in the model and was statistically significant (P=.05).

	Parameter Est ± S.E.	χ^2	P-Value	Odds Ratio
Induction	-0.193 ± 0.091	4.5	0.03	0.8
Four week calving [a]	0.375 ± 0.095	15.6	<0.001	1.5
Waikato	0.351 ± 0.12	8.8	0.003	1.4

a Calved before the end of the fourth week after the herd planned start of calving.

Calving induction, 4 week calving, submission rates and the Taranaki region were significant main effects on pregnancy status at the end of mating (Table 47). Induced cows were less likely to be pregnant at the end of mating, (odds ratio 0.59). Breed, breeding index and lactation number did not have significant effects on pregnancy status ($p > 0.05$). No first order interaction terms were significant.

Table 47. Final logistic regression model for pregnancy status at the end of mating. The covariate herd was included in the model and was statistically significant (P=0.02).

	Parameter Est ± S.E.	χ^2	P-Value	Odds Ratio
Induction	-0.52 ± 0.14	12.7	<0.001	0.59
Four week calving [a]	0.54 ± 0.17	10.1	<0.001	1.7
Submission (21 day)	1.05 ± 0.17	40.0	<0.001	2.9
Taranaki	1.31 ± 0.48	7.4	0.007	3.7

[a] Calved before the end of the fourth week after the herd planned start of calving.

Discussion

This retrospective study identified a significant direct reduction in the milk yield of induced cows, which would limit the gains achieved from increasing lactation length under seasonal management conditions. The number of extra days lactation required to balance the negative effects of induction observed in this study for milk components can be estimated as the difference in lactation production (304 litres) divided by the expected production in early lactation of 21.9 litres/day for this study (Figure I). This is about 14 days. The effect of induction was greatest for cows induced early in the calving season so the actual number of additional lactation days required to achieve break even increases in production may be greater than this estimate.

Reproductive performance was also reduced by induction, although submission rates were not different. Similar observations were made in an early study of calving induction in New Zealand (Moller and MacDiarmid 1981), and more recent studies have suggested similar effects (Morton and Butler 1995). Cows calving in the first 4 weeks had improved pregnancy rates. This is consistent with many studies associating the number of days from calving to service with improved pregnancy rates (Brightling et al. 1990, Lee et al. 1989). Induction may therefore have a positive indirect effect on the likelihood of cows conceiving in a given mating season because the number of days from calving to service is increased. A positive reproductive response will only result if calving date is advanced sufficiently to counter the direct negative effects observed. This should be considered when induction is used to improve herd reproductive performance.

The greater daily production deficit for cows induced early in the calving season suggests there may be changes in the initiation of lactation, but changes in metabolic or disease state after calving cannot be excluded. For example, retained placenta has been shown to increase following induction (Malmo 1991) and also to reduce milk production (Erb et al. 1985). Lactation persistency was not altered by induction in this study as no difference in the number of induced and non-induced cows dried off before each herd test was observed. This is a retrospective study therefore the possibility that some cows died or performed so poorly that they were not established on the data set cannot be excluded and is considered to be a minor potential bias.

There are several possible explanations for the greater production deficit observed for cows induced in the first 4 weeks after the PSC. These cows may have been induced at a shorter gestation length, which could alter udder development and hence production capacity. The interaction between stage of pregnancy at induction and subsequent milk production has previously been investigated but no significant effect was demonstrated (Morton and Butler 1995). The stage of pregnancy at induction was not available in this study. Cows induced later in the season may have a different body condition score compared with those induced earlier, which will modify the production response.

Induced cows in this investigation may have been subject to external factors. The induced cows will have conceived later in the previous mating season and there is potential for the same factors to be influencing performance in the current lactation. Morton and Butler (1995) suggested that previous conception date is unlikely to be closely associated with the lactation production for the following season if calving date, previous production, age and herd are controlled for, which was the case for this study. Confounding, due to pre-existing reproductive pathology, cannot be excluded, but the incidence of reproductive disease in New Zealand herds is low and may not be an important factor (Brightling et al. 1990).

This study indicates that under some New Zealand management conditions, a significant negative production and reproductive response to induction occurs. The impact of some recommended management strategies for induced cows, such as improved body condition score at calving, need further evaluation considering the effects observed in this study.

Chapter 7

Reproductive Performance of Individual Cows

Reproductive Performance of Individual Cows

Introduction

The investigation of the reproductive performance of individual cows within herds continues the identification and quantification of important factors that modify the reproductive outcome in seasonally calving dairy herds in New Zealand.

This chapter has two main objectives;

Identify significant determinants of individual cow performance

The first purpose of these investigations was to identify important demographic, reproductive and health factors that modify the performance of groups within New Zealand seasonally calving dairy herds. These included the effects of region, breed, lactation number, calving date, calving events, genetic index, milk production and some recorded health events on the reproductive performance of cows in herds. Some of this information has been previously described in the literature and is reviewed in Chapter 1, but there is only limited, recent information available for herds in New Zealand.

Develop predictive models for inclusion in DairyFIX

An expert system evaluating herd reproductive performance must have the "knowledge" to accurately evaluate each diagnostic or performance measure within a herd. The investigation must consider the relationship between each aspect of herd performance and the effects of herd demographics including breed and age profiles. The relationship and relative importance of the performance indicators has been described in the path models of herd data. However, to further quantify the demographic effects and the effects of each intermediate measure of a seasonal mating plan on the outcome as measured by the herd in-calf and empty rates it was necessary to investigate individual cow performance. In this chapter predictive models of cow performance are developed for inclusion within the expert system. Some of these models are subsequently used within the DairyFIX system to estimate the expected performance of the cows within a herd and then compare this with target performance.

Four principal aspects of seasonal reproductive performance were considered in the analysis of individual cow data, namely the calving pattern, submissions, measures of conception, in-calf and empty rates. The path models described above and the literature was used to determine if each independent variable could potentially affect the outcome for each model. These variables were then included in the particular model for investigation. The variables of interest were generally those reported in DairyMAN as this is the data to be used by the DairyFIX system when retrieving data from DairyMAN.

Statistical Methods

Continuous outcome variables were investigated in a generalised linear model using the Proc Mixed analysis module in SAS for Windows. Variance components were estimated by restricted maximum likelihood (REML). F-tests for fixed effects were based on type III sums of squares. The association between independent variables and categorical outcome variables were evaluated using the Glimmix procedure in SAS for Windows using the default logit link function and binomial error distribution. The Glimmix procedure is a SAS macro for fitting generalised mixed linear models using a variety of link functions and error distributions. The procedure allowed for the evaluation of logistic regression models while still including a random effect for herd.

In the Glimmix procedure the model outcome Y is the log to the base e of p/ (1-p) where p is the estimated probability of a positive outcome for the binary dependent variable. Model estimates and "Mu" are reported in the Glimmix procedure for each category within a class effect and for specific contrasts. Mu is equivalent to p for each specific category and is equal to $1/(1+\exp(-\beta))$ where β is the parameter estimate for a particular category.

Cows in these data are not independent because observations within herds may be statistically correlated due to herd factors that modify reproductive performance. For this reason "Herd" was included in all models as a random effect. The inclusion of herd as a random effect in each model sets up a common correlation among all cows within each herd in the statistical models. Also, most outcome variables were measured against herd specific variables which removes some of the herd dependent effects. For example the individual cow's calving performance was measured as the number of days from the PSC (planned start of calving) for the herd to the calving date. Similarly the mating performance variables were considered relative to the herd's PSM (planned start of mating date).

Independent variables of interest were initially offered to the models separately. Variables that were significant at p=.05 were included in a multi-variate model. Non-significant variables were removed using a backward stepwise procedure. Interaction terms were included in each model and if statistically significant they were retained in the final model.

For both the mixed linear models and the logistic regression models using the Glimmix procedure, pre-planned comparisons and estimates of effects were investigated for some of the independent factors. For "Post hoc" investigations the "Bonferroni" adjustment was used when determining the statistical significance.

Table 48. Description and type of outcome varibles considered for analysis

Code	Description	Type
PSC_CAL	Planned Start of Calving to Calving	Continuous in days
CAL_PSM		
CAL4	Calved by the end of the fourth week after the herd PSC	Binary
CAL8	Calved by the end of the eighth week after the herd PSC	Binary
PSM_SER	Planned start of mating to first service	Continuous in days
SUB21	Twenty one day submission. First service recorded in the first three weeks after the herd PSM	Binary
PSM_NR	Planned start of mating to the first service that meets the non-return criteria.	Continuous in days
NR1st 28	Twenty eight day no-return for first service. No subsequent service recorded in the 28 days after a cow's first service in the mating period	Binary
PSM_CON	Planned start of mating to Conception (by Pregnancy test)	Continuous in days
CONC1st	Conception to first service. Pregnancy test confirmed	Binary
INCALF4	Pregnant or non-return to service in first four weeks of mating	Binary
INCALF8	Pregnant or non-return to service in first eight weeks of mating	Binary
EMPTY	Empty at end of mating (by non-return or pregnancy test criteria	Binary

Data Management

Cows calving more than 30 days before a herd planned start of calving or more than 140 days after the PSC were excluded from all analyses because the information for these cows may not be complete for the period of investigation. Some may be carryover cows that have continued lactating through two seasons. The performance of carryover cows could not be investigated because there was no opportunity to exclude cases with missing calving. That is the carryover cows could not be distinguished from cases where the calving date had not been entered into the database or DairyMAN. Similarly, all cows with matings that were more than 10 days before a herd PSM or more than 140 days after the PSM were excluded as they could not be considered as part of the mating period being investigated. Matings outside this range are more likely to belong to a separate mating period particularly in Autumn/Spring mating herds. Cows with a valid PSM date but no recorded matings were retained.

One thousand eight hundred and twenty eight cows were removed from the DairyMAN data because the calving date was more than 40 days before the herd PSC or more than 140 days after the PSC calving or no valid calving date existed. A further 341 cows were excluded because the first service was more than 20 days before the herd PSM or more than 140 days after the herd PSM. Cows without a recorded mating were not excluded. Two thousand nine hundred and eleven cows were similarly removed from the National Dairy Database herds because a calving occurred outside the specified range and 61 cows because a first service occurred outside the specified range. A summary of the missing data for some important variables is shown in Table 49 for the subset of data that met the above criteria.

Records with other missing data were case-wise deleted from all statistical analyses.

Table 49. Summary of missing values for the independent variables included in the statistical models

	National database herds N=52841	DairyMAN N=34624	Pregnancy Test herds N=12815
Breed	394	316	71
BI	86	491	109
Lactation Number[a]	nil	nil	nil
MS	14324	8783	3608
MS2[b]		5824	1912

a All animals recorded on the national database and in DairyMAN must have a lactation number
b Only lactation total production available for the national database herds

Variables Included in the Analysis of Individual Cow Performance

Region

The regional classification that is commonly used in the dairy industry was used for all statistical analyses. These regions were Northland (REGION 1) Waikato, (REGION 2), Bay of Plenty (REGION 3), Taranaki (REGION 4), Wellington (REGION 5) and the South Island (REGION 6). A map of the regional classification is shown in the Appendix.

Breed

Holstein/Friesian (54%), Jersey (19%) and Holstein/Friesian/Jersey cross-breeds (16%) are the most common breed types in New Zealand (Livestock Improvement 1994). Cows were categorised into five groups for the purpose of these analysis. Friesian (FR), Jersey (JR), Cross-breed (CROSS) which were any combination including Friesian or Jersey breeds, pedigree Friesian (FPED) and pedigree Jerseys(JPED). Cows were regarded as pure breed Friesian or Jersey if the genetic record showed at least 15/16ths of the particular breed There were a small number of Ayrshires that were not included in analyses of breed effects. Cows with no breed recorded were excluded from the analysis. No attempt was made to distinguish between the different Cross-breed groups and the specific effects of sire (or the cow) were not included in these analyses.

Lactation Category

All animals were categorised by lactation number. The number of cases decreases with increasing lactation number so all animals in lactation five or greater were classed together. Lactation number is an approximation of parity but some errors may occur where calving dates have not been recorded or completed lactations remain unrecorded for individual cows. This can occur for example if a heifer calves but has very poor performance. In some cases these animals are retained and enter the herd in the following season after a second calving but the information for the first calving is unrecorded.

Classification by Days Calved at the Planned Start of Mating

Although the number of days from calving to PSM is continuous and may approximate a normal distribution, a classification variable was chosen to correspond with the information available in DairyMAN herd analyses. DairyMAN reports the stock profile at the PSM using five categories for days calved as shown in Table 50.

Breeding Index

The genetic worth of New Zealand dairy cows was measured with several Breeding Indexes until June 1996 when the system was redesigned to account for additional breed and animal differences, including body weight. Production trait indexes for milkfat, protein and milk yield were based on ancestry and individual cow production performance. The "Total BI" combines the production indexes with an economic adjustment and includes some traits other than production. The index used in DairyMAN and in all analyses is the "Total BI" which is generally referred to simply as the "BI" within the dairy industry. The index can be validly compared across herds but cannot be directly compared across breed. For this reason an interaction effect between breed and BI was always investigated in the statistically models where either of these variables was statistically significant.

Milk Production

Milk production is measured as milk yield which is the volume in litres, milkfat in kilograms and protein in kilograms. Milkfat and protein are usually added together and this is called the "milksolids" (MS). It is not equivalent to total milk solids because other components and particularly lactose is not included. Most New Zealand dairy herds production test 4 times within each season. The first production test is approximately 2 months after the herd Planned Start of Calving (PSC) and subsequent tests are at two month intervals. The proportion of the herd that are production tested at each of these dates varies through the season. The first herd test often has fewer cows because some animals have not yet calved. The fourth test may also have reduced numbers or be cancelled completely depending on seasonal effects and the proportion of the herd still lactating. Some herds with extended average lactation lengths have a fifth herd test. The lactation production was measured in a similar way to that described above for the herd analyses. The lactation total production at the last herd test for each cow was divided by the number of days in milk to give an average daily production for milk yield and milksolids. Production at the second herd test was also included in some analyses as it always occurs during the mating period. Production at the first herd test was not considered because a significant proportion of late calving cows would be excluded due to missing values.

Calving Descriptor

Four calving types can be recorded. A normal (N) calving is any calving without a recorded abnormality. Calving Induction (C_I), abortion and premature calving descriptions can be recorded. Abortions and premature calvings were combined in these analyses C_AP). Also twinning (TWIN) could also be recorded as a separate event.

Health Events

Health events can be recorded in DairyMAN. Some events are predefined by the program but others can be defined by users of the program. A large number of different health events that corresponded to similar diseases were therefore recorded. Only diseases that were recorded by a number of herds could be included in the statistical models. It is recognised that this data is subject to missing data and must be viewed with caution. Lameness, calving induction and assisted calvings were the health events that were included in the analyses. As lameness in particular is one of these most common health problems in New Zealand herds is was considered worthwhile to include these health events in some specific models in order to determine the effect on mating performance. Also calving induction is widely practiced in New Zealand and because of its importance has been considered in detail in Chapter 6.

Table 50. Independent variables included in the analysis

Variable	Category	Description
REGION	1	Northland
	2	Waikato
	3	Bay of Plenty
	4	Taranaki
	5	Wellington, Manawatu and Hawkes Bay
	6	South Island
HERD		Unique herd identifier
BREEDCAT	1	Friesian Pedigree
	2	Friesian
	3	Cross
	4	Jersey
	5	Jersey Pedigree
LACCAT	1	Lactation 1
	2	Lactation 2
	3	Lactation 3
	4	Lactation 4
	5	Lactation 5 or greater
PSMCAT	1	Calved <20 days at PSM
	2	Calved 20-39 days at PSM
	3	Calved 40 to 59 days at PSM
	4	Calved 60 to 79 days at PSM
	5	Calved >79 days at PSM
BICAT	0	BI <125
	1	BI>124
BIINDEX	integer	Breeding Index
SEXC	0	Female Calf
	1	Male calf
C_I	0	Normal Calving
	1	Induced Calving
C_AP	0	Normal calving
	1	Abortion or premature calving
TWIN	0	Twin not recorded
	1	Twin calves
ASSIST	0	No assistance recorded
	1	Assisted calving
MS	kg	Average daily Milksolids for lactation
MS2 [a]	kg	Daily Milksolids at herd test during mating
HEAT [b]	0	No pre-mating heat recorded
	1	Pre-mating heat recorded
LAME [c]	0	No lameness recorded
	1	Lameness recorded in lactation
PD	0	Cow not pregnancy tested
	1	Cow pregnancy tested
PREG	0	Herd not pregnancy tested
	1	Herd pregnancy tested

[a] only available for herds using DairyMAN
[b] only for herds recording heats.
[c] only for herds recording lameness

Statistical Assumptions.

The following assumptions must be made for valid mixed linear models:

1. The response variable is continuous
2. The residual values have a normal distribution with a mean of zero
3. The variances in each group of the model are the same
4. Individual cases are independent
5. The relationship is linear

Similar assumptions apply for the logistic regression models except that the outcome variable is categorical and not continuous. The inclusion of herd as a random effect controlled for within herd associations. The mixed linear models do not require that the data be "balanced".

Examination of the distribution of the seasonal reproductive variables demonstrated that many were not normally distributed. This is particularly true of the number of days from the PSM (planned start of mating) to any cow event. The number of days from the planned start of calving to calving (PSC_CAL) and the number of days from calving to the planned start of mating (CAL_PSM) did approximate a normal distribution, but the Kolmogorov-Smirnov test statistic and the Lilliefors probabilities were both significant (see Figure 6 on page 59). The data for PSC_CAL is therefore not normally distributed (and therefore CAL_PSM). Although the PSC_CAL is not normally distributed the statistical analyses are robust and this variable was retained as an outcome variable for the analyses of individual animal performance.

The CAL_PSM (Figure 25) and PSM_SER (see Figure 7 on page 60) were severely skewed and not distributed normally by visual inspection. They were not included in the multivariate analyses of individual cow performance. Categorical outcome variables consistent with those used in DairyMAN and the New Zealand Dairy Industry were used in these case. These include SUB21, NR1st 28, CONC_1st, INCALF4, INCALF8 and EMPTY which all have a binary outcome (Table 50).

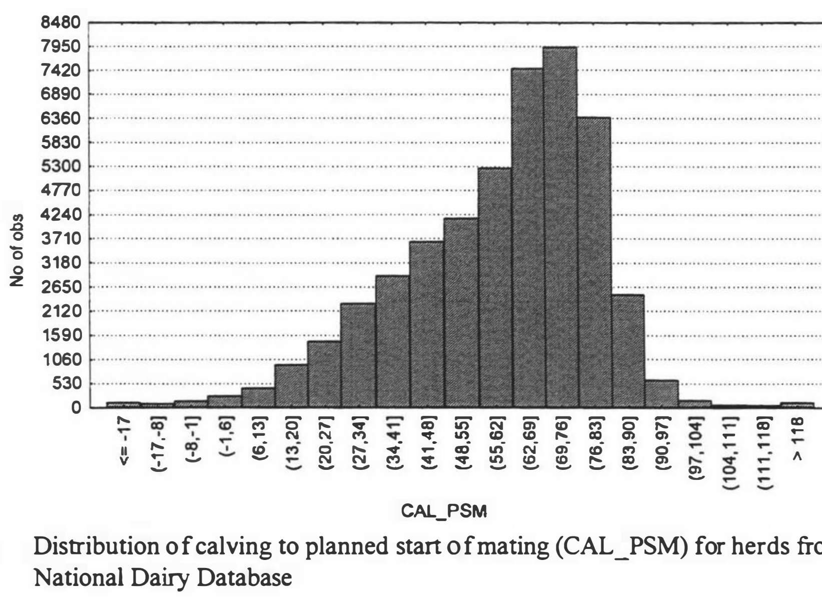

Figure 25. Distribution of calving to planned start of mating (CAL_PSM) for herds from the National Dairy Database

Results: Statistical Models of Individual Reproductive Performance

All dependent variables in these models were categorical except for the PSC_CAL which was used as one measure of calving performance.

Calving Performance

Variables Offered to each Model

The region (REGION), breed (BREED, lactation number (LACCAT), breeding index (BICAT), induction (C_I), abortion (C_AP), sex of calf (SEX1) and twinning (TWIN) where investigated in separate analyses and a final mixed linear model was developed for the dependent variable PSC_CAL as described previously.

For the binary outcome variables CAL4 and CAL8 a similar model was used. In these models a logit link function and binomial distribution were used within the Glimmix procedure.

Tests of Hypotheses

Planned Start of Calving to Calving (PSC_CAL)

The structure of the final mixed linear model for the outcome PSC_CAL was of the form;

$$Y_{ijklmnopq} = \mu + H_i + R_j + B_k + L_l + G_m + I_n + A_o + S_p + T_q + I_n{*}S_p + L_l{*}I_n + L_l{*}G_m + e_{ijklmnopq}$$

where;

μ	sample mean
$Y_{ijklmnopq:}$	performance of the ijklmnopq th cow
H_i	random effect of the i^{th} herd
R_j	fixed effect of the j^{th} Region
B_k	fixed effect of the k^{th} Breed
L_l	fixed effect of the l^{th} Lactation category
G_m	fixed effect of the m^{th} Breeding Index category
I_n	fixed effect of the n^{th} Induction category
A_o	fixed effect of the o^{th} Abortion category
S_p	fixed effect of the p^{th} Calf sex category
T_q	fixed effect of the q^{th} Twinning Category
$I_n{*}S_p$	fixed interaction effect of the nth Induction and Pth Calf sex category
$L_l{*}I_n$	fixed interaction effect of the ith Lactation and nth Induction category
$L_l{*}Gm$	fixed interaction effect of the ith Lactation and mth Breeding Index category

The independent class variables REGION ($F_{5,29863}$=7.7, P<0.001), LACCAT ($F_{4,29863}$=9.0, P<0.001), BICAT ($F_{1,29863}$=57.8, P<0.001), C_I ($F_{1,29863}$=1000, P<0.001), C_AP ($F_{1,29863}$=410, P<0.001), SEX1 ($F_{1,29863}$=13.5, P<0.001) and TWIN ($F_{1,29863}$=20.1, P<0.001) were all significant main effects for PSC to CAL. There was a significant interaction between C_I and SEX1 ($F_{1,29863}$=7.3, P<0.001), C_I and LACCAT ($F_{4,29863}$=27, P<0.001) and BICAT and

LACCAT ($F_{4,29863}$=7.3, P<0.001). The BREED was not significant as a main effect or as an interaction effect.

Four Week Calving (CAL4)

The REGION ($F_{5,29876}$=7.2, P<0.001), BREED ($F_{4,29876}$=3.7, P=0.01), LACCAT ($F_{4,29876}$=4.8, P<0.001), C_I ($F_{1,29876}$=281.7, P<0.001), C_AP ($F_{1,29876}$=28.4, P<0.001), and SEX1($F_{1,29876}$=13.5, P<0.001), were significant main effects. There was a significant interaction between LACCAT and C_I ($F_{4,29876}$=8.8, P<0.001), and SEX1 and C_I ($F_{1,29876}$=5.6, P=0.02).

Eight Week Calving (CAL8)

The REGION ($F_{5,29881}$=3.9, P=0.002), LACCAT ($F_{4,29881}$=12.6, P<0.001), C_I ($F_{4,29881}$= 325, P<0.001), and SEX1 ($F_{4,29881}$=23.5, P<0.001), and the interaction between LACCAT and C_I ($F_{4,29881}$=12.8, P<0.0001) were statistically significant main effects. BREED and C_AP were not significant and were removed from the model.

Specific Effects of Each Classification Variable

Region

The four and eight week calving rates (CAL4 and CAL8) for Northland were significantly lower than for all other regions except the Bay of Plenty where there was no significant difference (Table 51). The least square mean PSC_CAL for Northland was also significantly different from all other regions. The PSC_CAL for Northland ranged from 11.2± 3.5 (Bay of Plenty) to 8.1 ±2.0 days (South Island) longer than other regions. There was no difference in PSC_CAL, CAL4 and CAL8 for the other regions.

Table 51. Estimated probability of CAL4 and CAL8 (Mu) and the least square mean PSC_CAL for cows in herds using DairyMAN (Total number of herds included: 142)[a]

	CAL4			CAL8			PSC_ CAL	
Region	Mu	Lower	Upper	Mu	Lower	Upper	LSM	S.E.
Northland	0.62	0.48	0.76	0.83	0.12	1.54	21.5	1.8
Waikato	0.81	0.72	0.90	0.96	0.02	1.90	11.4	1.1
Bay of Plenty	0.83	0.68	0.98	0.97	0.10	1.84	10.3	3.2
Taranaki	0.82	0.73	0.91	0.96	0.02	1.90	11.0	1.4
Wellington	0.78	0.67	0.89	0.94	0.04	1.84	12.4	1.5
South Island	0.75	0.64	0.86	0.95	0.04	1.86	13.4	1.5

a Mu = 1 / (1-exp(β_x) where β_x is the coefficient estimate for independent variable x. This is the estimated probability of a positive outcome for the class variable. The lower and upper give the 95 percent confidence range.

Breed

The BREED was not a significant main effect for PSC_CAL and CAL8, but was significant for CAL4. The estimated probability of CAL4 for Friesians was 0.75 which was statistically significantly lower than 0.77 for cross-breeds (P=0.006) and 0.79 for Jerseys (P=0.001). There was no statistically significant difference in the CAL4 between Cross-breeds and Jerseys (P=0.06) (Table 52)

Table 52. Estimated probability of CAL4 (Mu) for each breed class in herds using DairyMAN (Total number of herds included 142)

Breed Classes	Mu	Lower	Upper
Friesian Pedigree	0.79	0.68	0.90
Friesian	0.75	0.65	0.85
Cross-breed	0.77	0.67	0.87
Jersey	0.79	0.69	0.89
Jersey Pedigree	0.77	0.66	0.88

Mu = 1 / (1+ exp(-β_x) where β_x is the coefficient estimate for independent variable x. This is the estimated probability of a positive outcome for the class variable. The lower and upper give the 95 percent confidence range.

Lactation Number

The LACCAT was a statistically significant main effect in all three models. Lactation one non-induced cows had a significantly lower PSC_CAL and therefore earlier calving date than all other lactation categories (P<0.001). There were also significant differences in the PSC_CAL for mature non-induced cows with the trend being generally that as lactation number increased the PSC_CAL decreased (Table 53). The significant interaction between LACCAT and C_I indicated different effects of lactation number depending on the induction status. The induced lactation one animals had a very late calving date compared with all other lactation groups(P<0.0001). For the Induced class there was no significant difference for PSC_CAL between other lactation classes (P<0.05).

The LACCAT had a similar effect for non induced cows on the estimated probability of CAL4. The lactation one (LACCAT1) cows had a statistically superior CAL4 compared with all other lactation classes for non induced cows (P<0.001). There was a similar trend toward an improved calving rate for all animals greater than LACCAT 1. The model estimate for each non-induced lactation class for the outcome CAL8 only differed significantly between LACCAT 1 and LACCAT 5 (P<0.01).

For induced cows the CAL4, CAL8 was significantly lower for LACCAT 1 (P<0.01) when compared with all other lactation classes and is consistent with the finding for PSC_CAL. No other comparisons of LACCAT within the Induced class were statistically significant (P>0.05).

Table 53. The least square mean planned start of calving to calving (PSC_CAL) for induced and non-induced cows in each lacation category*

LACCAT	Non Induced		LACCAT	Induced	
	mean	S.E.		mean	S.E.
1	0.77	1.09	1	35.06	2.34
2[a]	6.59	1.08	2[c]	18.07	1.25
3[a]	6.21	1.09	3[c]	19.90	1.34
4[b]	5.31	1.09	4[c]	18.06	1.42
5[b]	4.86	1.07	5[c]	18.49	1.26

* lactation classes sharing the same superscript are not significantly different.

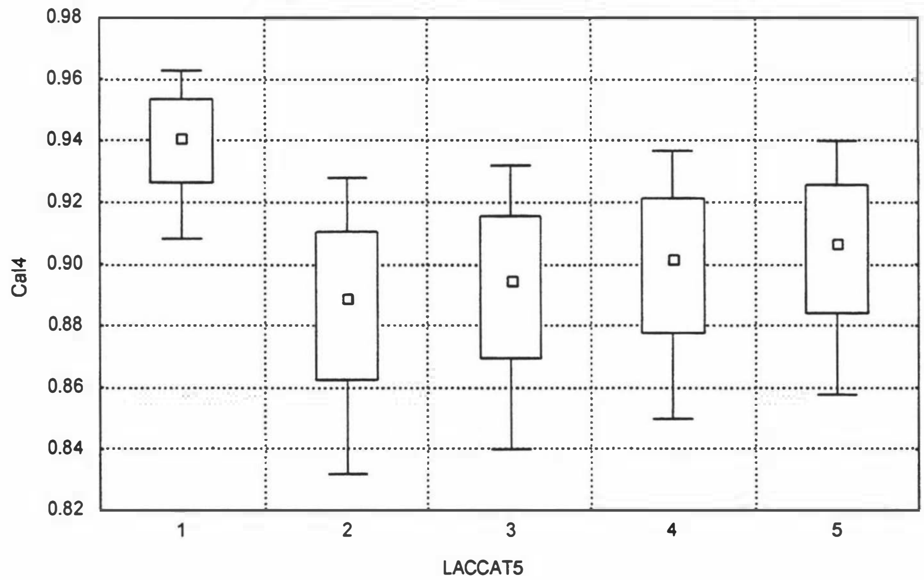

Figure 26. Model estimates for the chance of calving before the end of the fourth week after the planned start of calving (CAL4) for non-induced cows in each lactation number category. LACCAT 2 and 3, 3 and 4 and 4 and 5 were not significantly different. All other effects were statistically significant. (The estimated probabilities are the linear logistic model transformed parameter estimate. The boxes represent the linear logistic transformed standard error of the estimate and the whiskers the linear logistic transformed 95 percent confidence interval.)

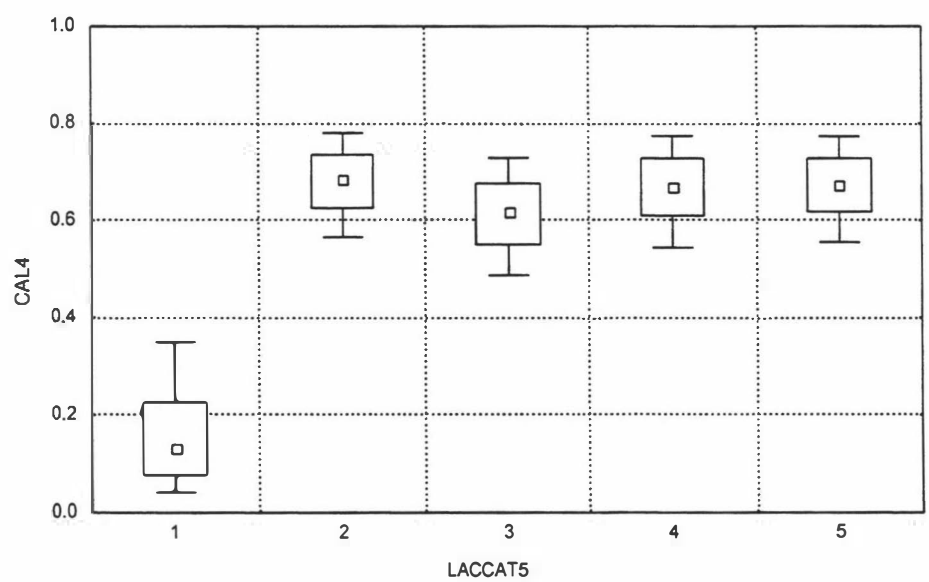

Figure 27. Model estimates for the chance of calving before the end of the fourth week after the planned start of calving (CAL4) for induced cows in each lactation number category. LACCAT 1 was statistically significantly different from all other lactation categories. No other comparsions were statistically significant for the induced cows. (Linear logistic model transformed parameter estimate. The boxes represent the linear logistic transformed standard error of the estimate and the whiskers the linear logistic transformed 95 percent confidence interval.)

The Calf Sex and Twinning

The sex of the calf (SEX1) had a significant effect on PSC_CAL. For a heifer calf the median PSC_CAL was 12.6 ± 2.2 days which was 1.4 ± 0.8 less days than for a bull calf (P<0.01). Where twins were recorded the least square mean PSC_CAL was 4.4 ± 1.9 days less than for a single birth (P<0.01). Consistent main effects were obtained for CAL4 and CAL8 for SEX1. The estimated probability of calving before the end of the fourth week after the PSM 0.92 (0.88-0.96) for a female calf and 0.90(0.85-0.95) for a male calf. The difference was statistically significant (P<0.01). TWIN was not statistically significant for CAL8 or CAL4 (P>0.05).

Inductions and Abortions

The Induced cows had a significantly later estimated date for calving for all LACCAT classes. The main effect, least square mean difference between the C_I classes was 17.26 ± 1.1 days (P<.0001). The main effect estimated Mu for CAL4 for non-induced cows was 0.91 (0.86-0.94) and for Induced cows was 0.54 (0.41-0.67) which was statistically significantly different. The CAL8 were also significantly lower for induced cows. For non-induced cows the CAL8 was 0.97 (0.97-0.98) and for induced cows was 0.88 (0.84-0.91). Abortions and premature calvings (C_AP) were as expected, significantly earlier with a least square mean difference of 26.2 ± 1.9 days (P>.01) and a statistically significantly lower CAL4 (P<0.0001). There was no significant effect of C_AP on CAL8.

Breeding Index

Cows with a high BI (BICAT=1) had a PSC_CAL of 12.4 ± 2.2 days which was significantly higher than for low BI cows of 14.2 ± 2.2 days(P<0.0001). The effect of BICAT on PSC_CAL was statistically significant (P<.001) for all LACCAT classes except lactation 3. The dependent variable, CAL4 and CAL8 were not modified by the BICAT and BICAT was removed as a main effect from these models.

Submission Rates

Variables Offered to Model I

The independent class variables REGION, BREED, LACCAT, BICAT, PSM_CAT, C_I, C_AP, SEX1 and TWIN and the continuous variable MS2 were investigated in separate analyses. A final model included all significant main and interaction effects.

Tests of Hypotheses

The BREED ($F_{4,28324}$=9.1, P<0.001), LACCAT ($F_{4,28324}$=9.7, P<0.001), PSMCAT ($F_{4,28324}$=11.8 P<0.001) and MS2 ($F_{1,28324}$=18.3, P<0.001) were significant main effects. There was a significant interaction between MS2 and PSMCAT ($F_{4,28324}$=4.7, P=0.008) and between MS2 and LACCAT ($F_{4,28324}$=3.6, P=0.006). The REGION, BICAT, C_I, C_AP and SEX1 were not significant as main effects nor as interaction effects.

Specific Effects of Each Classification Variable

Region

Region was not significant as a main effect and was removed from the final models.

Breed

For the specific comparison of each breed class (Figure 28), Jersey cows had superior mating performance compared with cross-breeds (P<0.01) and Friesians (P<0.0001). Cross-breeds had intermediate performance that was significantly different from both Jersey and Friesian cows (P=0.0001). Pedigree Jerseys had statistically significantly lower performance compared with Jersey (P=0.008) and Cross-breeds (P=0.03) but, was not significantly different from Friesians (P=0.4). Friesian Pedigree cows had inferior performance to Jersey cows (P=0.02), but were not detectably different from other breed classes (P>0.1). The number of cases of Pedigree cows was proportionally much less than for the main breed classes, so the models estimates have a much greater standard error and the possibility of type II errors must be considered.

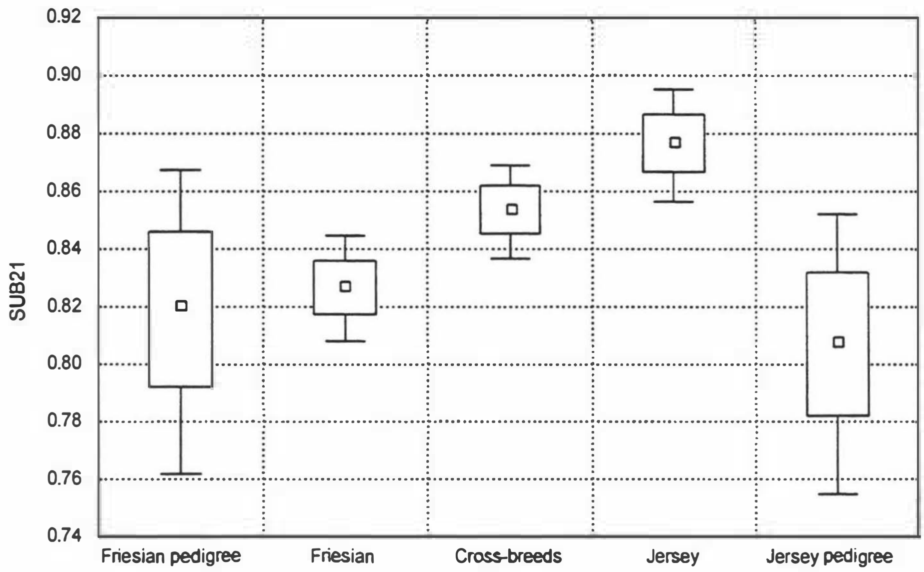

Figure 28. Model estimates for the chance of submission by day 21 for each breed category. Friesian, Cross-breeds and Jerseys all had significantly different performance (P<0.01). Both Friesian pedigree and Jersey pedigree had inferior performance compared with Jerseys (P<0.02). The performance of the Jersey pedigree class was also significantly lower than for cross-breeds (P<0.03). (Linear logistic model transformed parameter estimate. The boxes represent the linear logistic transformed standard error of the estimate and the whiskers, the linear logistic transformed 95 percent confidence interval.)

Lactation Number

The submission rates for LACCAT 1 cows was statistically significantly lower than that for all other lactation classes (P<0.01). The LACCAT 2 submissions were also lower than for LACCAT 3 (P<0.0002) and LACCAT 5 (P<0.05), but not significantly different from LACCAT4 (P=0.06). The LACCAT 3 and LACCAT 4 were not significantly different (P=0.2), but both had superior performance compared with old cows in the LACCAT class (P<0.0001). The overall trends are graphically represented in Figure 29. There was also a statistically significant interaction between MS2 and LACCAT. The effect of MS2 was greatest for LACCAT 1 animals, tended to reduce for LACCAT2 and 3 and then increased slightly for LACCAT4 and 5 (Table 54).

As the statistical model included the effects of days calved (PSMCAT) the effects of lactation number (LACCAT) in this model are distinct from the indirect effects that lactation number has on the calving patterns as described above.

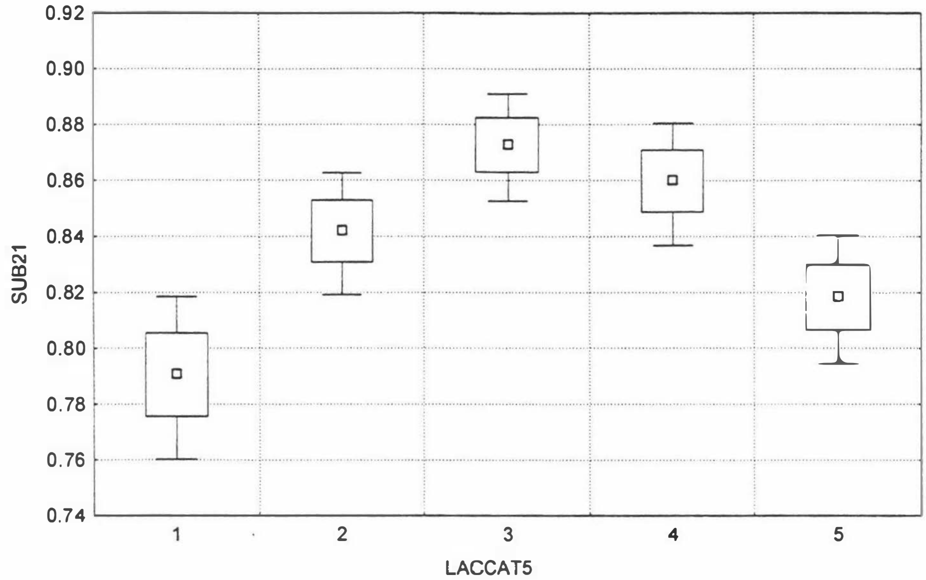

Figure 29. Model estimates for the chance of submission by day 21 for each lactation category. (Linear logistic model transformed parameter estimate. The boxes represent the linear logistic transformed standard error of the estimate and the whiskers the linear logistic transformed 95 percent confidence interval.)

Days Calved at the Planned Start of Mating

The effect that days calved at the PSM (PSMCAT) has on subsequent mating performance is graphically depicted in Figure 30. The probability of submission increases as the PSMCAT increases. All post hoc comparisons are statistically significant ($P<0.001$) except that between PSMCAT4 and PSMCAT 5 ($P=0.06$).

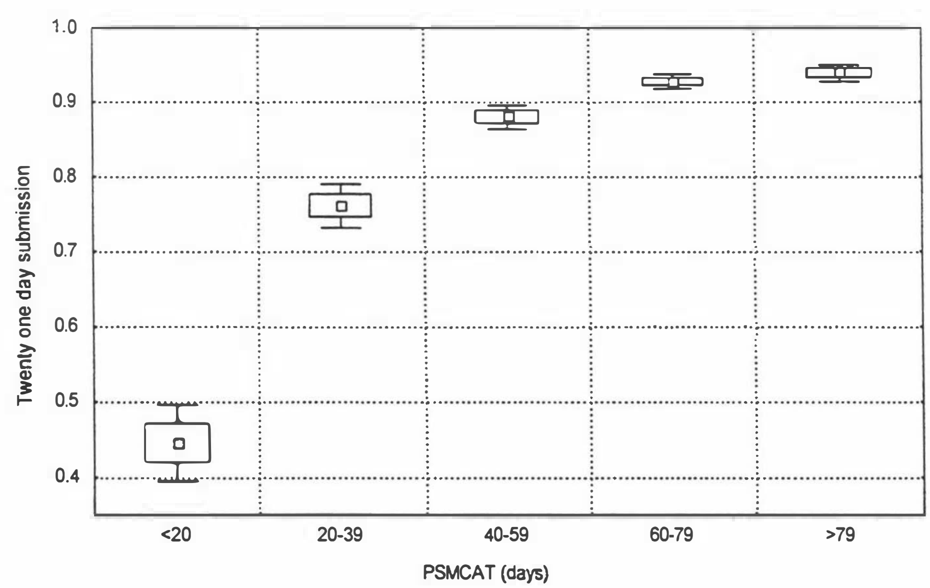

Figure 30. Model estimates for the chance of submission by day 21 for each category of days calved at the PSM (PSMCAT). (Linear logistic model transformed parameter estimate. The boxes represent the linear logistic transformed standard error of the estimate and the whiskers the linear logistic transformed 95 percent confidence interval.)

Milk Yield

Milk yield was significant as a main effect with an increased probability of submission in the first 21 days after the start of mating (SUB21) with increasing yield, but this was modified by LACCAT and PSMCAT. This interaction effect may be due to the variation in days calved at the herd production test (Table 54). Milk yield for individual cows varies with the number of days calved and follows a lactation curve that typically shows increasing milk production until a post calving peak followed by a gradual reduction as lactation advances. The herd production test date is fixed for all cows within a herd, so the milk yield values recorded for each cow are likely to be dependent in part on the number of days calved. It is therefore not unexpected that there is a statistically significant interaction between milk yield and PSMCAT (Table 54).

Table 54. Model coefficient estimates for Milksolids and the significant interaction effects. N=28324. The T test compares the estimate with the model estimate for the final group within each class [a]

	Estimate	SE	N	t	P [b]
INTERCEPT	1.5327	0.3286	125	4.66	0.0001
BREEDCAT 1	0.0825	0.2331	28323	0.35	0.7234
BREEDCAT 2	0.1267	0.1575	28323	0.8	0.421
BREEDCAT 3	0.3249	0.1547	28323	2.1	0.0357
BREEDCAT 4	0.5277	0.1581	28323	3.34	0.0008
BREEDCAT 5	0	.	.	.	.
PSMCAT 1	-2.1297	0.3719	28323	-5.73	0.0001
PSMCAT 2	-1.0108	0.3106	28323	-3.25	0.0011
PSMCAT 3	-0.3396	0.2867	28323	-1.18	0.2363
PSMCAT 4	-0.3321	0.2751	28323	-1.21	0.2274
PSMCAT 5	0	.	.	.	.
LACCAT5 1	-0.743	0.2321	28323	-3.2	0.0014
LACCAT5 2	0.3522	0.2617	28323	1.35	0.1785
LACCAT5 3	0.9824	0.2965	28323	3.31	0.0009
LACCAT5 4	0.266	0.3118	28323	0.85	0.3936
LACCAT5 5	0	.	.	.	.
MS2	0.5521	0.1985	28323	2.78	0.0054
MS2*PSMCAT 1	-0.5417	0.2422	28323	-2.24	0.0253
MS2*PSMCAT 2	-0.3697	0.211	28323	-1.75	0.0798
MS2*PSMCAT 3	-0.2641	0.2001	28323	-1.32	0.1868
MS2*PSMCAT 4	0.0983	0.1959	28323	0.5	0.6159
MS2*PSMCAT 5	0	.	.	.	.
MS2*LACCAT5 1	0.364	0.1619	28323	2.25	0.0246
MS2*LACCAT5 2	-0.1187	0.1637	28323	-0.73	0.4682
MS2*LACCAT5 3	-0.3605	0.1751	28323	-2.06	0.0396
MS2*LACCAT5 4	0.028	0.182	28323	0.15	0.8778
MS2*LACCAT5 5	0	.	.	.	.

a The dependent variables have been described in a glossary of terms on page 131. The T statistic and the P value test the statistical difference of the class to the last class within a particular category.

b The test of statistical significance compares the estimate with the last class within the particular category which has an estimate of zero. The statistical significance of specific comparisons are not shown in the solution to the statistical model.

Variables Offered to Model II

A second model of submission rates considered only a subset of herds that recorded pre-mating heats and some health events including lameness. The BREED LACCAT PSMCAT MS2 variables that were statistically significant in the first model and LAME, ASSISST, HEAT were offered to the model.

Tests of Hypotheses

The LACCAT ($F_{4,6921}$=11.8, P<0.001), PSMCAT ($F_{4,6921}$=31.6 P<0.001) HEAT ($F_{1,6921}$=377, P<0.001) and ASSIST ($F_{1,6921}$=4.8, P=0.03) were significant main effects. There were no significant interaction effects.

Specific Effects of Each Classification Variable

Cows with a pre-mating heat recorded had dramatically increased submission rates. The model estimate for twenty one day submission for cows with a pre-mating heat was 0.899 (0.870-0.922) compared with only 0.622 (0.560-0.680) for cows without a recorded pre-mating heat. Cows with an assisted calving also had inferior submission rates with an estimate of 0.763 (0.690-0.823) compared with unassisted cows of 0.820 (0.786-0.849). The effects of LACCAT and PSMCAT were similar to those occurring in the previous model. LAME was not a statistically significant determinant of twenty-one day submission rates.

Conception Rates

The conception performance was first evaluated for 47 herds that pregnancy tested most cows. Two analyses were considered. The first included the major independent factors that could modify conception and were recorded in all herds. The second analysis examined a subset of 14 of these herds that recorded some additional records including health events and pre-mating heats.

Variables Offered to Model I and Model II for Conception to First Service

The REGION, BREED, LACCAT BICAT, PSMCAT, SUB21 and C_I were evaluated in separate models for inclusion in the final Model I. A second analysis (Model II) considered a subset that also recorded pre-mating heats (HEAT), lameness (LAME) and assisted calvings (ASSIST).

Tests of Hypotheses Model I The LACCAT ($F_{4,11477}$=4.6, P<0.001), PSMCAT ($F_{4,11477}$=31.8, P<0.001), C_I ($F_{4,11476}$=10.9, P<0.001) and the interaction LACCAT*PSMCAT ($F_{16,11477}$=1.7, P=0.04) and LACCAT*C_I ($F_{4,11477}$=3.0, P=0.02) were significant fixed effects. The REGION, BREED and BICAT were not statistically significant effects and were removed from the model.

Specific Effects of Each Classification Variable

Lactation Number

The pre-planned comparisons of lactation number (Figure 31) showed that the LACCAT1 cows had inferior estimates for conception compared to LACCAT2 (P=0.001) and LACCAT3 (P=(0.007), but were not statistically significantly different from cows of greater lactation number (P>0.1). The LACCAT2 class also had superior estimates for conception compared with LACCAT4 (P=0.04) and LACCAT5 (P=(0.001). The LACCAT2 and LACCAT3 (P=0.5) and LACCAT3 and LACCAT4 (P=0.2) did not differ significantly, but the estimated performance of LACCAT3 was superior to that for LACCAT5 (P=0.03).

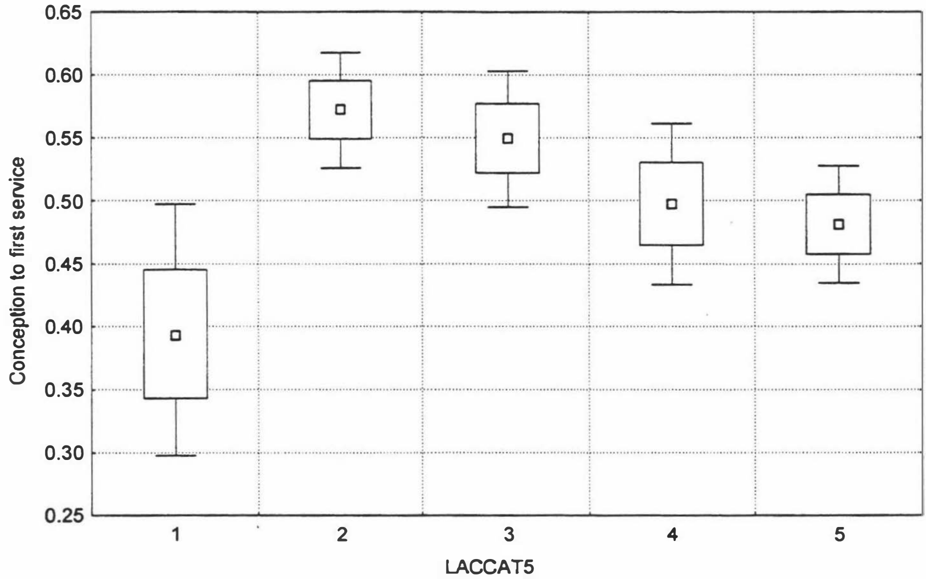

Figure 31. Model estimates for the chance of conception for each lactation category (LACCAT). (Linear logistic model transformed parameter estimate. The boxes represent the linear logistic transformed standard error of the estimate and the whiskers the linear logistic transformed 95 percent confidence interval.)

Days Calved at the Planned Start of Mating

The estimated probability of conception increased with each PSMCAT(Figure 32). The PSMCAT 1 class had a statistically significantly lower estimate compared with all other classes (P<0.0001) except PSMCAT2 (P=0.09). All other comparisons within the PSMCAT were statistically significant (P,0.01) except between PSMCAT4 and PSMCAT5 (P=0.2)

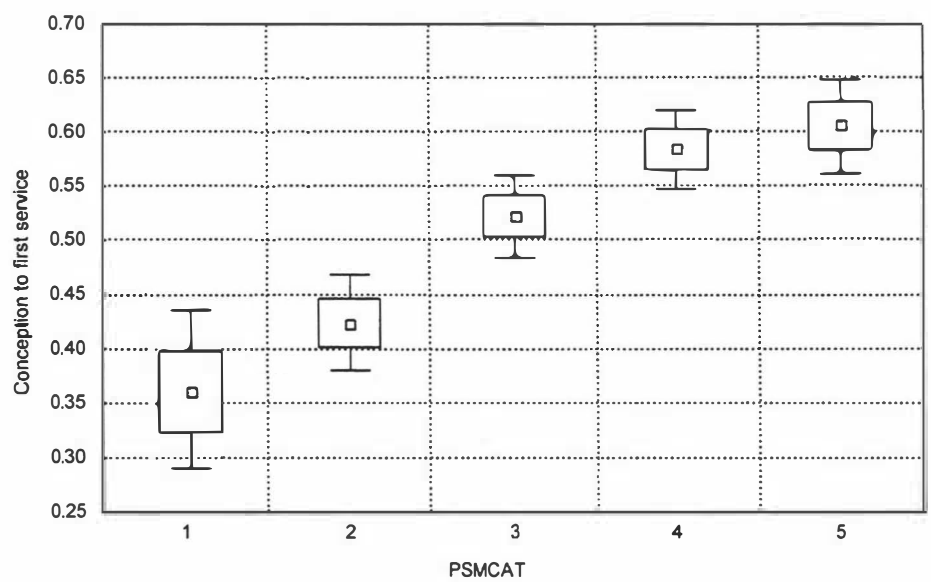

Figure 32. Model estimates for the chance of conception to first service (CONC_FIR) for each category of days calved at the PSM (PSMCAT). (Linear logistic model transformed parameter estimates. The boxes represent the linear logistic transformed standard error of the estimate and the whiskers the linear logistic transformed 95 percent confidence interval.)

Calving Induction

Calving Induction (C_I) had a statistically significant negative effect on the CONC_FIR. Induced cows were however not distributed uniformly within the calving group and were generally late calving cows. For this reason the specific effects of induction were considered in a separate analysis that matched the induced cow group within each herd to contemporaries calving at the same time as described above.

Tests of Hypotheses Model 2

This model considered some specific disease events and heat recording information that was available in a small group of herds. The REGION, BREED, LACCAT, BICAT, CAL_SER, C_I, HEAT, LAME, and ASSIST were evaluated in separate models. The power of this model was limited by the sample size and the categorical variable PSMCAT was not statistically significant in a separate model using this limited cow sample. The continuous variable CAL_SER was included as an alternative in this model as the intention was to consider specific health and disease status and the model was not to be used specifically within an expert system that required the use of specific variables from DairyMAN. CAL_SER is normally distributed and linearity can be assumed because the effects of the herd PSM date is removed. The LACCAT ($F_{4,4575}$=3.0, P=0.02), CAL_SER ($F_{1,4575}$=70.6, P<0.001), LAME ($F_{1,4575}$=4.0, P=0.05), C_I ($F_{1,4575}$=5.5, P=0.02), HEAT ($F_{1,4575}$=10.2, P=0.002), and ASSIST ($F_{1,4575}$=13.8, P<0.001), were statistically significant main effects. There were no interaction effects that were significant. The REGION, BREED and BICAT were not statistically significant.

Specific Effects of Each Classification Variable

Lactation Number Calving Induction

The effects of LACCAT and C_I were similar to those in the first model.

Calving to Service

Calving to service had a positive association with CONC_FIR. The parameter estimate was 0.015 ± 0.002 and was statistically significant within the final model (P<0.0001). The relationship is similar to that for PSMCAT in Model I.

Lameness

The estimated probability of conception was statistically significantly lower for lame cows than non-lame contemporaries (P=0.05). Cows with a recorded lameness during the lactation had an estimated conception chance at first service of 0.404 percent (0.335-0.478) compared with 0.465 percent (0.419-0.512) for non-lame cows.

Pre-mating Heats

Cows with at least one pre-mating heat had a statistically significantly higher estimated probability of conception to first service (P=0.002). The estimated probability of conception for cows without a pre-mating heat was 0.406 (0.342-0.472) compared with 0.464 (0.415-0.514) for those with a heat.

Assisted Calving

Cows that were recorded as having had an assisted calving (ASSIST) had statistically significantly lower estimated probabilities of conception (P=0.0002). The effect was considerable with the assisted cows having an estimated probability of conception of only 0.372 (0.302—0.449) compared with 0.499 (0.455-0.543) for unassisted cow.

Non-Return Rates

Variables Offered to the Model

The REGION, BREED, LACCAT, BICAT, PSMCAT, SUB21 MS2 and C_I were evaluated in separate analyses. A final model included all significant main and interaction effects.

Tests of Hypotheses

The BREED ($F_{4,24313}$=2.5, P=0.04), and PSMCAT ($F_{4,24313}$=62.1, P<0.001), were significant as main effects. The LACCAT was not significant as a main effect ($F_{4,24313}$=1.7, P=0.15), but was significant as an interaction with PSMCAT ($F_{16,24313}$=1.7, P=0.04). The REGION, BICAT, SUB21, MS2and C_I were not statistically significant in separate analyses and were excluded from the model.

Specific Effects of Each Classification Variable

The estimates for non-return (Figure 33) were statistically significantly lower than for Friesian (P=0.03) and cross-breeds (P=0.02). The estimates for the pedigree jerseys was also statistically significantly lower than for Friesian (P=0.03) and cross-breeds (P=0.02). No other comparisons between breeds were significantly different.

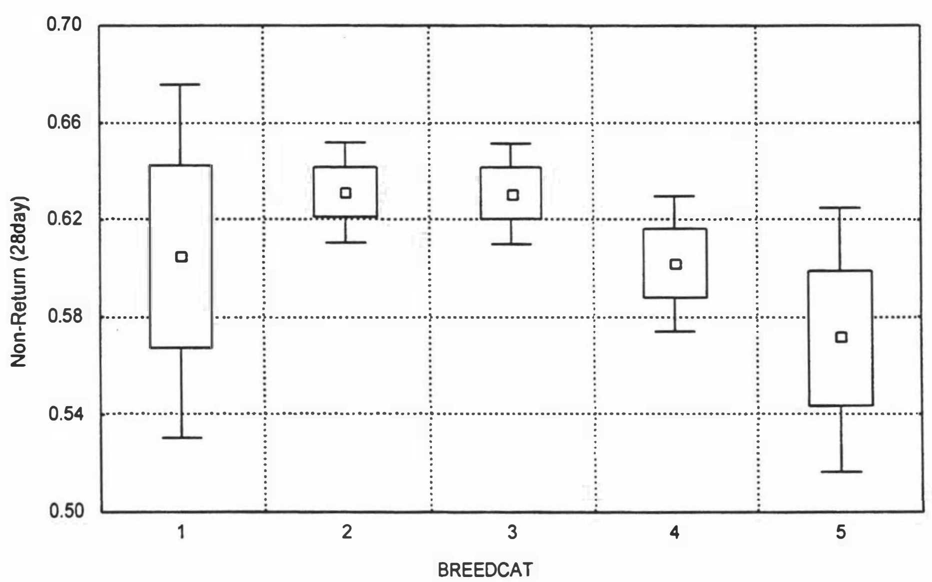

Figure 33. Model estimates for the chance of twenty-eight day non-return to first service for each breed class. Friesian and Cross-breeds were statistically significantly different from Jersey and Jersey pedigree(P<0.02). (Linear logistic model transformed parameter estimate. The boxes represent the linear logistic transformed standard error of the estimate and the whiskers the linear logistic transformed 95 percent confidence interval.)

In-Calf and Empty Status for Cows in Pregnancy Tested Herds

The purpose of these analyses was to identify an quantify the effects that primary animal factors such as breed and lactation number have on a cow's chance of becoming pregnant during the mating period. Therefore intermediate effects of SUB21 and the measures of conception were excluded in these models.

As previously discussed, the DairyMAN program determines in-calf status either from pregnancy testing records or by a specified non-return criteria. Herds that primarily use non-return as the method of estimating conception status and in-calf rates often pregnancy test a small proportion of cows. These animals represent a potentially biased group. In addition there are some animals within herds that intend to use whole herd pregnancy testing that are not examined. These have usually been culled before the planned veterinary visit. As the purpose of these statistical models is to quantify individual cow performance from DairyMAN data and to determine the expected performance of herds based on the individual animals performance and compare this with the DairyMAN reproductive monitor in an expert system, the investigation of in-calf rates for pregnancy tested and non-pregnancy tested herds were separated into individual models. All animals from herds that used whole herd pregnancy testing were included in one model and animals from the remaining herds in a separate model. This classification provided an estimate of the in-calf rates for herds that accounted for the levels of missed cows at pregnancy testing and estimates for the herds using non-return rates primarily, but accounting for some selective pregnancy testing.

Variables Offered to the Model

The REGION BREED, LACCAT BICAT PSMCAT MS2, and C_I were evaluated in separate analyses for both INCALF4 and INCALF8. A final model included all significant main and interaction effects.

Four Week In-Calf

Tests of Hypotheses

The REGION ($F_{4,11535}$=4.3, P=0.002), BREED ($F_{4,11535}$=2.8, P=0.03), PSMCAT ($F_{4,11535}$=88.8, P<0.001) C_I ($F_{1,11535}$=7.0, P=0.008) were statistically significant fixed effects. The LACCAT was not statistically significant as a main effect ($F_{4,11535}$=1.1, P=0.4) but was significant as an interaction with BREED ($F_{16,11535}$=1.7, P=0.04). The BICAT and MS2 were not statistically significant in a separate analysis and was removed from the model.

Specific Effects of Each Classification Variable

Although REGION was statistically significant as a main effect, specific differences between region were confined to the comparison with REGION 5 (Figure 34). The Region 5 had statistically significantly lower four week in-calf estimates compared with REGION 2 (P= 0.001) and Region 4 (P=0.002). There were no other comparisons of REGION that were statistically significant.

The specific comparison between each breed class showed that Friesians had statistically significantly lower chance of being in-calf by four weeks after the PSM than cross-breeds (P=.003). There was a tendency for the performance of Friesians to also be inferior to Jerseys but this was not statistically significant (P=0.08). Other comparisons within breed were not statistically significant.

As there was an interaction between breed and lactation number, the estimates for each lactation number were compared within breed. For the specific comparison of the different LACCAT classes for Friesians, the model estimates for LACCAT 1 (Figure 36) were statistically significantly different from all other lactations (P<0.0001). LACCAT 2 was significantly different from LACCAT 5 (P=0.004), but not from LACCAT 3 (P=0.8) or LACCAT4 (P=0.6). The LACCAT 3 was also significantly different from LACCAT 5 (P=0.003), but not from LACCAT 4 (P=0.5). The LACCAT 4 did not differ from LACCAT 5 (P=0.06).

For Cross-breeds (Figure 37) the LACCAT1 was only statistically significantly different from LACCAT3 (P=0.0002). The LACCAT3 was also different from LACCAT2 (P=0.002), and LACCAT5 (P=0.0001). Other comparisons were not statistically significant.

The Jersey breed showed a similar trend to the cross-breeds (Figure 38). The LACCAT3 was significantly different from LACCAT1 (P=0.04) and LACCAT5 (P=0.02). No other comparisons within this breed were statistically significant. As the number of cross-breeds and Jerseys was lower than for Friesians, the power to detect similar differences was reduced.

The results indicated that differences in the performance of specific lactations occurred between breeds. This is particularly evident for LACCAT2 where performance for Friesians was not different from the next two lactations and was superior to that for LACCAT1. In contrast the LACCAT2 for cross-breeds was not different to LACCAT1 but was inferior to LACCAT3.

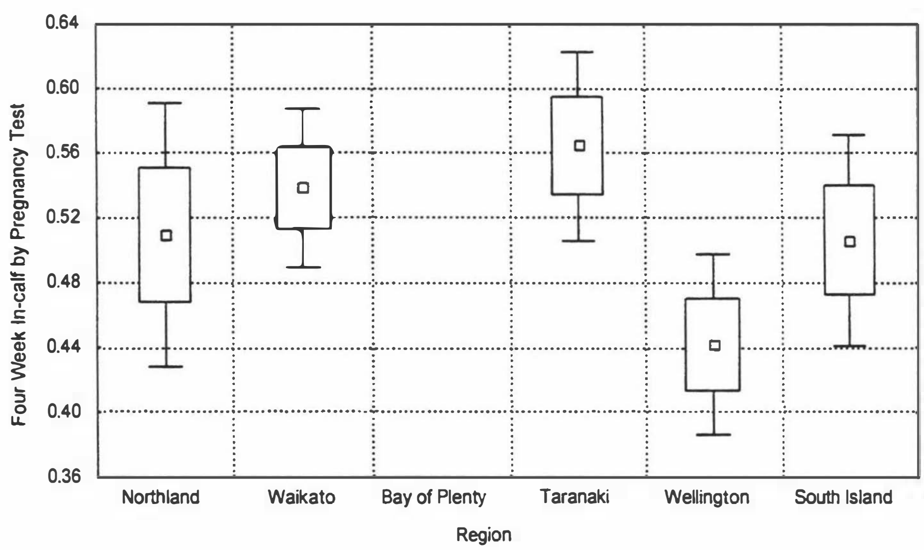

Figure 34. Model estimates for the chance of a cow being in-calf by four weeks after the herd planned start of mating for each region. The in-calf status was determined from pregnancy test status at the end of the mating period for those herds that used whole herd pregnancy testing. The In-calf estimates for the Wellington region were statistically significantly lower than for the Waikato (P=0.0001) and Taranaki Regions (P=.0002). There was insufficient data from the Bay of Plenty for estimates to be calculated. (Linear logistic model transformed parameter estimate. The boxes represent the linear logistic transformed standard error of the estimate and the whiskers the linear logistic transformed 95 percent confidence interval.)

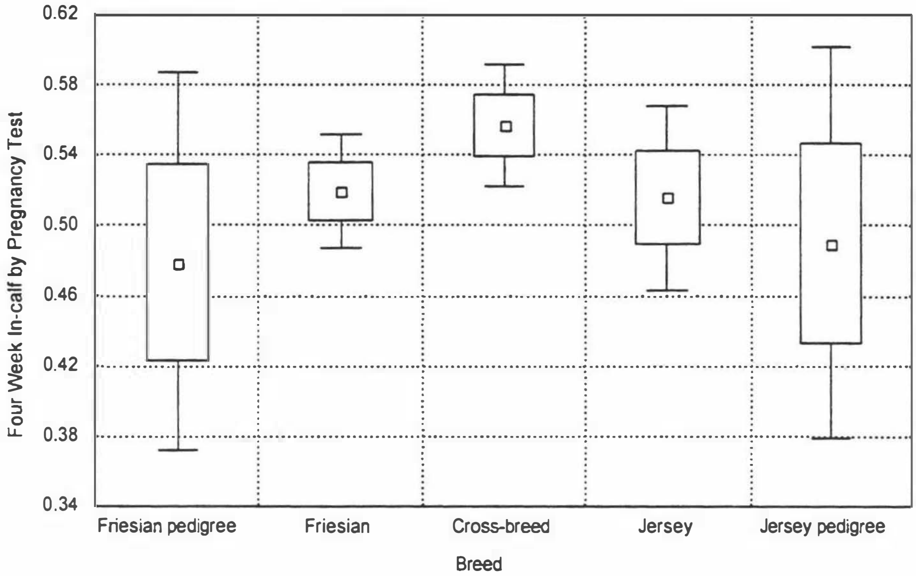

Figure 35. Estimates for the chance of a cow being in-calf by four weeks after the herd planned start of mating for each breed category. The In-calf status was determined from pregnancy test status at the end of the mating period for those herds that used whole herd pregnancy testing. The estimate for Friesian was statistically significantly lower than for Cross-breed. (P =0.05) (Linear logistic model transformed parameter estimate. The boxes represent the linear-logistic transformed standard error of the estimate and the whiskers the linear logistic transformed 95 percent confidence interval.)

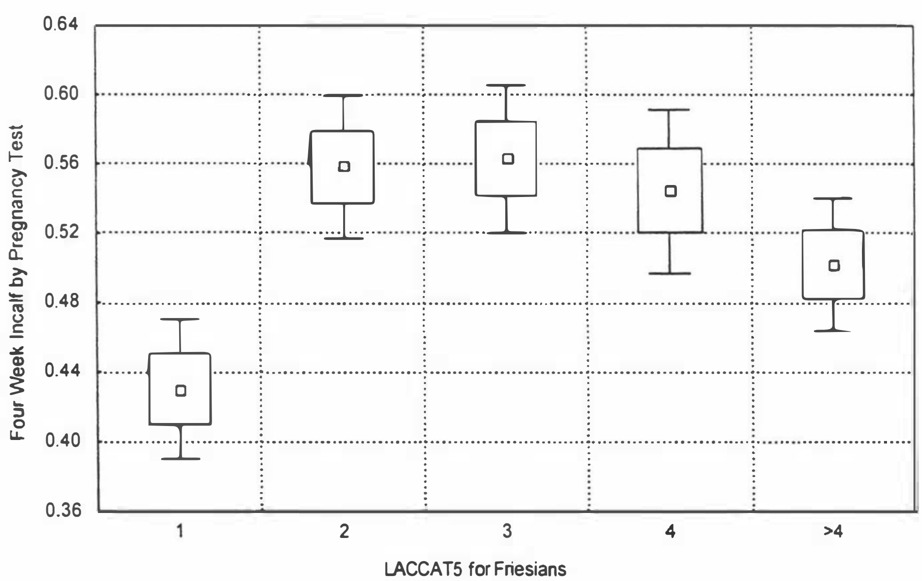

Figure 36. Model estimates for the chance of a Friesian cow being in-calf by four weeks after the herd planned start of mating for each lactation category. The In-calf status was determined from pregnancy test results at the end of the mating period for those herds that used whole herd pregnancy testing. (Linear logistic model transformed parameter estimate. The boxes represent the linear logistic transformed standard error of the estimate and the whiskers the linear logistic transformed 95 percent confidence interval.)

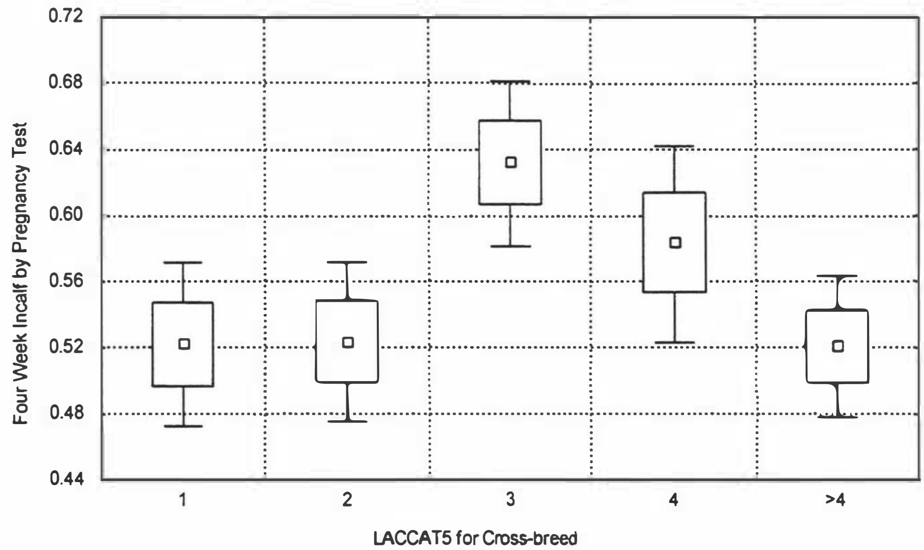

Figure 37. Model estimates for the chance of a Cross-breed cow being in-calf by four weeks after the herd planned start of mating for each lactation category. The In-calf status was determined from pregnancy test results at the end of the mating period for those herds that used whole herd pregnancy testing. (Linear logistic model transformed parameter estimate. The boxes represent the linear logistic transformed standard error of the estimate and the whiskers the linear logistic transformed 95 percent confidence interval.)

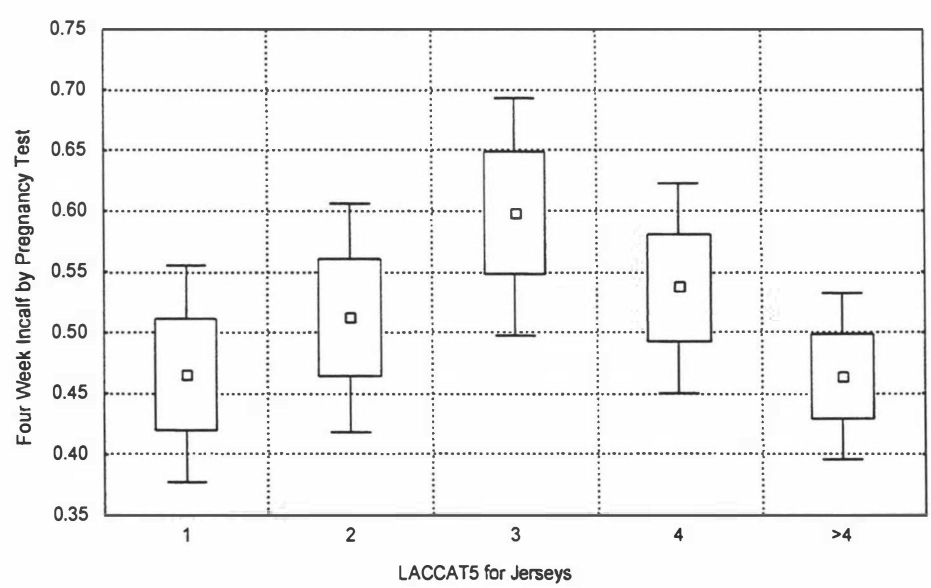

Figure 38. Model estimates for the chance of a Jersey cow being in-calf by four weeks after the herd planned start of mating for each lactation category. The in-calf status was determined from pregnancy test results at the end of the mating period for those herds that used whole herd pregnancy testing. (Linear logistic model transformed parameter estimate. The boxes represent the linear logistic transformed standard error of the estimate and the whiskers the linear logistic transformed 95 percent confidence interval.)

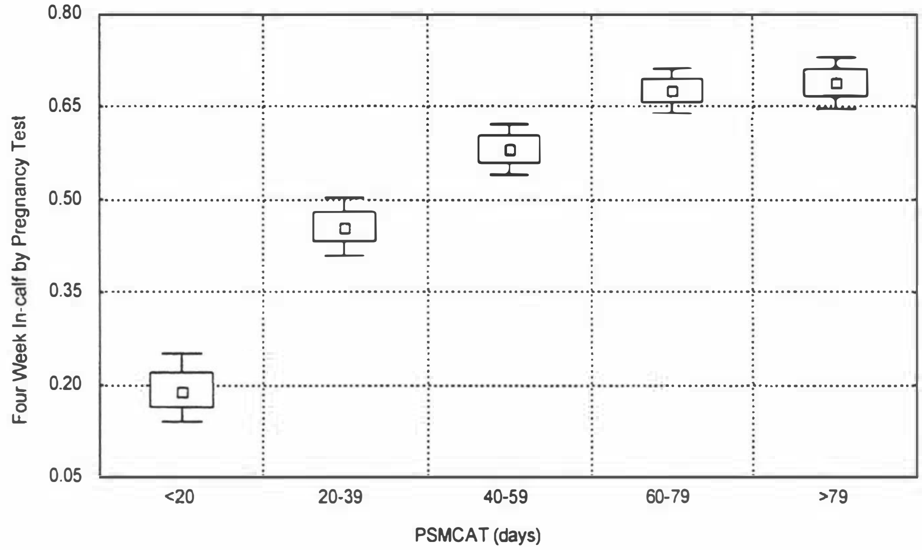

Figure 39. Model estimates for the chance of a cow being in-calf by four weeks after the herd planned start of mating for each category by days calved(PSMCAT). The in-calf status was determined from pregnancy test results at the end of the mating period for those herds that used whole herd pregnancy testing. (Linear logistic model transformed parameter estimate. The boxes represent the linear-logistic transformed standard error of the estimate and the whiskers the linear logistic transformed 95 percent confidence interval.)

Eight Week In-Calf

Tests of Hypotheses

The REGION ($F_{4,11601}$=3.4, P=0.009), LACCAT ($F_{4,11601}$=5.6, P<0.001) and PSMCAT ($F_{4,11601}$=49.9, P<0.001) were statistically significant fixed effects. The C_I was not statistically significant as a main effect ($F_{1,11601}$=2.9, P=0.09) but was significant as an interaction with LACCAT ($F_{4,11601}$=2.5, P=0.04). The BREED, BICAT and MS2 were not statistically significant in separate analyses and were not included in the final model.

Specific Effects of Each Classification Variable

Cows in the REGION5 had a statistically significantly lower chance of being in-calf by eight weeks after the start of mating (INCALF8) compared with REGION4 (Figure 40) and tended to be lower than for REGION2 (P=0.07). The REGION4 was statistically significantly superior to REGION2 (P=0.03) and REGION6 (P=0.02).

For the comparison of different lactation classes within the non-induced group the LACCAT1 had statistically significantly lower estimates for INCALF8 compared with LACCAT3 (P=0.0001) and LACCAT4 (p=0.0002). The LACCAT2 was also statistically significantly lower than for LACCAT3 (P=0.005) and LACCAT4 (P=0.02). The LACCAT3 and LACCAT4 had superior estimates compared with LACCAT5 (P<0.003).

The statistically trends within the PSMCAT for the outcome INCALF8 (Figure 42) are similar to INCALF4. The estimated probability of INCALF8 increases as PSMCAT increases. All comparisons except that between PSMCAT4 and PSMCAT5 were statistically significantly different((P<0.001).

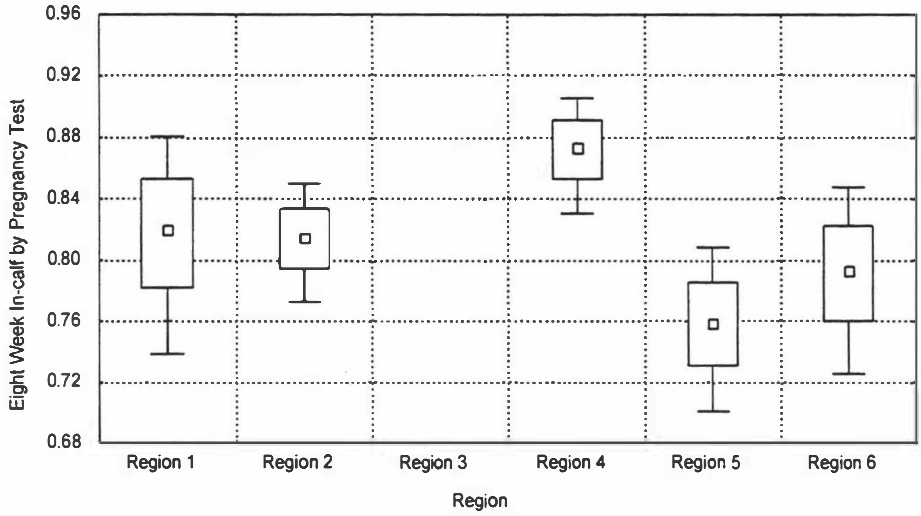

Figure 40. Model estimates for the chance of being in-calf by eight weeks after the herd planned start of mating for each region. The in-calf status was determined from pregnancy test status at the end of the mating period for those herds that used whole herd pregnancy testing. The in-calf estimates for the Wellington region were statistically significantly lower than for the Taranaki (P=.0002) but not for the Waikato (P=0.07). The Taranaki (REGION4) was significantly superior to the estimated performance for cows in the Waikato (REGION2) (P=0.03) and the South Island (REGION6) (P=0.02) There was insufficient data from the Bay of Plenty (REGION3) for estimates to be calculated. (Linear logistic model transformed parameter estimate. The boxes represent the linear logistic transformed standard error of the estimate and the whiskers the linear logistic transformed 95 percent confidence interval.)

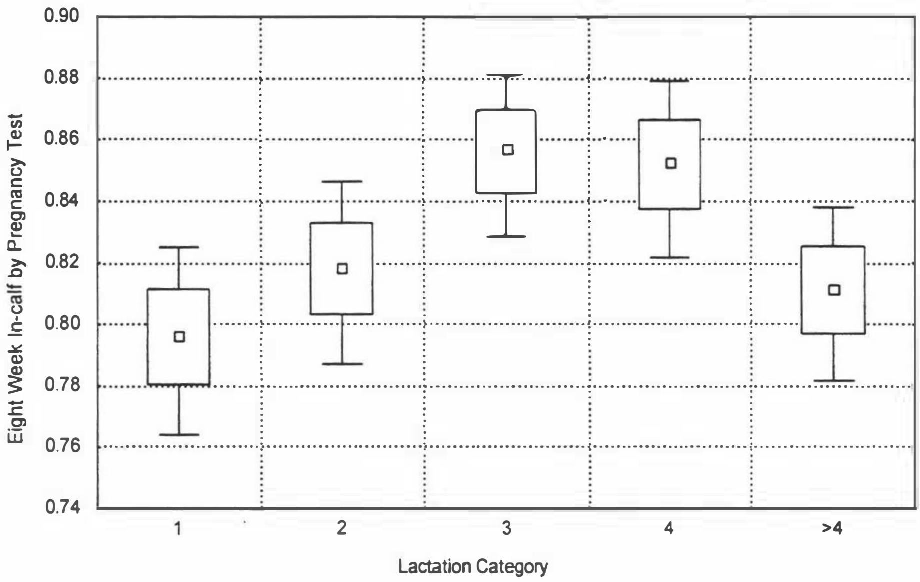

Figure 41. Model estimates for the chance of a cow being in-calf by eight weeks after the herd planned start of mating for each lactation class (LACCAT) for the non-induced cows. LACCAT3 and LACCAT4 were statistically significantly greater than for each of the other three lactation classes (P<0.02). The In-calf status was determined from pregnancy test results at the end of the mating period for those herds that used whole herd pregnancy testing (Linear logistic model transformed parameter estimate. The boxes represent the linear-logistic transformed standard error of the estimate and the whiskers the linear logistic transformed 95 percent confidence interval.)

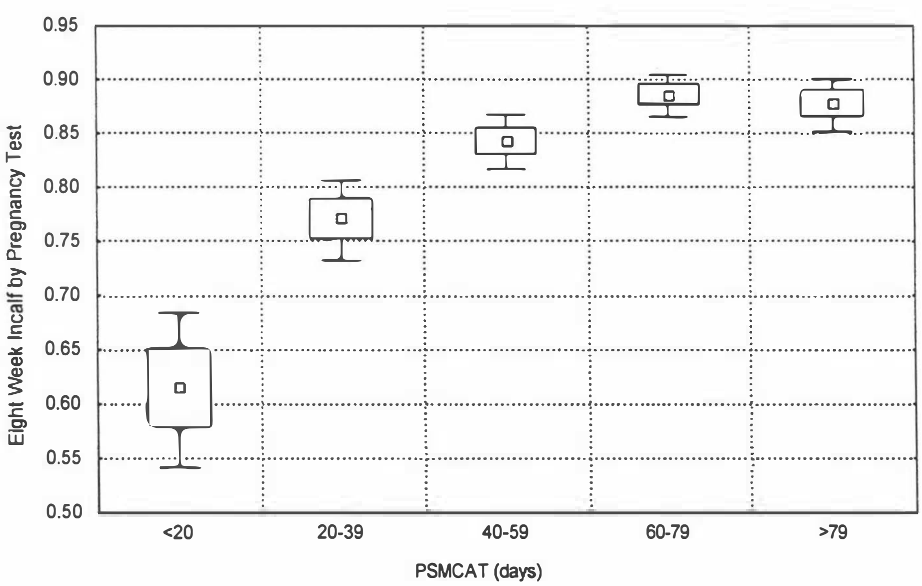

Figure 42. Model estimates for the chance of a cow being in-calf by eight weeks after the herd planned start of mating for each category by days calved (PSMCAT). All classes were statistically significantly different (P<0.003) except between 60-79 days (PSMCAT4) and >79 days (PSMCAT5). The In-calf status was determined from pregnancy test results at the end of the mating period for those herds that used whole herd pregnancy testing. (Linear logistic model transformed parameter estimate. The boxes represent the linear-logistic transformed standard error of the estimate and the whiskers the linear logistic transformed 95 percent confidence interval.)

In-calf Outcome for Cows in DairyMAN Pregnancy Test Herds with Submission and Conception as Independent Effects

To determine the impact of reduced submission rates or conception rates on the outcome of a mating period as measured by the in-calf rates the relationship between these variables must be known. The estimated probability of a cow being classified as in-calf within the first four or eight weeks after the planned start of mating and the probability of being classified empty at the end of mating are in part a mathematical consequence of submission (SUB21) and the measure of conception (CONC_FIR or NR_FIR). However other factors may affect the relationship and in particular the eight week in-calf rates will be modified by submission patterns and conception rates that are not directly measured by SUB21 and CON_FIR. Models including these intermediate variables for the outcome INCALF4, INCALF8 and EMPTY were evaluated.

Four Week In-Calf

Only the PSMCAT ($F_{4,11500}$=4.1, P=0.003), SUB21 ($F_{4,11500}$=292, P<0.001) and CONC_FIR ($F_{1,11500}$=385, P<0.001) were retained in the final model for INCALF4 for pregnancy tested herds. All other variables were not significant when included in the final model and were therefore excluded.

Specific Effects of Each Classification Variable

Not surprisingly the submission within 21 days of the planned start of mating (SUB21) has a critical effect on the estimated proportion of cows that are pregnant at the end of four weeks. The estimated probability of INCALF4 for a cow submitted in the first 21 days was 0.91 compared with 0.02 for cows not submitted in the first 21 days. The difference is statistically significant (P<0.0001). The estimated probability of INCALF4 for cows conceiving to the first service was 0.93 compared with 0.01 for cows that failed to conceive to a recorded first serve. Again the difference is statistically significant (P<0.0001). The PSMCAT remained a significant main effect in this model. The differences in classes within the PSMCAT were similar to the previous model for INCALF4 (Figure 39) with all comparisons except that between PSMCAT4 and PSMCAT5 being statistically significant (P<0.001).

Eight Week In-Calf

The LACCAT ($F_{4,11478}$=4.4, P=0.002), PSMCAT ($F_{4,11478}$=7.7, P<0.001), SUB21 ($F_{1,11478}$=326, P<0.001), and CONC_FIR ($F_{1,11478}$=1053, P<0.001), were statistically significant main effects for INCAL8. The interaction between LACCAT and PSMCAT ($F_{16,11478}$=1.8, P=0.03), LACCAT and SUB21 ($F_{4,11478}$=6.0, P<0.001), and LACCAT and CONC_FIR ($F_{4,11478}$=2.4, P=0.05), were also statistically significant. Other effects were not significant in separate analyses of were not significant when included in the final models and were therefore excluded.

Specific Effects of Each Classification Variable

Cows that were submitted in the first 21 days had an estimated probability of being in-calf by 8 weeks after the herd PSM of 0.95 compared with 0.81 for cows not submitted in the same period. The difference was statistically significant(P<0.0001). Cows conceiving to first service had an estimated probability of being in-calf at the end of 8 weeks of 0.99 compared with 0.52 for cows failing to conceive to a first service. This simply means that almost all first services occur within the first eight weeks of the PSM, but a failure to achieve conception to first service has a profound effect on in-calf rates. These results confirm the importance of submission rates and conception rates to the mating outcome. The effects for PSMCAT are similar to previous models with all comparisons being statistically significant except that between PSMCAT4 and PSMCAT5. The LACCAT1 and LACCAT2 were not significantly different but both were significantly lower than for LACCAT4 LACCAT5 (P<0.02). The LACCAT2 was also significantly lower than for LACCAT3 (P=0.03). The main effect interactions indicate that LACCAT modified the effect that SUB21, CONC_FIR and PSMCAT had on INCALF8.

Empty Status at the End of Mating for Cows in Pregnancy Tested Herds

The status of cows at the end of mating was evaluated for herds that pregnancy tested. This outcome variable was not considered for the remaining herds where non-return has been used as the criterion for determining in-calf status. This is because all cows without a return to oestrus will be considered to be in-calf without any consideration of the period of heat detection within each herd. In herds that do not pregnancy test all cows with a service would be considered pregnant and all cows without a recorded service as not pregnant. The empty rate is therefore simply a measure of the number of cows not submitted for the complete mating period rather than a measure of the number of cows that failed to be in-calf. This does not apply to the same degree to the four week in-calf rate because a significant portion of the mating season remains where returns to service may be recorded and therefore allow classification of some mated cows as not in-calf in the first four weeks due to a recorded return within the specified non-return period. The eight week in-calf rate is for similar reasons much less accurate in herds that use non-return as the criterion for determining in-calf status, but the error is not as great as in the calculation of empty rates.

Variables Offered to the Model

The REGION, BREED, LACCAT, BICAT, PSMCAT, MS2, and C_I were evaluated in separate analyses for the outcome EMPTY using the GLIMMIX procedure. A final model included all significant main and interaction effects.

Tests of Hypotheses

The REGION ($F_{4,11605}$=8.1, P<0.001), LACCAT ($F_{4,11605}$=11.3, P<0.001), PSMCAT ($F_{4,11605}$=17.1, P<0.001), and C_I ($F_{1,11605}$=19.6, P<0.001), were significant main effects. The BREED, BICAT and MS2 were not statistically significant in separate models or when included in the combined model and were therefore excluded from the analysis. There were no statistically significant interaction terms.

Specific Effects of Each Classification Variable

The EMPTY status for cows in REGION 4 (0.01±0.01) was statistically significantly lower (P<0.001) than for REGION1 (0.08 ± 0.04), REGION2 (0.08 ± 0.04), REGION5 (0.11 ± 0.07) and REGION6 (0.07 ± 0.05). There were no other comparisons between regions that were statistically significant. The effects for LACCAT, PSMCAT and C_I followed similar trends to the results for INCALF4 and INCALF8. The estimate for LACCAT1 was statistically significantly higher than for LACCAT2, LACCAT3 and LACCAT 4 (P<0.001), but not for LACCAT5. LACCAT5 also had a significantly higher estimate for the chance of being empty at the end of the mating period compared with LACCAT 2, LACCAT3 and LACCAT4 (P<0.002). All comparisons of PSMCAT classes were statistically significant (P<0.03) except that between PSMCAT1 and PASCAT2 and between PSMCAT4 and PSMCAT5. Induced cows had an estimated probability of being empty of 0.93 (0.90 - 0.95) compared with 0.95 (0.94-0.97). The difference was statistically significant (P=0.0001).

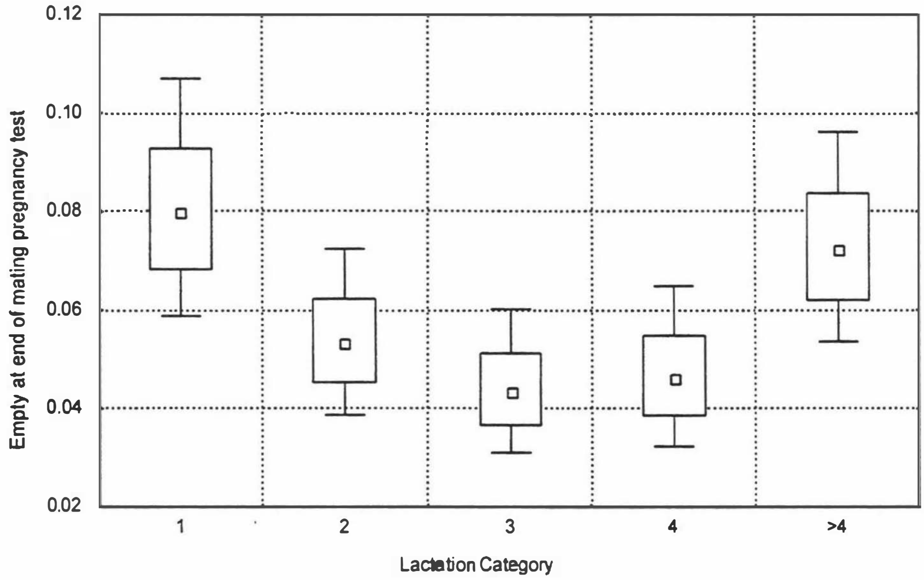

Figure 43. Model estimates for the chance of a cow being empty at the end of mating for each lactation class (LACCAT). LACCAT1 and LACCAT5 were statistically significantly greater than for each of the other three lactation classes (P<0.002). The In-calf status was determined from pregnancy test results at the end of the mating period for those herds that used whole herd pregnancy testing (Linear logistic model transformed parameter estimate. The boxes represent the linear-logistic transformed standard error of the estimate and the whiskers the linear logistic transformed 95 percent confidence interval.)

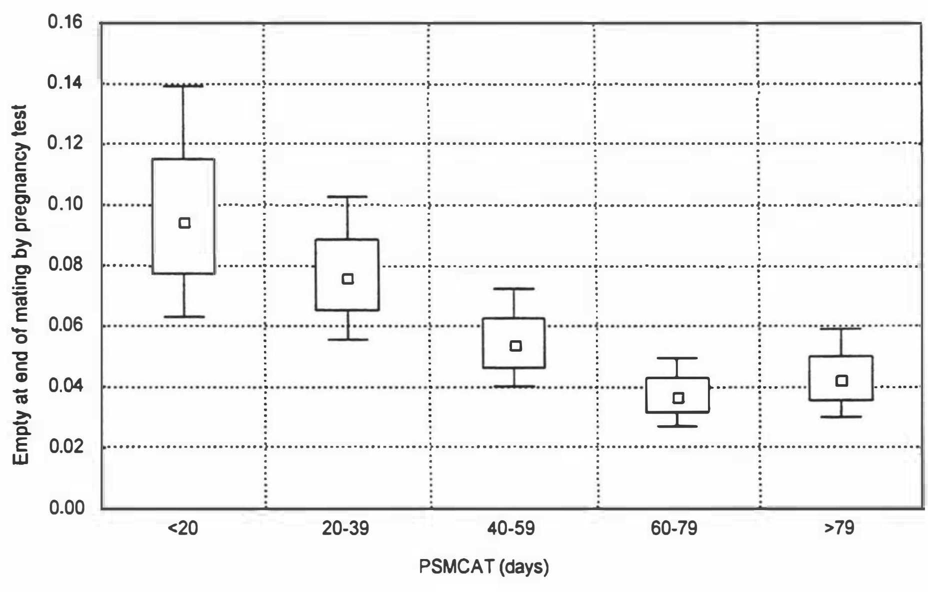

Figure 44. Model estimates for the chance of a cow being empty at the end of mating for each category by days calved (PSMCAT) at the planned start of mating. All classes were statistically significantly different (P<0.03) except between 60-79 days (PSMCAT4) and >79 days (PSMCAT5) and between <20 days (PSMCAT1) and 20-39 days (PSMCAT2). The In-calf status was determined from pregnancy test results at the end of the mating period for those herds that used whole herd pregnancy testing. (Linear logistic model transformed parameter estimate. The boxes represent the linear-logistic transformed standard error of the estimate and the whiskers the linear logistic transformed 95 percent confidence interval.)

In-calf Status for Cows in All Herds Using DairyMAN as Determined by Non-Return Status

These models estimate the association between the independent variables and the chance of a cow being in-calf at the end of the fourth and eighth week of mating. In this case all herds using DairyMAN were included and the criterion for "in-calf" for a cow was determined from estimates of conception by 28 day non-return. That is, a cow was considered in-calf to a recorded service if there were at least 28 days between the service and the last recorded information entry into DairyMAN (called the update date) and the cow had not been seen to return to service or show oestrus within the 28 day period. Although returns after the non-return period are not used in calculations of non-return rates, they must be considered when estimating in-calf rates. Therefore, in-calf rates based on non-return become less accurate as the mating period advances and comparisons between groups must be done with caution. Despite this, many DairyMAN users do not pregnancy test and an understanding of the relationship between the independent variables and the calculated herd performance is essential if an expert system is to be used with this type of data.

Variables Offered to the Model

The REGION, BREED, LACCAT, BICAT, PSMCAT, MS2, and C_I were evaluated in separate analyses for both INCALF4 and INCALF8 calculated using only non-return data. A final model included all significant main and interaction effects.

Four Week In-calf Rates

Tests of Hypotheses

The REGION ($F_{5,32713}$=2.7, P=0.02), BREED ($F_{4,32713}$=3.0, P=0.02), LACCAT ($F_{4,32713}$=30.1, P<0.001), PSMCAT ($F_{4,32713}$=244.7, P<0.001), and C_I ($F_{1,32713}$=7.5, P=0.006), were significant main effects. The milk yield (MS2) was not significant and there were no statistically significant interaction terms.

Specific Effects of Each Classification Variable

Although the models estimated the probability of INCALF4 for REGION3 the limited data has meant that the estimate has a large S.E. and confidence intervals (Figure 45). REGION2 (Waikato) and REGION3 (Bay of Plenty) had statistically significantly superior estimates for INCALF4 by non-return calculation than either REGION5 (Wellington) or REGION6 (South Island) (P<0.02) (Figure 45). No other comparisons were statistically significant.

The Lactation 3 and lactation 4 classes (Figure 46) were not statistically significantly different but both had higher estimates for INCALF4 using non-return data than each of the other lactation categories (P<0.001). The LACCAT2 was also superior to the estimate for LACCAT1 (P=0.001) and LACCAT4 was superior to LACCAT5 (P=0.001).

The comparison within PSMCAT was similar to the previous analysis of INCALF4 using pregnancy test results. All comparisons were statistically significant (Figure 46) including that between PSMCAT4 and PSMCAT5 (P<0.02). PSMCAT5 had superior performance compared with all other classes within PSMCAT.

Non-induced cows had an estimated chance of INCALF4 using non-return data of 0.64 (0.57-0.63) compared with 0.57 (0.54-0.61) for Induced cows. The difference was statistically significant (P<0.01).

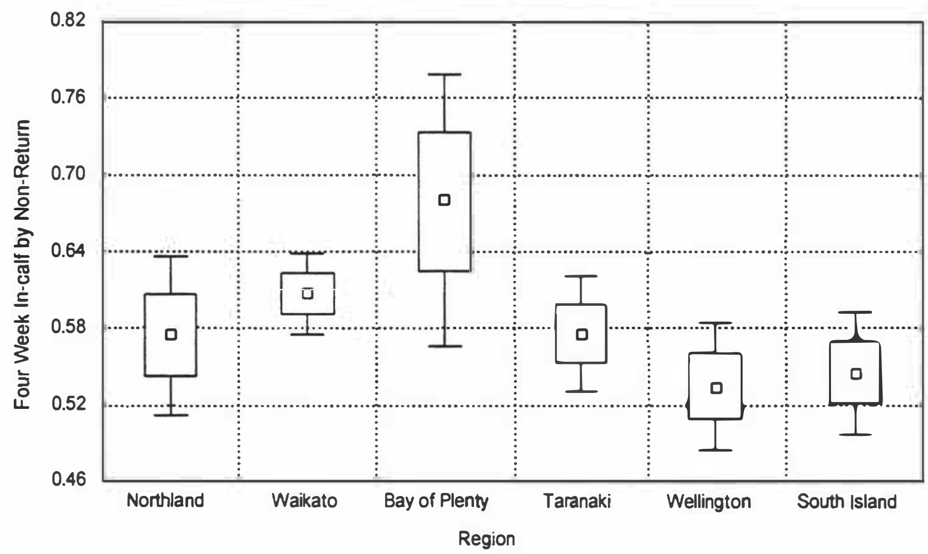

Figure 45. Model estimates for the chance of a cow being in-calf by four weeks after the herd planned start of mating for each region using only non-return criteria. The in-calf status was determined from non-return data only. The In-calf estimates for the Wellington and South Island region were statistically significantly lower than for the Waikato and Bay of Plenty (P<0.02). (Linear logistic model transformed parameter estimate. The boxes represent the linear logistic transformed standard error of the estimate and the whiskers the linear logistic transformed 95 percent confidence interval.)

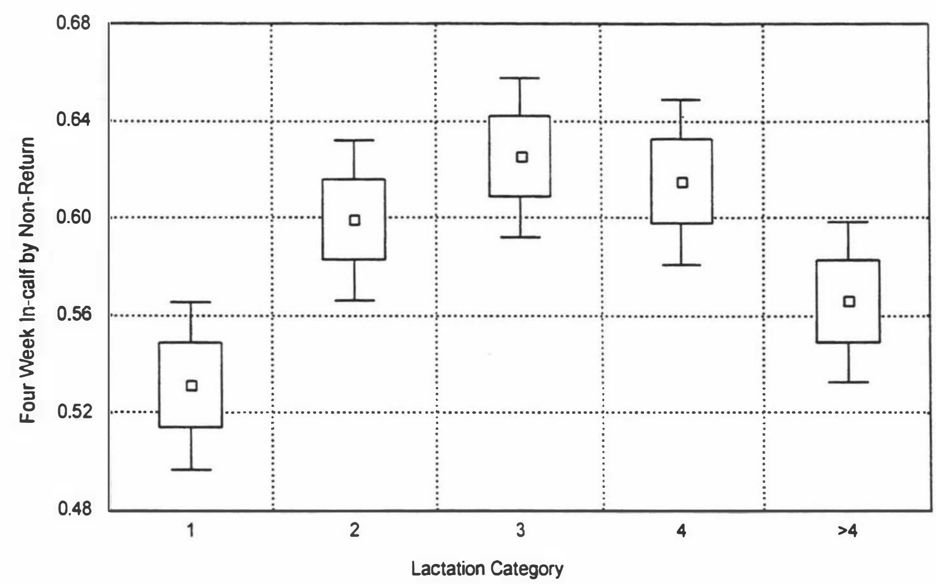

Figure 46. Model estimates for the chance of a cow being in-calf by eight weeks after the herd planned start of mating for each lactation class (LACCAT) for the non-induced cows. LACCAT3 and LACCAT4 were statistically significantly greater than for each of the other three lactation classes (P<0.02). The LACCAT2 were superior to LACCAT1 (P=0.001) and LACCAT4 was superior to greater than 4 (P=0.001). Other comparisons including that between LACCAT1 and LACCAT5 were not statistically significant (P>0.05). The in-calf status was determined from non-return data only. (Linear logistic model transformed parameter estimate. The boxes represent the linear-logistic transformed standard error of the estimate and the whiskers the linear logistic transformed 95 percent confidence interval.)

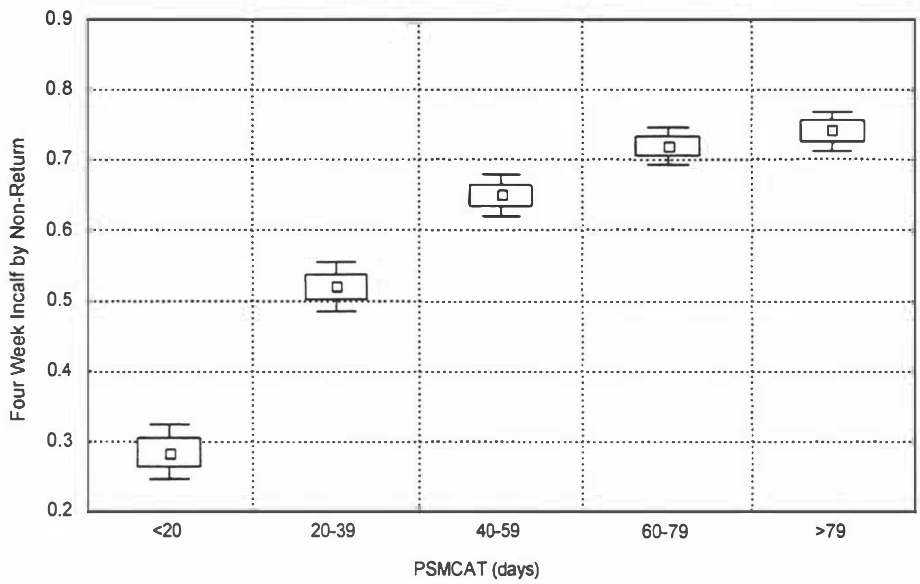

Figure 47. Model estimates for the chance of a cow being in-calf by four weeks after the herd planned start of mating for each category by days calved (PSMCAT). All classes were statistically significantly different (P<0.02). The in-calf status was determined from non-return data only. (Linear logistic model transformed parameter estimate. The boxes represent the linear-logistic transformed standard error of the estimate and the whiskers the linear logistic transformed 95 percent confidence interval.)

Eight Week In-calf Rates

Tests of Hypotheses

The LACCAT ($F_{4,32996}$=20.8, P<0.001), PSMCAT ($F_{4,32996}$=112.3 P<0.001), and C_I ($F_{1,32713}$=6.7, P=0.01), were significant main effects. No other variables or interaction terms were statistically significant and were therefore not retained in the final model.

Specific Effects of Each Classification Variable

For the outcome INCALF8 using non-return criteria the LACCAT2 LACCAT3 and LACCAT 4 were not statistically significantly different(P>0.1) (Figure 48). All however had significantly higher estimates for INCALF8 compared with LACCAT1 and LACCAT5 (P<0.001). The LACCAT1 and LACCAT5 were not statistically significantly different (P=0.3).

All comparisons of all PSMCAT (Figure 49) classes were statistically significant with the estimate for INCALF8 increasing with higher PSMCAT (P<0.05).

The non-induced cows had an estimated probability of INCALF8 of 0.90 (0.89-0.91) which was statistically significantly greater than for induced cows of 0.89 (0.97-0.90) (P=0.01).

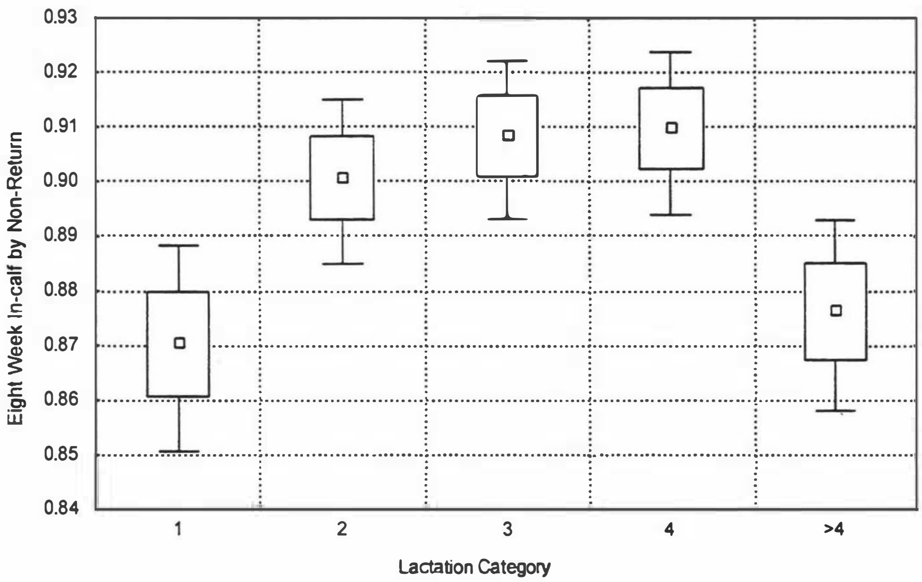

Figure 48. Model estimates for the chance of a cow being in-calf by eight weeks after the herd planned start of mating for each lactation class (LACCAT). LACCAT3 and LACCAT4 were statistically significantly greater than for each of the other three lactation classes (P<0.02). The in-calf status was determined from non-return data only. (Linear logistic model transformed parameter estimate. The boxes represent the linear-logistic transformed standard error of the estimate and the whiskers the linear logistic transformed 95 percent confidence interval.)

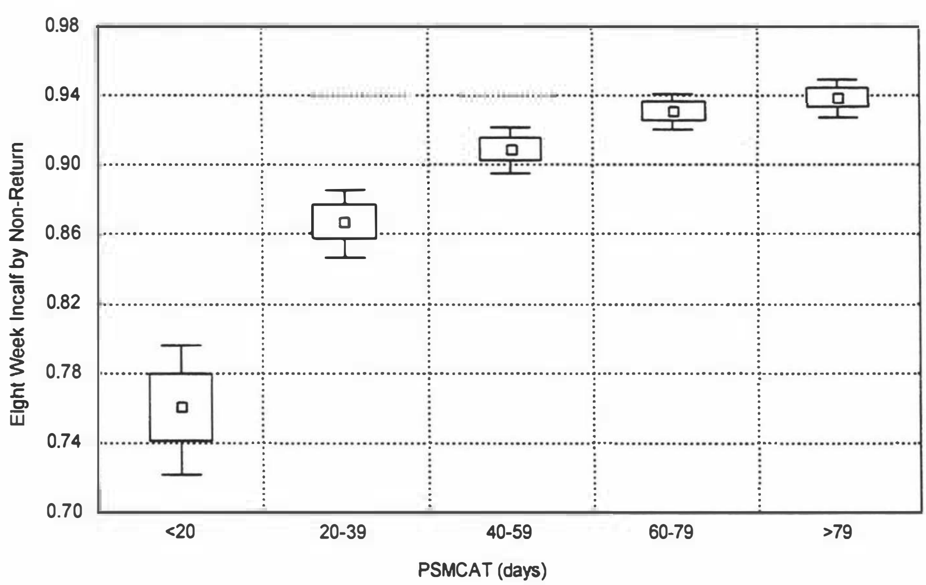

Figure 49. Model estimates for the chance of a cow being in-calf by four weeks after the herd planned start of mating for each category by days calved (PSMCAT). All classes were statistically significantly different (P<0.003) except between 60-79 days (PSMCAT4) and >79 days (PSMCAT5). The in-calf status was determined from non-return data only. (Linear logistic model transformed parameter estimate. The boxes represent the linear-logistic transformed standard error of the estimate and the whiskers the linear logistic transformed 95 percent confidence interval.)

Discussion

The most important variables considered in these models estimating submission, conception and in-calf rates are PSMCAT, LACCAT5, BREED and some health events. There are some significant variations for the measures of conception that depend on the method used to determine pregnancy status. Each of these factors is considered separately in the following discussion.

Days Calved at the Start of Mating

The PSMCAT of a cow is determined by the calving date relative to the rest of the herd. This may be modified if the PSM date for a herd is shifted relative to the calving date within a season, but this does not occur often. The herd profile for PSMCAT is therefore determined by the calving pattern and the PSM date relative to the PSC. The calving pattern of a herd is the result of :

1. Previous season reproductive performance
2. Culling strategies
3. Stock purchases
4. Pregnancy loss
5. Inductions
6. Heifer replacements

In this first version of DairyFIX to be described in the following chapters the calving pattern may be identified as a principal cause of a herds failure to achieve acceptable reproductive performance in the following season when investigating the performance of an individual herd. This is because the PSMCAT has a pivotal effect on subsequent performance. Except for inductions, which can be investigated using the data available within the season of interest the DairyFIX program does not further evaluate the impact that culling, stock purchase, abortions or the previous seasons mating performance had on the calving pattern. The user of DairyFIX can investigate the reproductive performance of the previous year as a separate task but culling and stock purchase decisions are not solely determined by the desire to achieve good mating performance and could be the subject of an independent expert system.

Numerous studies have demonstrated the importance of calving pattern and the number of days calved at the start of mating on subsequent mating performance (Brightling et al. 1990). These studies confirm such findings and quantify the effects for use in DairyFIX. These models show that any factor that modifies the calving pattern or calving date of an individual cow will indirectly modify the submission, conception and in-calf outcomes. Submission rates, pregnancy rates, non-return rates and in-calf rates all increased as the PSMCAT increased. The differences in performance were large and this variable is the most important determinant of the reproductive performance of individual cows.

Region

Regional variations in reproductive performance were observed in the calving pattern and the in-calf status at the end of mating. The Northland region had an inferior calving performance that would modify subsequent performance through the effects of days calved at PSM (PSMCAT). The Taranaki region had exceptionally low empty rates and superior in-calf rates compared with most other regions. This was not however reflected in differences on the submission rates or conception rates between regions. The Wellington region showed a low in-calf rate and high empty rate. An analysis of herd data identified low conception rates in this region, but a significant effect was not demonstrated in individual cow analyses. The lower in-calf rates however must be a consequence of either reduced submission or pregnancy rates for at least a part of the mating period. It is possible that the observed effect is due to an additive non-significant effect of both aspects of performance.

Lactation Number

Lactation number had a significant effect on most reproductive performance variables. Herd owners tended to mate heifers earlier that the adult herd and this is demonstrated by the earlier calving date for this class. While the cows starting lactation 1 calved significantly earlier than the rest of the herd their subsequent reproductive performance was inferior. It is notable that although the lactation 1 cows calved earliest they also had the poorest submission rates. Conception to service was also low for this group. Submission rates were at an optimum in the third and fourth lactation and declined as lactation number (and therefore parity and age) increased. Conception rates were the highest for lactation 2. Similar trends were found when non-return was used as the measure of pregnancy The lactation 3 and lactation 4 animals generally had superior in-calf performance due to the combined effects of submission and conception performance. However the effect did vary with breed and Lactation 2 Friesians appeared to recover more effectively from poor performance in lactation 1 than other breeds, although the overall performance of Friesians for the 4 week in-calf rate was inferior to cross-breeds. The combined lactation 5 and greater group generally had inferior performance compared with lactation 2, lactation 3 and lactation 4 animals. It is not possible from these analyses to determine the performance of the lactation 5 animals relative to the younger groups independent of the effect of animals in higher parities, as these had been combined. As a group these cows did not have inferior performance when compared with the lactation 1 animals. Herd managers did not adversely affecting the reproductive performance of their herds due to the retention of aged cows for this reason. Further it may be that many herds could improve mating performance if the proportion of young animals was reduced, however this may be unacceptable for production and other health reasons. The proportion of most herd in the aged classes is usually low so their impact on herd performance is small (see Figure 5 on page 53).

The performance of each lactation class depends on the culling effects imposed on the herd by the farm manger and this may bias the results. Data on the reasons for culling within herd was not available in these studies and therefore could not be included in the models. The performance of older classes of animals may be significantly different if a greater proportion of these animals were retained in the herd and not culled for reproductive and other reasons.

Breed

Breed had an important effect on calving pattern and submission rates but not on conception rates. Jersey cows calved earlier, had improved submission rates and no significant difference in conception rates than Friesian cows. Cross-breed cows tended to have an intermediate performance. The four week in-calf rates were modified by breed. Friesians showed inferior performance compared with Cross-breeds. The Pedigree groups were in much smaller numbers and the power to detect a significant difference was therefore greatly reduced. In some cases the performance of pedigree animals was inferior to the commercial bred animal. The Jersey cows showed poorer non-return rate performance. This result should be interpreted with caution because the analysis of conception rates did not show a similar effect and the improved submission rates (and therefore heat detection rates) that were observed for Jersey cows may result in a greater proportion of this group being detected as returns to oestrus after mating. That is the effect may simply be due to differences in either the oestrous activity, display of behavioural oestrus or cycling activity between breeds.

Health

The performance of induced cows was inferior but they were not distributed uniformly by PSMCAT. A separate analysis of cows induced to calve has been reported (Hayes and Morris 1996) and is found in Chapter 5.

Lameness during the lactation (occurring either before or after mating) was associated with reduced conception rates but submission rates were not altered. Lameness has been shown to be associated with oestrous activity and the lame cow class may therefore have been associated with increased submission rates in some situations (Tranter 1992). This study did not consider the temporal association between lameness and a reproductive event. The reduced conception rates may be due to reduced feed intake and decreasing body condition in lame cows. Assisted calvings also reduced fertility. It has been previously shown that calving assistance can reduce conception rates due to endometritis or other reproductive disease (Erb et al. 1985, Kawata 1996). This suggests that although reproductive disease is almost completely unrecorded in herds using DairyMAN there is likely to be some unobserved effects. The observations in Chapter 2, that conception rates reduce with increased service number for some groups of cows support the possible presence of reproductive pathology.

Milk Production

The genotypic and phenotypic effects of milk production on reproductive performance have been widely discussed. A recent New Zealand study demonstrated a negative genotypic association between milk production and some reproductive variables including submission rates (Grosshans 1996). The current investigation does not consider these genetic effects and has simply included milk production at mating in the linear models without the inclusion of sire or other genetic effects. High milk production is associated with an increase in submission rates but the variable is likely to be confounded by nutritional status. The nutritional status of individual cows within a herd will be correlated and because herd was included as a random effect in these statistical models, the estimates may not accurately reflect the true association between milk production and expected reproductive performance. For this reason it may not be appropriate to use the model developed here within an expert system for estimating performance of herds based on milk yield.

The four week in-calf rates are dependent on the intermediate effects of the submission rates and first service conception rates. This has been previously demonstrated in the path models of herd performance but is also confirmed by the models of individual in-calf performance that included the intermediate variables. Breed, days calved at PSM, lactation number and other factors modify the in-calf rates through their effects on either the submission rate or first service conception rates. When 21 day submission and first service conception is included in a model for the four week in-calf rates there is no residual effect from other variables. In other words these two outcomes can be accurately used to estimate the four week in-calf rate. This however does not apply to the eight week in-calf rate. Although there is no reason to presume that the eight week in-calf rates are not equally dependent on submission and conception rates this variable calculates performance over a longer time period after the planned start of mating than either the twenty one day submission rate or first service conception rate. In addition, the time when bulls are introduced into a herd may correspond with changes in the heat detection rate within the herd. Submissions during this period may not reflect the true performance of a herd as measured by the in-calf rate and in some cases herd managers cease heat detection completely. This is because natural matings followed by conception may go unrecorded, but will contribute to the eight week in-calf rate if the herd is pregnancy tested. As a consequence some of the external variables remain significant in the models for CAL8 that include SUB21 and CONC_FIR.

Health and Other Factors

Caution must be used in the interpretation of these analyses for some of the independent variables included in these models, due to incomplete recording and because some classes had small numbers. The power to detect a significant difference in performance varied greatly for different variables. Twins and abortions resulted in an earlier calving. Calving in cows having a heifer calf on average occurred a day and a half earlier. The number of days from calving to PSM (PSMCAT) had a major effect on performance, so the calf sex (and any other variable affecting calving date) will affect subsequent mating performance. There may be other interacting effects that could not be considered in this investigation. For example, while an abortion will result in an earlier calving it may also require assistance and result in retained foetal membranes. Both of these effects are known from the literature to reduce fertility.

Cows with a recorded pre-mating heat had superior conception rates which were independent of the effect of days calved at service. The commonly recommended objective to optimise the number of cows showing pre-mating heats will therefore have an effective impact on performance (assuming that a response or change in pre-mating heat rates can be achieved).

Limits to performance

The observed performance of lactation 3 and 4 Jersey cows which had calved greater than 80 days, gives a good indication of the upper limit to the performance for an individual cow. With these factors included in the submission rate model for a cow producing 1.5 kilograms of milksolids/day the twenty one day submission rate is 95.2 percent. If we assumed that all such cows would be expected to be cycling at the start of mating then this also gives an estimate of the proportion of cows missed on heat in the first three weeks of mating. This also approximates the proportion of heats missed. This suggests that approximately 5 percent of heats are typically missed in New Zealand herds which is consistent with the estimate calculated from the return intervals analysis. This class of animal had estimated conception rates to first service of 69.4 percent. The again gives some indication of realistic upper limits to performance under current management conditions (see Figure 9 on page 62).

Models for DairyFIX

The purpose of this chapter was to quantify the performance of individual cows in New Zealand herds and identify some factors that significantly modified performance. A second objective was to have develop predictive models that could be used in DairyFIX where appropriate to calculate an expected herd reproductive performance.

Of the models described in this chapter the most important are those that estimate the effect of the number of days calved at the PSM and the variation between different lactation categories. These are included in the design of DairyFIX in the following chapters. Although breed and various health events had an important effect on performance the magnitude of this variation is not large. Consequently these models have not been utilised in this version of DairyFIX, however the associations between these events are considered. For example, a high incidence of lameness in a dairy herd is considered by the expert system to be associated with reduced in-calf rates and can be reported as a cause of reduced performance. The statistical models therefore support the use of such rules within DairyFIX.

Chapter 8

DairyFIX - An Expert System for Reproductive Problem Solving

DairyFIX - An Expert System for Reproductive Problem Solving

The Development of DairyFIX: An Overview.

Expert Systems in Veterinary Medicine

Knowledge based expert systems have been developed for many aspects of dairy cattle medicine and dairy farm management. BOVID (Blood et al. 1989) is a diagnostic program that interrogates the user on the observed clinical signs for an individual clinical case. From this it provides a list of differential diagnoses. The system uses expert knowledge included in a data base of diseases. The probability of specific clinical signs occurring in a particular disease case is used as the basis of the inference process that lists the differential diagnoses in order of probability.

The availability of tools and inference engines specifically designed to aid expert system development has promoted the design of other systems. Examples include the investigation of mastitis problems (Gray et al. 1992), complete farm management (Pellerin et al. 1994, Hogeveen et al. 1991), culling decisions (Allore et al. 1992), and investigations of reproductive disease for individual animals (Levins and Varner 1987). These and other systems are reviewed in more detail in Chapter 1.

Expert Systems for Herd Reproductive Performance

Advanced management information systems including DairyMAN have been developed in recent years that provide monitoring and diagnostic reports for investigating reproductive problems in dairy herds. The manual process of retrospectively analysing the mating performance of seasonal calving dairy herds is well documented (Tranter 1991, Brightling et al. 1990). Farmers often, will not have the necessary skills to complete this process and fully utilize the advanced diagnostic tools available in computer programs such as DairyMAN. Veterinarians may lack the time or have difficulty charging adequately for this time investment. Limited computer skills may also contribute to an incomplete investigation when using these traditional herd management programs. Expert systems that assist with the investigation of herd reproductive performance problems have been developed for non-seasonal dairy herds. A simple system can be down-loaded from the American National Dairy Database. This can be accessed from the internet site http://www.wam.umd.edu/~markv/ndd.html.

DairyFIX (Dairy Fertility Investigation eXpert. Version 2.0), is an expert system and knowledge base to aid the investigation of reproductive performance problems in seasonally calving dairy herds using data retrieved from DairyMAN. DairyFIX ensures the most complete investigation is done given the limitations of available information and allows farmers and consultant veterinarians to quickly focus on the most significant aspects of reduced performance.

Expert System Technology

Expert systems have been defined by many authors. Liebowitz (1991) provided the simple definition, " The ability to perform at the level of an expert". Expert Systems generally separate the knowledge within a particular narrow field of experience from the processing methods and the raw data.

Many knowledge based expert systems have been built in recent years. Some of those relevant to this thesis have been previously discussed. There are also some very large systems that contain the knowledge of many experts which has been collected and compiled over several years. These systems therefore contain more "knowledge" than any single human expert can have. An example is the system "XCON/R1 developed by Digital Equipment which knows the combined knowledge of many experts on how to configure computer systems (McDermott and Bachant 1984). Many smaller expert systems can derive the knowledge from the literature. Knowledge engineering is required for many systems because undocumented expertise must be obtained from interviewing experts in an iterative process. This can require many interviews and the use of methods for handling conflicting views of various experts before the knowledge can be coded into an expert system. Inconsistencies and errors in a human expert's knowledge may be apparent when there is an attempt to represent the knowledge in an expert system. An experienced knowledge engineer is necessary to perform these tasks adequately. The conventional approach can also be extremely expensive. Kalter (1992) described the development of a run-time version of an expert system to diagnose dairy herd management problems. In this case a detailed interview of experts was the initial knowledge acquisition process. This require significant resource with the complete project having a budget of $210,000 US.

The development of DairyFIX was limited to the investigation of seasonally calving dairy herds. Although most systems previously described have obtained the knowledge from a defined group of experts and have designed the system using people skilled in the construction of knowledge bases an alternative approach was used in this project, because there was ample information available and the initial tasks were relatively simple. This alternative approach uses the information derived from the literature, the mathematical relationships from the analyses in the previous chapters and the expert knowledge of the author to define the expert system rules. This approach substantially reduces the development costs and removes many of the difficulties associated with a large development team and conflicting expert opinion.

Expert systems generally rely on an inferencing process defined by the human expert's knowledge and DairyFIX also uses these processes. DairyFIX is in some respects however not a classical expert system because it is able to use algorithms to define many of the problems. These algorithms were defined from the literature and the statistical models in the preceding chapters. Inferencing systems must be able to explain the findings so that the user can understand the reasoning methods and path.

The basic structure of an expert system is depicted in Figure 50. The expert knowledge is a distinct part of the programme called the "Knowledge base". It stores all the expert information that has been coded into the system. Knowledge acquisition from this source takes place during an inferencing session schedules the processing path. Some hypotheses become facts (True) during a session as the data is processed. All processing takes place via a user interface that is developed as a separate entity. It provides systems for the user to enter data and answer questions as well as inform the user of progress and finally report the results of an investigation.

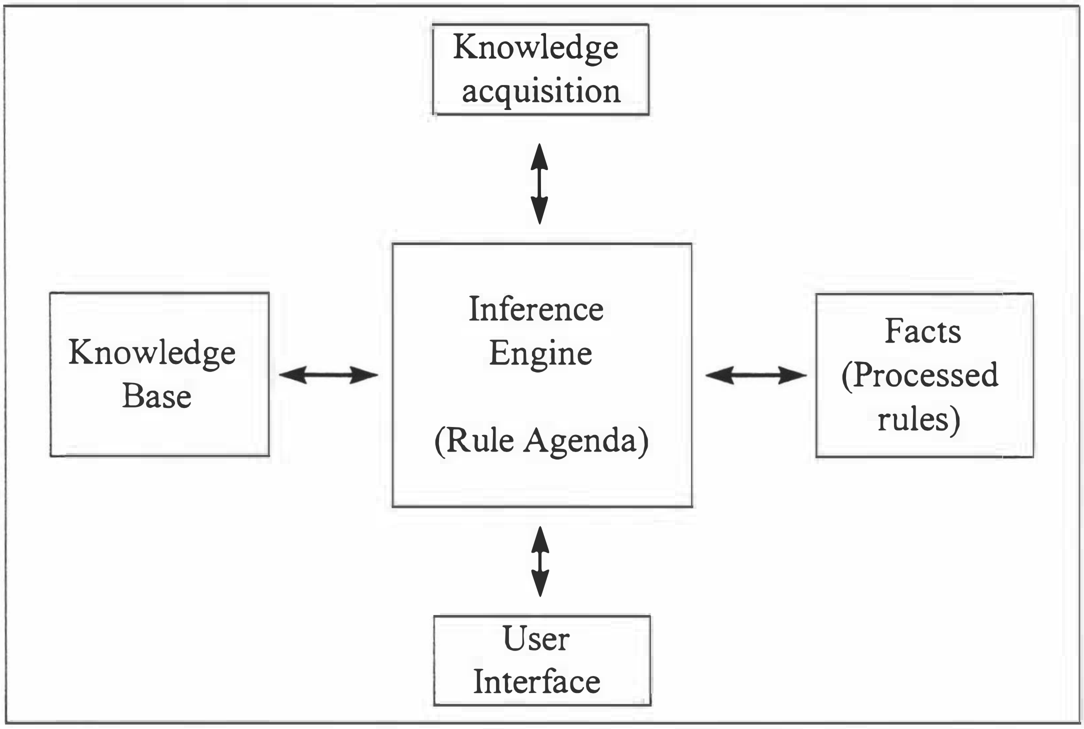

Figure 50. Basic structure of a rule based expert system

Smart Elements: The Development Tool

A number of expert system shells have been developed with powerful graphical interfaces and with an array of knowledge base design tools that were suitable for developing DairyFIX. "Smart Elements" (Neuron Data Inc. 1993) was chosen as the development tool because it provided the facilities to complete all stages of development without, it was expected, the need for advanced computer programming skills. Smart Elements is an example of an expert system shell. This software package was also chosen because it supported the development of an expert system and was able to produce commercial software packages in compiled run-time format. Smart Elements is one of the most complete expert system shells offering all the necessary features. Some of these features are described in more detail below.

Smart Elements: Features and Limitations

Smart Elements is a sophisticated rule based expert system shell that provides the following features. The reader is referred to Neuron data's documentation for this system including the volumes on knowledge design (Neuron Data Inc. 1993) for more detail.

Object Orientated Tools

The Smart Elements environment provides a large range of tools for representing or modelling a domain of knowledge as objects, classes and properties. Objects are small pieces of information required for a particular expert system application. Objects that have features in common can be grouped into classes. Properties are characteristics of objects and classes of objects that contain information about the specific object or class. These properties can be inherited from a class or object to another class or object.

Rule Based Reasoning

Rules form the basic structure of most expert systems and they contain the knowledge necessary to solve problems within a domain.

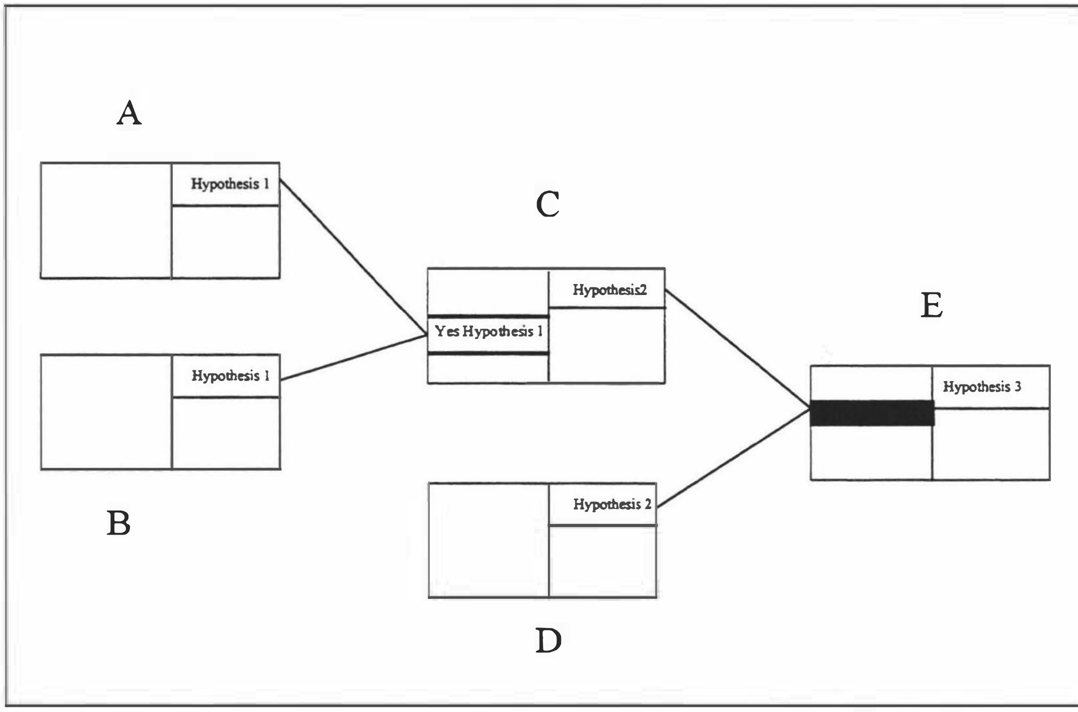

Figure 51 The outcome (hypothesis) for a rule can be a criterion for another rule in the domain. Suggesting Hypothesis 3 places rule E on the agenda. Rules A to D are activated by backward chaining because rule E cannot be evaluated without knowing the status of the preceding rules

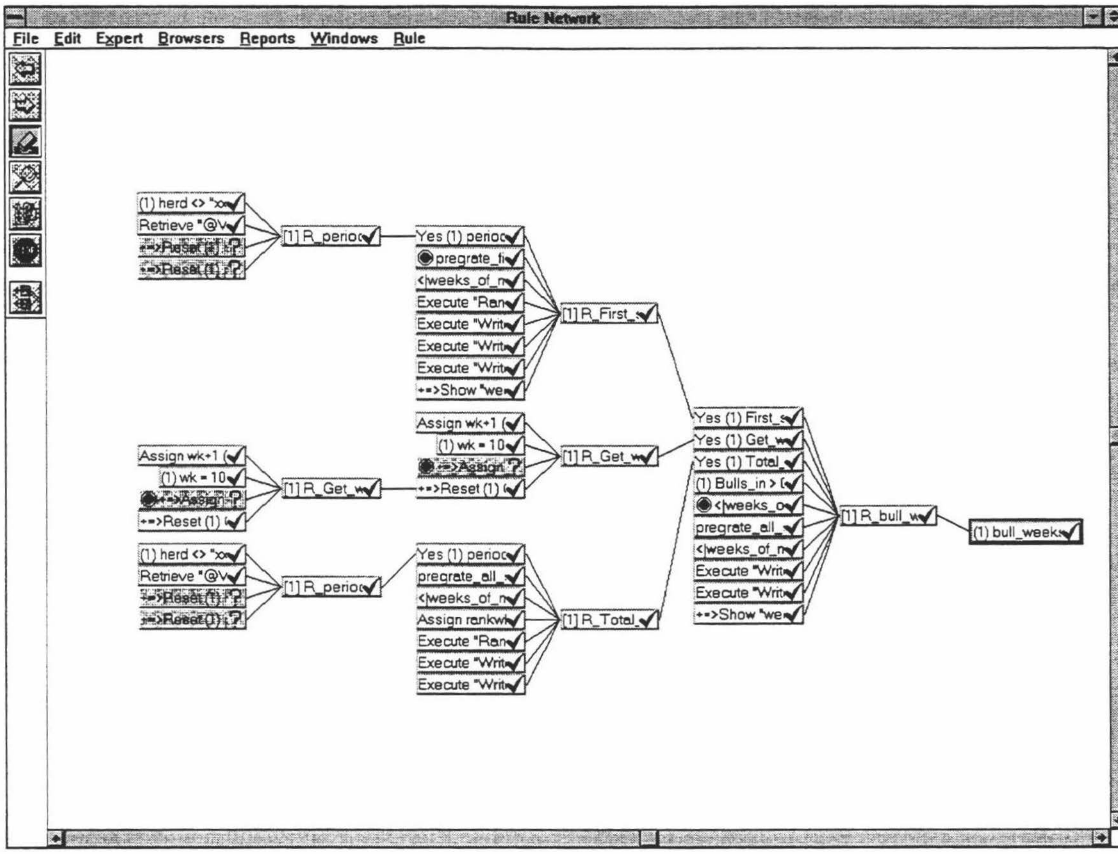

Figure 52 The rule network display used in Smart Elements for graphically representing rules and the linked between rules. The display also show the current status of each rule during an inference process. In this example all rules have been "fired" and the hypotheses are marked with a tick which indicates that the rule is "true"

Data Retrieval

Sophisticated Inference Engine

The inference engine is the core of the Smart Elements system shell. The methods, ordering and pathways for knowledge investigation are defined by this system. Smart Elements has most of the sophisticated elements required for developing expert systems.

There are several types of inference methods including, in order of priority;

Backward chaining

Suggesting

Hypothesis forward

Gates and forward action effects

Volunteering information

Context links

All of the inference mechanisms allow an expert system to reach relevant conclusions because the knowledge is linked in a logical structure. A complete evaluation of all rules in a knowledge base is not necessary to reach valid conclusions because the appropriate rules need only be activated.

The user can process knowledge by either suggesting that an outcome is true or by providing some initial data. Rules are then activated or "fired" using the criteria set by the inference process. In the latter case a forward process is followed as a consequence of being provided with some information. Where an outcome is "suggested" a backward chaining investigation is initiated (Figure 51). The forward and backward chaining processes can be controlled in a way that determines the extent of an investigation. An exhaustive investigation evaluates all rules that have any link to the initial rules that are evaluated. That is, all rules with the same hypothesis will be placed on the agenda and evaluated once any single one of the rules is "fired" (activated) by the inference process. The ability to both forward and backward chain a set of rules is one of the more important features of a good expert system shell. A complex set of inference priority criteria can be modified to control the way different types of rules are processed by the system. Rules can be implicitly assigned a relative processing importance or the system can be restricted to a narrow set of rules of just forward or backward chaining. The outcome for processing any rules is either that the rule is "true", "false" or "unknown" An option to forward chain false or unknown rules is another example of the complex options available within Smart Elements. The different inference processes each have their own defined priority level. With the default options chosen, backward chaining has the highest priority. That is, all rules that have an hypothesis that is part of the left side criteria of the rule currently being evaluated will be investigated first. Other options including context links and action effects via gates have the lowest priority. There are often many relevant rules and hypotheses on the agenda at any time. Whenever a rule is processed the inference engine needs to determine which rules to evaluate next. This is called conflict resolution and is determined by the priority for each rule

The source of data to be used for evaluating a rule is defined by the "order of sources" This simply defines the order in which different options are used. For DairyFIX the first option is to look for the data in a related data base file that has been derived form DairyMAN. If none exists the second option is to ask via the interface for the operator to provide the information before processing can continue.

By utilising the different types of links it is possible to separate rules out into separate "islands" that are evaluated completely before other areas are investigated. Weak links between these islands allow the associated knowledge islands to be processed after another is completed.

Software Development Tools

The complete Smart Elements system provides a comprehensive set of development tools for producing release versions of expert system software. The development interfaces are used to produce an operational system. Once completed this code can be used in conjunction with a user interfaced developed using the tools provided for generating screens, windows, menus and control features. This software is then compiled with a run-time version of the inference engine to produce a stand alone expert system.

Disadvantages

It is extremely difficult to appreciate all the complex features of an expert system shell such as Smart Elements. These systems have been developed over several years and aim to incorporate all tools required to develop simple and complex expert systems in any domain of expertise. Unless the user has considerable experience with the tools there may be difficulties developing an operational system. The author found that an enormous amount of time and testing was required to become familiar with those aspects of Smart Elements that were required to develop DairyFIX. It is the author's strong view that these tools should not be used by the knowledge experts, but rather used by computer programmers trained in the use of knowledge based development shells. This is considered a major limitation of the approach taken with the development of DairyFIX.

Smart Elements is an expensive development environment and the cost of producing licensed "run-time" versions for releasing operational expert systems was prohibitive. An alternative is to develop the system within Smart Elements because it contains the tools to represent knowledge, but then re-code the completed DairyFIX system in a lower level computer language.

Knowledge representation can become confusing in the author's experience. This again illustrates the need for very skilled operators to effectively use the system. The methods that determine how rules with many common hypotheses are linked is complex. The introduction of a single new rule can completely change the way the rules are displayed on-screen.

Much of the knowledge that was incorporated into DairyFIX is procedural. The interpretation of performance can be mathematically defined and the consequences of changes in the performance in one area have clear and precise effects on others. This type of knowledge can be represented in standard computer programming code that follows a series of steps in a logical ordered and repeatable manner. The advanced features of an expert system shell are not necessary for this type of knowledge. Confusion can arise because the powerful graphical interfaces will represent the knowledge or rules in a variety of ways that depends on many factors that do not represent the procedural nature of the system.

DairyFIX currently exists as a development program within the Smart Elements environment. The program will be transferred to the operational environment that is used by the Windows version of DairyMAN. Development of a final operational version of DairyFIX can proceed with the release of the Windows version of DairyMAN (to be called DairyWIN).

Knowledge Acquisition

A survey of dairy farmers using DairyMAN and herds from the New Zealand National Dairy Database was used to determine the current performance levels of New Zealand herds and develop a data set of appropriate performance targets. Published information on the performance of New Zealand dairy herds (MacMillan 1982) was also used.

The knowledge required to investigate the mating performance of seasonal calving dairy herds was derived from the literature. The investigative process is based on manual techniques using DairyMAN (Tranter 1991) and methods used in Victoria (Brightling et al. 1990). This was validated from path models that identified the important causes of poor reproductive performance for the surveyed DairyMAN and National Dairy Database herds. The diagnostic tree depicted in Figure 1 forms the basis for a herd investigation and the reporting of results.

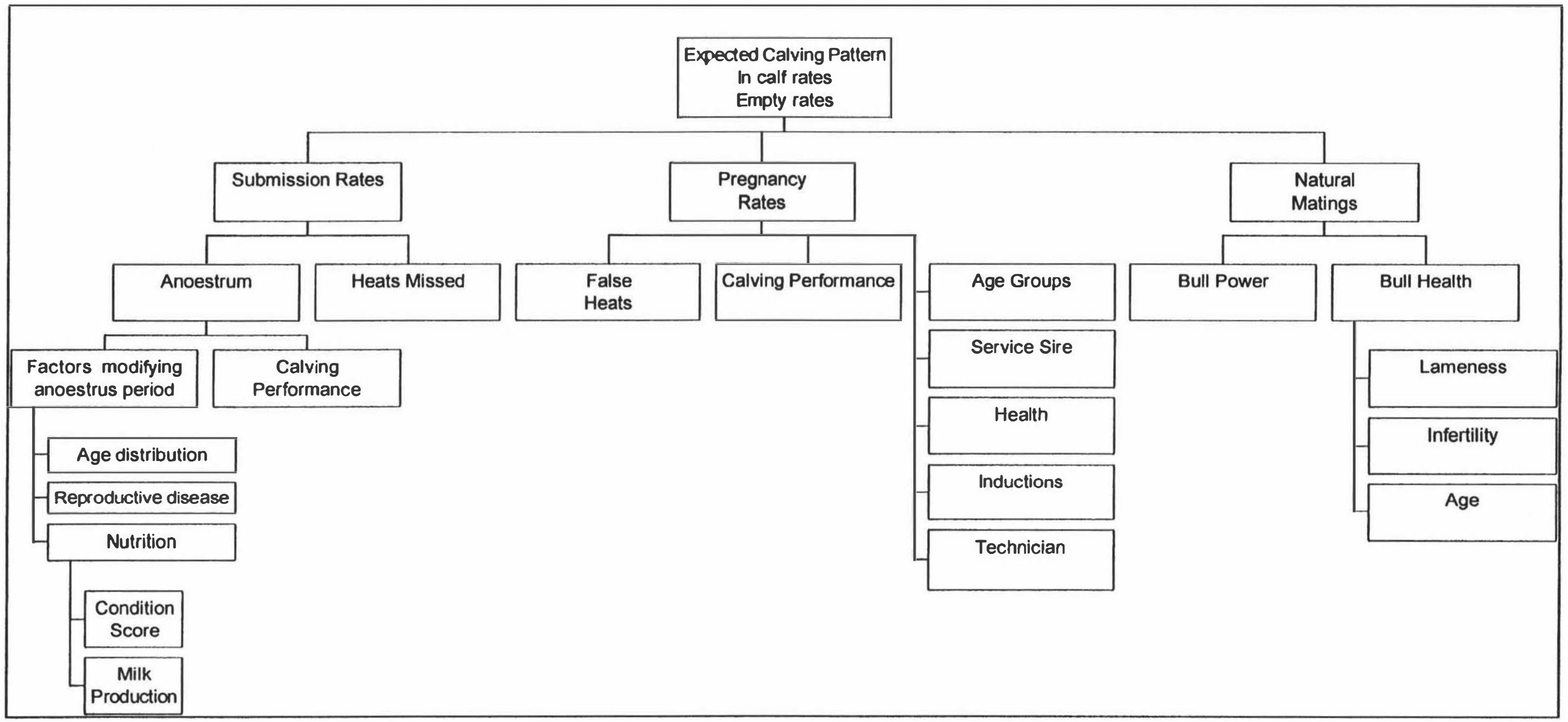

Figure 53 The diagnostic tree used by DairyFIX that includes information available in DairyMAN

System Design

DairyFIX is a software module that will link with the Windows version of DairyMAN and operate interactively. This means that DairyFIX will retrieve data from DairyMAN by automatically running reports as they become necessary during a herd investigation. The information in these reports will then be used by DairyFIX for further assessments of performance. Data from the reproductive performance monitor is used as the basis for investigation. Performance for each parameter is classed as;

1. Performance achieves targets and is acceptable.
2. Below target performance
3. At lower performance standard classed as a warning level
4. Performance is at a level that requires action.

This investigation identifies those areas of performance that do not meet targets without considering the interactions between the main performance parameters. For example, the submission rates are classified independently of the major factors that could modify performance, such as the calving pattern. The outcome of this stage is a descriptive list of performance results (Table 2) and a graphical view using the knowledge tree where each area below target is colored to identify the problem severity.

Table 55 Sample output from stage one of the DairyFIX investigation

DairyFIX reproductive analysis of basic data. **Conception Performance**
You have pregnancy tested most cows. The pregnancy rate information will be more accurate than NON-RETURN analysis. Non-return information is reported but will usually be excluded from subsequent analyses.
The Pregnancy rate for first services is 31 percent and is in the action range The pregnancy rate for all services is 34 percent and performance is in the action range The serves per conception is 2.9
The first services non-return rate is 40.0 percent and is in the action range. The non-return rate for all serves is 55.0 percent and is below target.

Stage two investigates the expected performance at each level considering information previously evaluated. The calving pattern is the primary influence on all subsequent performance and is considered first. Heat detection accuracy and efficiency are then considered. Often there is insufficient information available to calculate heat detection efficiency using the reproductive performance monitor because the period of mating is very short. In these cases the program will retrieve or obtain additional data from DairyMAN (eg. Veterinary visits for anoestrous cows) that may allow an estimate to be made. Where there is inadequate information from all sources the user is requested to provide an estimate of performance.

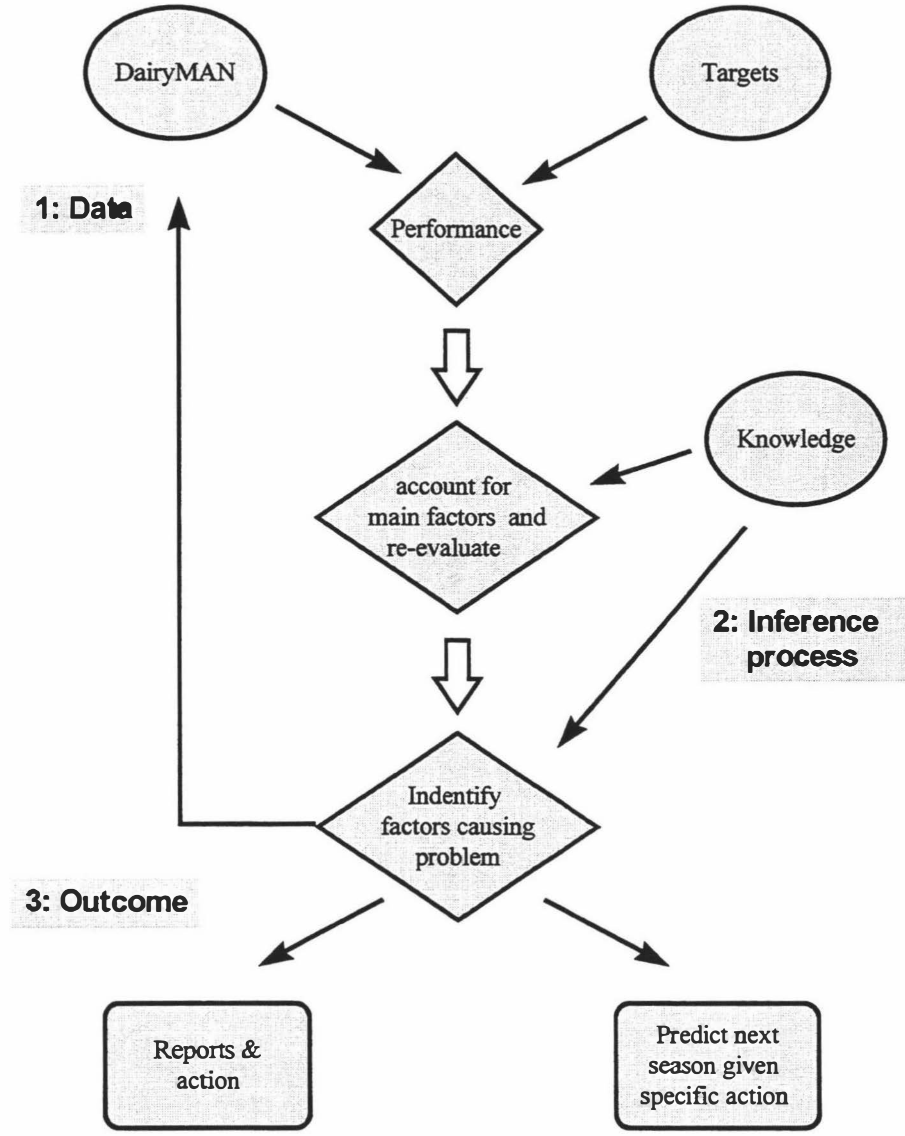

Figure 54 Simplified structure of DairyFIX

If performance in a particular area is still identified as below target after considering the major causes of poor performance the more specific data from DairyMAN is retrieved and the knowledge process continued. For example, a detailed investigation of pregnancy rates is performed if the calving pattern and poor heat detection (Cows mated that are not on heat) do not adequately explain the observed herd performance. To complete this task each major cause that can be confirmed by data that is recorded in DairyMAN, is considered. For pregnancy rates this would include;

1. Semen (Poor sires identified)
2. Natural matings and Artificial Breeding
3. Health (Reproductive disease, lameness and calving induction)
4. Age groups (is the problem confined to a particular age group)
5. Technician (If multiple technicians were used)

In some cases the knowledge process is continued beyond the information available in DairyMAN. This requires the user to provide specific information. For example, the natural mating period can be further investigated with some limited information from the user. This can include the number of bulls used, disease and lameness problems and if the bulls had been examined prior to use. The number of functional bulls is then compared to a calculated requirement to determine if there was adequate bull power.

The Output

The output of DairyFIX is a list of identified problems that are defined as accurately as possible given the available information. Each problem is classified by severity or its impact on the mating season. Residual deficits of performance that cannot be investigated using DairyMAN data will occur. Some recommendation for further investigation are offered. For example, if pregnancy rates are low, but there are no identifiable causes then specific disease and trace element investigations may be required. DairyFIX can also make a prediction about next season's performance given various management strategies.

Discussion

DairyFIX will assist users to adopt an agreed method of investigating herd reproductive problems. In many cases the main modifiers of performance such as calving pattern, heat detection and nutrition will be identified as the principal areas for concern. In cases where unusual performance changes are being experienced then DairyFIX will recognize this and more detailed clinical investigations may then be required. For veterinarians, the system should automate the task of working through the investigation of an individual herd. The aim is to identify the problems and produce only the relevant reports that can be used for discussion with the herd manager.

The Limitations of DairyFIX

Because DairyFIX users a set of pre-defined rules there is limited opportunity for changing the inference process in a completed software package. Expert systems will never replace the human expert. The decisions required to resolve a problem, remain the domain of the consultant veterinarian and farmer. There will always be aspects of human thought such as the ability to make judgments that are not easily replicated by a computer program.

DairyFIX will quickly produce results is a standard and repeatable format.

DairyFIX: System Documentation

Purpose of DairyFIX

DairyFIX is an expert system that automates the investigative process that human experts use when assessing the performance of seasonally calving dairy herds and the diagnostic process that is appropriate where reduced performance is identified. The system is mostly limited by the available data that can be retrieved from DairyMAN although the user has the option of manually entering some or all data.

This section describes the technical details of the development version of DairyFIX and the algorithms and expert logic used for the interpretation of herd data. This version of DairyFIX can be operated and tested by suggesting hypotheses within the Smart Elements environment or by running a compiled version that has preset modes for initiating the investigative process. The compiled run-time version opens with a banner screen shown in Figure 55 and then loads the main interface shown in Figure 56. The development version used within the Smart Elements testing environment can be run using any of the sophisticated features of the expert system shell. This includes the forward or backward chained investigation of rules within specific domains or an exhaustive test of all rules used in DairyFIX.

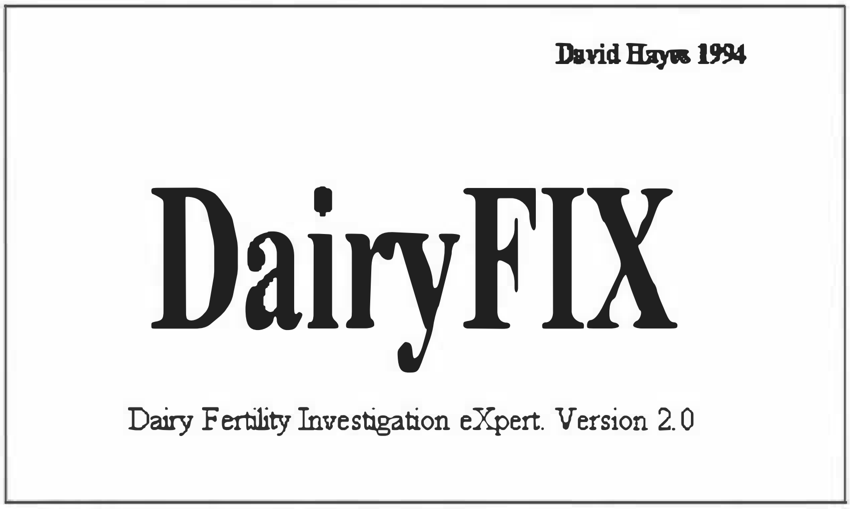

Figure 55 Introductory banner for the developement version of DairyFIX

Model Estimates as Predictors of Performance

DairyFIX uses a combination of heuristic knowledge and mathematical algorithms used to compare a herd's performance with targets. The heuristic knowledge (expert opinions and "rules of thumb") were derived from the literature. The algorithms included in some rules were derived primarily from the individual cow analyses detailed in the previous chapters and from the literature. These statistical models of individual cow performance were compared with previously published data when available. Provided there were no inconsistencies that could not be explained, the models were incorporated into the system. The estimates from these models give an expected herd performance after some preliminary data is provided for the herd. A forward stepwise process is used where performance is re-evaluated against the models with each additional performance or demographic variable added to the analysis. The process is similar to that previously described by Brightling et al (1990) in that a herd's calving pattern and heat detection are always considered first in an automatic run of DairyFIX. This is because many causes of reduced performance can be explained by these two factors alone. The impact of any other variable cannot be easily assessed unless the influence of the herd's calving pattern and heat detection have been accounted for. Using this forward stepwise process, aspects of performance can be identified as the primary causes of reduced performance. Variables are generally added in a similar order to the path models shown in the analysis of herd data. As the statistical models of individual cow performance were derived from herds with superior performance, each of these rules tests the hypothesis that the herd under investigation has performance that is either superior to, the same as or inferior to these herds. In some cases the outcome of these models of individual performance, given other expert knowledge, was considered inappropriate and another relationship usually based on the path model of herd level factors, was used for the particular rule. All relevant statistical models can be found in the Appendix.

Summary of the DairyFIX Knowledge Base

The general detail has been discussed in the previous chapter. The investigation of a herd's reproductive performance is based on the data reported in the DairyMAN reproductive monitor. Some additional data is retrieved to more accurately quantify performance and the user must supply the answer to a small number of questions.

The process follows steps as outlined below:

1. Identify Problems

The in-calf rates are used as the overall measure of herd reproductive performance. Should these fall below target then a problem exists. The system will however investigate each area of performance that is below target. The user has the option of initiating an immediate investigation within a particular area (eg submission rates) by "suggesting" a problem in that domain regardless of the system's initial assessment of performance. Although DairyFIX may suggest that overall performance is adequate this could be the result of superior performance in one area combined with lower performance in another. In this case there may still be opportunities for this herd to improve performance. Each performance aspect is therefore considered independently.

2. Determine the Effects of the Calving Pattern on the Outcome of the Mating Season

The single most important influence on seasonal herd reproductive performance is the calving pattern. This has been reported many times (Brightling, Larcombe, and Malmo, 1990) (Holmes and McClintock, 1995) and is demonstrated in all of the herd and individual cow models presented in the preceding chapters.

3. Estimate the Heat Detection Efficiency and Accuracy in the Herd Using All Available Information

Heat detection is the most difficult variable to assess because there are no accurate direct measures available in seasonal herds. As previously described the various measures can be confounded by the cycling pattern of cows in the herd (short returns), anoestrum, the period of heat detection and changes in the accuracy of heat detection over the mating period. It is possible that heat detection accuracy changes significantly during the mating period. It is recognised for example, that heat detection patterns change when bulls are introduced into the herd usually at the end of the fifth or sixth week of mating. This can occur because new errors are introduced (bulls mounting cows in the yard. These cows may not be on heat but rather unable to move). Accuracy may also increase if tail paint and paddock observations are a part of the heat detection system on farm. Herd managers may not record many of the matings to bulls, particularly if the herd is pregnancy tested, as there is no immediate need to observe heat.

For these reasons there are several methods for assessing heat detection. The proportion of heats missed is the most important aspect of heat detection and the most important measure of this is the ratio between double and single cycle intervals. This measure is very specific but sensitivity may be low if the period of heat detection is short.

The user is ultimately given the option of providing alternative figures for the heat detection accuracy and running the knowledge process using this data if necessary.

4. Investigate Specific Areas of Performance; Submission and Conception

If submission rates or conception rates were below target or if the user "suggests" a problem in this area then the investigation of this area of reproductive management is initiated. Again the effects of the calving pattern are first quantified and then the effects of heat detection assessed. Any residual deficiencies in performance are then investigated.

5. Additional Aspects of Herd In-calf and Empty Rates

If the 8 week in-calf rates are below performance targets or the herd empty rate is higher than target then aspects of the later part of the mating season are investigated in addition to any previous investigation of submission rates or conception rates. This includes an assessment of bull management and factors that may explain variations in performance with time.

6. Predicting Herd Performance in a Subsequent Season

An estimate of a herds performance for a following season can be calculated if the demographic profile, including culling and stock purchase information, is provided. In this way the user can determine the impact of current management skills or levels of performance over more than one year. This system can assume equivalent performance to the year under investigation or consider options for changes in performance. (eg. what would the expected outcome for a herd be if heat detection remained at an assessed level or what would happen if heat detection was improved by a measured amount). In some cases a more severe problem will be identified in following years because the calving pattern is deteriorating. The system does not consider the longer term effects of changes in cow body condition or pasture cover which is beyond the scope of the project. These factors can be modelled in systems such as FarmORACLE (Sauter, Morris, et al. 1996) or UDDER (Larcombe, 1990) and the results entered into DairyFIX.

Modular Approach

The expert system was partitioned into a number of modules to aid development, allow independent modification of different parts and because this approach separated the logical steps required to investigate the performance of an individual herd. Some of these knowledge "islands" can be run as completely separate entities if required.

The modules or knowledge base files are [a] :

DairyFIX.kb	Retrieves data from the DairyMAN reproductive monitor and then compares performance with targets and goals. Identifies problems to investigate.
Heats.kb	Estimates the heat detection efficiency and accuracy and evaluates the effects of heat detection on each performance variable.
Action.kb.	Determines which aspects of performance require specific investigation after the above knowledge bases have been run.
Calve.kb	Estimates the effect of calving pattern on the reproductive outcome for the herd (in-calf and empty rates).
Submission.kb	Investigation of aspects of submission performance that includes additional data from DairyMAN
Preg.kb	Investigates aspects of poor conception rates or non-return rates.

In-calf.kb	Some additional investigations of in-calf rates and changes in performance with time. There is a focus on the performance during natural matings where heat recording and measures of conception rates may be very inaccurate.
Predict.kb	Estimates the expected performance of this herd given a defined calving pattern and demographic profile for the next season.

(a All Smart Elements knowledge base files have the extension "kb"

The knowledge bases that investigate specific areas of performance such as "submission.kb" or "preg.kb" can be activated independently or called from the "Action.kb" knowledge base which in the automatic investigation controls the initiation of investigation for the different areas depending on the results of the Stage I and Stage II that are described in detail below. The development interface for the run-time version of DairyFIX is shown in Figure 56.

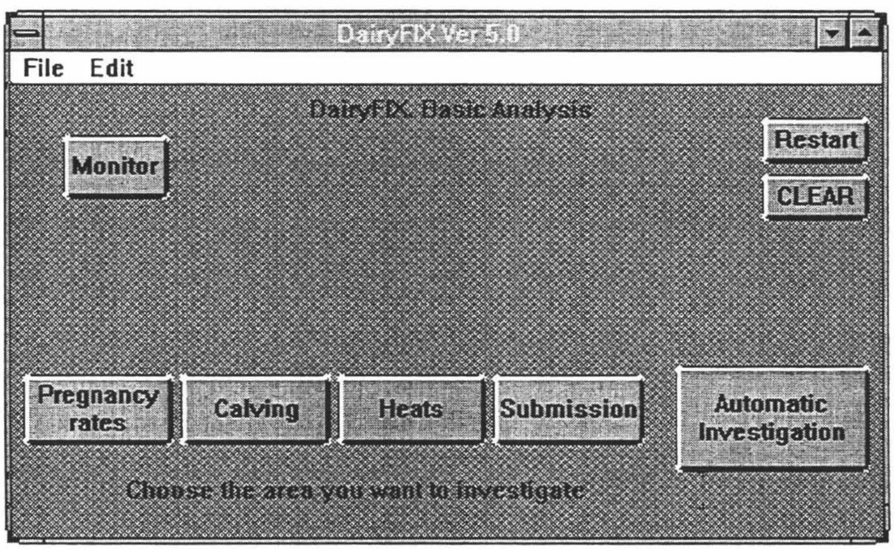

Figure 56. Main interface for the development version of DairyFIX showing user options that the system provides to initiate an investigation. The "monitor" button provides a comparison of performance against the target levels for each performance and diagnostic indicator shown in the DairyMAN reproductive monitor. This is the stage one investigation. An automatic investigation covers all aspects of performance and identifies the key problems. Specific investigations can be done using the other options.

DairyMAN Data for Investigation

The preliminary investigation requires data from two DairyMAN reports. These are the "Reproductive Performance Monitor" (Table 56) and the "Stock Profile at PSM" (Table 57).

Table 56. Sample of a DairyMAN herd reproductive monitor used as the basis for a DairyFIX investigation [a].

REPRODUCTIVE PERFORMANCE MONITOR

Update date 19/05/95

	PERIOD 1	TARGET
CALVING PERFORMANCE:		
Planned Start of Calving	04/08/94	
Date to End Calving Analysis	01/01/95	
Cows to Calve at PSC	293	
Cows Calved	291	
Percent Induced	10 %	10 %
4 Week Calving Rate	73 %	67 %
8 Week Calving Rate	98 %	95 %
SUBMISSION RATES:		
Planned Start of Mating : Begin	20/10/94	
End	20/10/94	
Cows to be mated	284	
Percent 2 year olds	21 %	25 %
Percent Calved < 40 days at PSM	10 %	10 %
Percent Reproductive Disorders	4 %	20 %
21 Day Submission Rate	80 %	90 %
28 Day Submission Rate	86 %	92 %
RETURN INTERVALS:		
Heat/Service Date Range : Begin	01/09/94	
End	01/05/95	
Return Intervals: % 2 - 17 days	18 %	13 %
% 18 - 24 days	56 %	69 %
% 39 - 45 days	5 %	7 %
Ratio of (18-24 cyc):(39-45 cyc)	12 : 1	9 : 1
CONCEPTION RATES:		
Conception Date Range : Begin	20/10/94	
End	01/05/95	
1st Service 49 Day NR	65 %	61 %
Total Services 49 Day NR	69 %	61 %
1st Service Pregnancy Rate	53 %	60 %
Total Services Pregnancy Rate	53 %	60 %
Services per Conception	1.9	1.7
IN CALF RATES: (by Preg Test)		
4 week In Calf Rate	57 %	57 %
8 week In Calf Rate	85 %	86 %
% Not In Calf By PSM + 100 Days	8 %	7 %
PREGNANCY LOSS:		
Date Range For P.D. : Begin	01/12/94	
End	01/06/95	
No. of Completed Pregnancies	1	
Av. Gestation at P.D. (weeks)	12	
Percent Abortions	100 %	5 %

a Targets shown are the default targets used in DairyMAN.

Table 57. Stock Profile data exported from DairyMAN in ASCII test format for use in DairyFIX

object		wktotal[a]
calved_20		7
calved20_39		30
calved40_59		52
calved60_79		108
calved_79		49

a This gives the number of cows in each class. Herd size is taken from the reproductive monitor.

Preliminary Data Supplied by the User

The user of the DairyFIX expert system must provide some information to allow the inference process to initiate. The Smart Elements development environment allows for the retrieval of information from a data file that has been exported from DairyMAN. In an operational system it would be preferable that the activation of the expert system module automatically initiates the running of certain DairyMAN reports. To produce these reports the user must enter or have predefined the criteria for each report. This includes the date ranges to include in the analyses and the criteria for calculating non-return rates within DairyMAN. Such information could also be available to the expert system module if required. The expert system also asks if the herd is pregnancy tested or if non-return is used as the measure of conception rates and therefore herd in-calf rates. The estimation of a herd's performance uses lower targets and the model estimates of performance tend to be lower where the herd is pregnancy tested. The period of heat detection must also be provided by the user. The knowledge base uses this data to assist with a calculation of the number of heats missed.

Knowledge Processing Stage One: Compare Performance with Targets

Load the Performance Target File

The cut off criteria for each performance variable is stored in an ASCII text file (Table 58) that DairyFIX loads at the beginning of the inference process and before retrieving any DairyMAN herd data. The values in this file can be readily modified so the system can accommodate changes in expected performance.

Table 58. Warning action and target criteria for herd reproductive performance. The data is in alphabetical order as this was required by the Smart Element data interface

object	warning	action	target
abortions	7.0	10.0	5.0
cows_calved_less_40_days	20.0	25.0	10.0
eight_week_calving_rate	85.0	75.0	95.0
eight_week_incalf_rate	75.0	65.0	86.0
four_week_calving_rate	60.0	50.0	67.0
four_week_incalf_rate	50.0	45.0	57.0
induced	15.0	20.0	10.0
nonreturn_all_serve	55.0	45.0	62.0
nonreturn_first_serve	55.0	45.0	62.0
not_in_calf_rate	10.0	15.0	7.0
pregrate_all_serve	50.0	40.0	60.0
pregrate_first_serve	50.0	40.0	60.0
ratio_heats	6.0	4.0	9.0
reprodisorders	25.0	30.0	20.0
returns_18_24_days	58.0	50.0	69.0
returns_2_17_days	20.0	30.0	13.0
returns_39_45_days	12.0	15.0	7.0
serves_per_conception	2.0	3.0	1.7
submission21	80.0	75.0	90.0
submission28	85.0	80.0	92.0
two_year_olds	35.0	40.0	25.0

Load Individual Herd Performance Data

DairyMAN Reproductive Monitor Data

The reproductive monitor for an individual herd is exported from DairyMAN (for DOS) as an ASCII text file that can be loaded into the Smart Elements inference process as described above (Table 56). The stock profile at the Planned Start of Mating (Table 57) is also loaded at this point.

Establish Date Ranges

Before the performance of a seasonal herd can be assessed using the data from DairyMAN the validity of the information must be checked. DairyMAN stores a data called the "Update date". This is the data that the last information has been entered into DairyMAN and approximates the period that DairyMAN has valid data for. The update date for the information from DairyMAN must be greater than or equal to the calving end date to allow the calving performance data to be investigated. Provided this criterion is met, the DairyFIX knowledge processing will commence. The investigation of more specific information will only proceed if the update date is appropriate for the particular analysis.

The user is also shown the date recorded in the DairyMAN reproductive monitor for the herds planned start of calving (PSC) and the planned start of mating (PSM) and asked to verify that they are correct. If the answer is no, the system advises that the DairyMAN report must be repeated and ceases the inference process.

Establish if Problems Exist

The stage one knowledge base (DairyFIX.kb) compares the performance for each variable in the reproductive monitor with the performance goals. Each variable is classified into a performance range

1. Achieves the target objective
2. Does not achieve target
3. Performance is in the warning range
4. Performance requires prompt action

Depending on the type of performance variable, improved performance may be associated with an increase or a decrease in the numerical value. The system assumes that there is no upper limit to performance. This is a reasonable assumption for most indicators of seasonal performance, but does not recognise, for example that some herd managers may have an upper limit to the concentration of calving that is determined by feed demands.

Output Stage One

Text Report

The DairyFIX expert system produces a series of text reports that summarize the areas of poor performance. Only those variables that are below the performance target, in the warning or in the action range are reported in these files. The complete set of text file output options is found in the Appendix. Performance that is above target is reported on screen as the system processes the data. The predefined text associated with each description is specific for each of the performance classifications. It provides the user with an indication of the importance of the findings, some recommendations and the steps that will be followed in DairyFIX.

DairyFIX analysis of basic information.
DairyFIX. Calving Performance

The percentage induced is 3.0 percent and below the industry accepted level. We will evaluate this in relation to your herd's calving pattern as increased inductions may be indicated.

The four week calving rate is 68.0 percent and is above target. Good calving performance will have a positive effect on the potential outcome of the mating season. the analysis to follow will consider this performance.

The eight week calving rate is 90.0 percent and is below target. The reduced calving performance may have a negative effect on the potential outcome of the mating season. The analysis to follow will consider this performance.

Submission Performance

The number of two year olds calved is at an acceptable level and not likely to affect reproductive performance at 24.0 percent.

The percent of cows calved less than 40 days is 15.0 percent. This is above target and therefore could affect the reproductive performance of the herd. This will be investigated further

There were no cows recorded as having reproductive problems during the mating season being analysed. This suggests they were not being recorded

The 21 day submission rate is below target at 85.0 percent.

The 28 day submission rate is below target at 90.0 percent

Heat Detection Performance

The 18 to 24 day returns is below target at 63.0 percent.

The number of returns between 2 and 17 days is in the warning range at25.0 percent.

Conception Performance

You have pregnancy tested ALL cows. The pregnancy rate information will be more accurate than NON-RETURN analysis. Non-return information is reported but will usually be excluded from the analysis.

The Pregnancy rate for first services is 31.0 percent and is in the action range

The pregnancy rate for all services is 34.0 percent and performance is very poor.

The non return rate for all serves is 55.0 percent and is below target.
Non-return rate for all serves is 55.0

The first services non-return rate is 40.0 percent and is in the action range.

The serves per conception is in the warning range at 2.9 percent.

In-calf Rates

There were NO abortions recorded during the period being analysed

The four week in-calf rate is 37.0 percent and requires action. Performance next season may be seriously compromised. We will predict next year's performance

The eight week in-calf rate is 68.0 percent and is in warning range.

The percentage of cows not in calf at 100 days is 22.0 percent and is in the action range

Figure 57. An example stage 1 text output from DairyFIX

Evaluate Heat Detection

User Information

The user of the DairyFIX expert system is asked to provide their own assessment of heat detection efficiency and accuracy. There are two reasons for this.

1. If the DairyMAN records cannot provide a useful measure of heat detection then the user's estimates are used for subsequent investigations of performance. The user is given the opportunity to replace the calculated figures.

2. The herd manager's understanding of heat detection problems is compared with an assessment derived from the data. If the herd owner's assessment is much

better than the calculated values then this may suggest a lack of understanding and recognition of a significant problem affecting herd performance. A specific rule is "fired" in these circumstances and the conflicting data is reported to the user with an explanation.

Heat Detection Accuracy: False Positive Heats

DairyMAN Reproductive Monitor

The proportional incidence of return intervals that are less than 18 days can be used to estimate the accuracy (proportion of false heats recorded) of heat detection. The variable is however modified by a number of other variables including.

1. The period of heat detection
2. The number of genuine short cycles between 8 and 12 days

The proportion of true short returns may vary between 7 and 14 percent of all return intervals (Macmillan, 1990). For example, if the proportion of short returns was 25 percent then 7 to 14 percent may be true short returns and 11 to 18 percent may be false heats. This is consistent with the individual cows data reported in Chapter 2. Returns longer than the normal oestrous interval may also be false heats. If all returns of greater than 24 days are excluded then the proportion of normal to short returns is a measure of the heat detection accuracy provided that the number of true short returns is accounted for.

To establish a standard comparison between herds for the accuracy of heat detection the following equation was used :

$$FalseHeatRate = \left(\frac{Short\_returns}{Normal\_length\_returns} - 0.15 \right) \times 100$$

This is an estimate of the false heat detection rate derived from the linear relationship between the proportion of short returns and the proportion of normal returns described in Chapter 2 and relationships described in the literature (Brightling et al, 1990) It assumes that up to 15 percent of returns can be in the short range in herds than have a zero false heat rate. The upper limit for this figure was set to 40 percent using a separate rule in the expert system knowledge base. The system would therefore not accurately represent any herd that had a false heat detection rate of greater than 40 percent, but this is considered extremely rare. No herds with performance at this level were identified in any of the evaluations of herd performance in the previous chapters. These upper and lower limits were described by Brightling, Larcombe, and Malmo (1990).

Heat Detection Quality: Proportion of Heats Missed

DairyMAN Reproductive Monitor Data

Provided that matings are recorded for a sufficient period the proportion of normal single cycle returns (18-24 days) to double cycle returns (36-48 days) can be used as an accurate measure of heats missed (Morris, 1980).

$$HDR = \frac{(\%18-24)-(\%36-48)}{(\%18-24)} \times 100$$

Other DairyMAN data

Alternative measure of heat detection are used if the return interval analysis is not complete. In particular the average interval between heats will give some indication of the number of heats missed if we assume that cows with one recorded heat do continue to cycle. The formula used is : This rule is fired if the period of heat detection is less than 9 weeks as the above rule becomes inaccurate.

$$HDR = \frac{21}{ABI} \times 100$$

Veterinary Examination of Individual Cows

Treatment of anoestrous cows is a common practice in New Zealand. This requires an examination by a veterinarian to determine if the animals are not cycling or have not been detected on heat. The individual results from these veterinary visits can provide useful information on the extent of an anoestrus problem and heat detection efficiency. The proportion of examined cows that are cycling as determined by palpation is directly proportional to the heat detection accuracy, but will also depend on the period of heat detection prior to the veterinary visit. Also, some cycling cows may have commenced oestrous activity within the period before examination. For example if the visit was three weeks after the start of mating then each cow will have had at least one opportunity to show oestrus if a 21 day true return interval is assumed. If the examination was 6 weeks after the start of heat detection then each cycling cow would have had at least 2 chances of detection. Cows that began cycling in the period before the veterinary visit will have had a variable period to show oestrus but will have cycled at least once.

An approximation of the proportion of heats missed is

$$HM = \frac{C}{N - A} \times \frac{D}{21}$$

where :

C Number of cows examined at the visit that were cycling

N Number of cows in the herd at the start of mating

A Number of anoestrous cows examined

D Days from start of heat detection to Veterinary Visit date

where 21 is assumed to be the average return interval for dairy cows

If a herd of 200 cows had a veterinary visit three weeks after the start of mating and did not use pre-mating heat detection then if 10 of 50 cows without heats recorded were found to be cycling, the heat detection rate is :

$$HM = \frac{10}{200-40} \times \frac{21}{21} = 0.06.$$ That is 6 percent of heats missed

The expert system does not attempt to differentiate between the two methods of calculating the proportion of heats missed if the ratio of double to normal cycles is ruled out as a valid method and significantly different values are obtained by the different methods. The system reports the figures to the user and asks them to nominate a value to use. An average of the two figures is highlighted as the default selection.

Output

The results of the various alternatives for assessing the heat detection in an individual herd is a percentage incidence for heats missed and the mating of cows not on heat. These figures are used in the expert system to determine the impact of heat detection on the reproductive performance indicators. The proportion of missed heats is the most important variable of the two because submission rates are reduced as the number of cows missed increases. Mating cows not on heat has little effect on submission rates (Brightling et al 1991) and will not affect in-calf rates although conception rates are reduced. These figures are displayed for the user before knowledge processing continues. The figures can be modified if required at this stage by the user.

Recommendations

If heat detection is identified as a problem and heats are being missed a list of possible solutions is provided for the user to consider. No attempt is made to determine if the suggestions are already implemented for the particular herd. The suggestions include :

1. Tail Paint and proper maintenance of tail paint
2. More observation time in the paddock
3. Improved cow identification
4. Use pre-mating heat detection with accurate recording of dates
5. Kamars and electronic aids including pedometers or some recently developed electronic transmitters for identifying cows on heat could be considered, but these are expensive
6. If heat detection is very poor teaser bulls could be considered
7. Proper training of staff and emphasising to them the importance of heat detection. Provide the appropriate DairyMAN reports and results of veterinary visits to illustrate the problem when it occurs.
8. Seek the advice of a human expert

If cows are being mated when not on heat the user is advised that this may not be a serious problem but may be affecting performance if it is due to mis-identification (so cows are also being missed when on heat) and there is a cost for inseminating the additional cows. If the herd manager does not use early pregnancy testing then this is suggested as an option as the expected calving dates based on non-return will be in error.

Knowledge Processing Stage II: Determine the Effect of Calving Pattern and Heat Detection on Performance

The next action to follow the initial classification of each variable into performance categories is to load the "Action.kb" knowledge base. This is a small set of rules that loads the appropriate knowledge bases for each identified problem or initiates a complete investigation. The performance variables that define a problem are the calving rates, submission rates, conception rates and in-calf rates. The user can choose to perform an automatic investigation where a "problem" is initially defined if the in-calf rates are below the target values. Alternatively the user can select an area of performance that is identified as below target or implicitly state that a problem exists in a particular area even if the expert system has not identified a problem in stage 1. After a problem is defined then the expert system assesses the impact of the calving pattern and heat detection on overall in-calf rates in the case of an automatic investigation or within a particular area if the user chooses this option.

Automatic Inference processing

The data in the "days calved and age profile at the PSM" report (Table 57) that is imported into the system from DairyMAN and the indicators of heat detection efficiency can be used to calculate an expected herd performance for in-calf rates using the statistical models. The actual performance is then compared to this calculated value. If performance is the same or superior to the calculated performance then the conclusion is that these factors account for most of the problem within the herd under investigation. On the other hand if performance is still below the expected performance then there are other factors requiring investigation. Associated with a low in-calf rate due to a poor calving pattern there will be a reduction in either submission or conception rates that are also a consequence of the calving pattern. Detailed investigations of each of these areas is performed if the calving pattern and heat detection do not adequately explain the problem or if performance was below the target value for submission or conception rates. If the in-calf rates are below target but neither the twenty one day submission rate or conception rates are below target then the investigation continues with an evaluation of the performance of different subgroups using the in-calf rate data. This is most likely to occur where the herd has had problems during the latter half of mating and where bulls are commonly run in the herd for natural mating.

The expected four week in-calf rate for the herd is calculated using the rule definition shown in Figure 58. This rule divides the herd into each of the five groups of cows based on days calved at the PSM that is reported in the DairyMAN stock profile report. The in-calf estimates for each group are derived from the statistical models of individual animal performance with the days calved at PSM being the only independent classification variable (Table 59). The expected performance of each group is multiplied by the proportion of the herd in that group and this is summed to give an overall estimate of the herds expected performance based on the herds calving pattern. The results of this rule give an estimate of the herd's expected in-calf rate performance assuming that in other respects the herd's reproductive performance is typical of a New Zealand herd including the accuracy and quality of heat detection. This model only applies to herds that pregnancy test, however it does account for a proportion of animals being assumed pregnant based on non-return, in a similar manner to the calculations used in DairyMAN.

```
(@RULE=        R_four_week_incalf_rate_expected_evaluated
                    (@LHS=
              (Yes    (Profile_at_psm_loaded))
              (Execute("CreateObjects")
(@WAIT=TRUE;@ATOMID=|parameter|;@STRING="@ROOT=d4,\
              @NUMOBJS=5";))
     (Assign  (20.4*calved_20.wktotal)               (d4_1))
     (Assign  (48.6*calved20_39.wktotal)             (d4_2))
     (Assign  (61.1*(calved40_59.wktotal)            (d4_3))
     (Assign  (70.2*(calved60_79.wktotal)            (d4_4))
     (Assign  (70.3*(calved_79.wktotal))             (d4_5))
  (Assign  (d4_1+d4_2+d4_3+d4_4+d4_5)   (four_week_incalf_expected))
                         )
  (@HYPO=       four_week_incalf_rate_expected_evaluated)
```

Figure 58. The DairyFIX code in text format from the Smart Elements environment for the rule calculating the predicted four week in-calf rates for pregnancy tested herds. Each "Assign" statement multiplies the expected in-calf performance for each of 5 groups classified by days calved by the proportion of the herd in the class. The last "Assign" statement sums these to give a total herd value.

If non-return data rather than pregnancy testing has been used to calculate in-calf rates then the appropriate estimates shown in Table 59 are substituted in the rule. Therefore a similar approach is used for herds that have non-return data only, but the model coefficients are different because the outcome variables including the four week and eight week in-calf rates tend to be overestimated when non-return calculations are used. The statistical model estimates for the probability of being in-calf in four and eight weeks after the PSM are also shown in (Table 59).

Table 59. Comparison of the model estimates used in DairyFIX and some estimates previously reported by Brightling (1990) for pregnancy tested herds and model estimates for herds using non-return criteria

	In-calf 4 weeks				In-calf 8 weeks			
	Non-Return	Pregnancy tests			Non-Return	Pregnancy tests		
Days calved at PSM	Model Estimate	Model Estimate	Nil heats missed [a]	10 % heats missed [a]	Model Estimate	Model Estimate	Nil heats missed [a]	10 % heats missed [a]
<20	26.9	20.4	22	21	69.2	61.3	69	68
20-39	50.4	48.6	50	46	82.1	77.6	87	85
40-59	64.1	61.1	69	64	88.0	84.7	93	91
60-79	71.4	70.2	74	69	91.0	88.9	94	93
>79	72.6	70.3	74	69	91.3	87.8	94	92

a Data from Brightling, 1990.

If the actual herd performance measured by the in-calf rates is superior or equal to the estimated performance then the system assumes that any performance below target is due to the effects of the herd calving pattern. Alternatively, the effects of the herd calving pattern may not account for all of the reduced performance. In this case other factors (not yet identified specifically by the system) are contributing to the reduced performance and are then investigated.

The distribution of the cows in a herd by days calved at the PSM is a direct consequence of the herd calving pattern (and any removals between calving and the PSM), however unexpected effects will occur if the herd has shifted the planned start of mating (PSM) relative to the planned start of calving (PSC). If the difference between the herd PSM and PSC is less than 83 days then the start of mating has been moved forward by the herd manager and this decreases the number of days calved for each cow at the PSM. In this case the system may report that the calving pattern is the major contributor to the poor performance when it is actually the shift in the PSM that has caused a negative effect for the particular year's performance being assessed. Where the days calved profile is shown to be a cause of reduced performance then the dates from the reproductive monitor are checked to determine if the PSM has been moved relative to the PSC. If this is true then this effect is reported to the user. The rule for assessing if the PSM has been changed relative to the PSC is shown in Figure 59.

```
(@RULE=        R_Earlier_psm_has_reduced_submissions
        @COMMENTS="This rule determines if mating has been moved forward from 0-160 days ";
        (@LHS=
                (Yes    (four_week_calve_rate_abovetarget))
                (Yes    (PSMCAT_accounts_for_low_submissions))
                (Yes    ((PSM-PSC) >0 and (PSM-PSC)<80)
        )
        (@HYPO=         Earlier_psm_has_reduced_submissions)
)
```

Figure 59. Rule to determine if the planned start of mating (PSM) has been shifted relative to the planned start of calving (PSC) within the season under investigation.

The estimated performance based on the herd calving pattern has been derived from herds using the DairyMAN program. These models did not include a measure of heat detection. The estimate therefore assumes that the heat detection is typical of a New Zealand dairy herd using DairyMAN. Although there is no direct information to indicate the proportion of heats missed this has been estimated from the herd data including the ratio of double to normal cycles as approximately 6 percent (see Chapter 2) .

Reasons for a Calving Pattern Below Target

The system has only limited information for the reasons for a poor calving pattern if this is identified as a problem. If the data is available the system recommends that the previous season is investigated to identify if performance in the preceding mating period was a factor.

If the rate of calving induction is below the industry target and the calving performance is also below target then the user is advised to consider an increased induction rate to improve the situation, if necessary, in subsequent seasons. The user is cautioned to ensure that cows selected for induction are maintained in above average body condition and induced to calve as early as possible so that the reproductive (and milk yield) improvement is optimized. If calving inductions are at or above the industry target and the four week calving rate is below target but the eight week calving rate is acceptable and induced calvings are occurring late in the calving season then the user is advised to consider earlier calving induction. In this current version of DairyFIX some of this data cannot be retrieved from DairyMAN and must be provided by the user when the information is requested by the system. The rules considering this issue are "fired" if the calving performance is below target.

DairyMAN does not record any cows as failing to calve if data is not present for the previous season. If the number of cows that fail to calve is greater than 4 as recorded in DairyMAN the user is asked the following questions :

Was pregnancy testing used in the previous season?

Were abortions observed for these cows?

If pregnancy testing was carried out for the entire herd then the user is advised to print a complete history for these cows and discuss the issue with their veterinarian to determine if an abortion problem or recording problem exists. If pregnancy testing was not used then a recommendation is made to consider pregnancy diagnosis of the complete herd to ensure empty cows are not carried over. If abortions were observed or have been recorded in DairyMAN the user is again advised to discuss the problem with their veterinarian.

Effect of Heat Detection on the In-calf Pattern

The expert system assumes that cows mated when not on heat will not alter the in-calf rates for a herd and that missing cows on heat will reduce the herd in-calf rates. This is an accurate assumption, however it does imply that the sensitivity and the specificity of heat detection within a herd are independent effects that can be evaluated separately. This may not always be valid because herd managers that do not have the ability to identify cows on heat will tend toward a random mating. This means that while cows not on heat will be mated, some cows that are on heat will also be missed. Confusing the signs of oestrus, for example identify a mounting cow as on heat rather that the cow being mounted may also cause a similar interaction in the two aspects of heat detection. Further, errors in cow identification may confound the measures of heat detection. Although the two measures of heat detection may not be independent the expert system is robust provided that the measures of heat detection are reasonably accurate.

The measure of heats missed can be used to reassess the expected in-calf rates for each week during the mating period. However, any effect that reduces the proportion of the herd that becomes pregnant in a period will increase the number of cows to be mated in subsequent periods. An approximation of this effect for the first three weeks of mating is simply the calculated in-calf rate less the calculated in-calf rate multiplied by the proportion missed if all cows are assumed to cycle at 21 day intervals. This can be represented as;

$$I_h = I_a - (I_a \times Hm)$$

where;

I_h is the expected in-calf rate that accounts for the proportion of heats missed
I_a is the actual in-calf rate
Hm is the proportion of heats missed.

However to estimate the four week in-calf rate the cows not becoming pregnant during the first week because of missed heats will increase the "available" cows in the fourth week of mating.

The expert system uses the approximation to reduce the effect of the heats missed on the expected in-calf rate using the following adjustment.

$$I_h = I_e - (I_e \times (HM + 0.06) \times 0.9)$$

where;

I_h Estimated in-calf rate adjusting for heat detection
I_e Estimated in-calf rate after adjusting for the calving pattern
HM Heats missed with a 0.06 adjustment to account for the estimated population rate of missed heats

As the data collected as part of the development of the DairyFIX expert system did not include specific information on heat detection efficiency this adjustment has been derived from the literature (Brightling, Larcombe, and Malmo, 1990). Also the estimate of in-calf rates based on the calving pattern includes all data in the model and therefore assumes a typical heat detection efficiency. The rate of missed heats has previously been estimated at 6 percent and a correction is included in the knowledge base at this point (HM). Figure 60 shows the DairyFIX rule for estimating expected four week in-calf rates with heat detection included.

```
(@RULE=R_four_week_incalf_rate_expected_evaluated for heats
    (@LHS=
        (Yes        (Profile_at_psm_loaded))
        (Execute    ("CreateObjects")
    (@WAIT=TRUE;@ATOMID=|parameter|;@STRING="@ROOT=d30,\
        @NUMOBJS=5";))
    (Assign    ((20*(1-0.9*heats_missed))*calved_20.wktotal)       (d30_1))
    (Assign    ((48*(1-0.9*heats_missed))*calved20_39.wktotal)     (d30_2))
    (Assign    ((61*(1-0.9*heats_missed))*(calved40_59.wktotal))   (d30_3))
    (Assign    ((70*(1-0.9*heats_missed))*(calved60_79.wktotal))   (d30_4))
    (Assign    ((70*(1-0.9*heats_missed))*(calved_79.wktotal))     (d30_5))
    (Assign    (d30_1+d30_2+d30_3+d30_4+d30_5)    (four_week_incalf_expected for
        heats))
    )
    (@HYPO=        four_week_incalf_rate_expected_evaluated for heats)
```

Figure 60. Rule calculating the expected four week in-calf rate for pregnancy tested herds given the herd calving pattern and estimated number of heats missed. Each "Assign" statement multiplies the expected in-calf performance adjusted for heats missed for each of 5 groups classified by days calved by the proportion of the herd in the class. The last "Assign" statement sums these to give a total herd value. A similar rule is used for estimating the eight week in-calf rates except that the appropriate estimates are substituted.

The adjustment of the eight week in-calf rates for heat detection uses a similar relationship except that the effect is much less as the cows have an increased chance of being detected at a return to oestrus and conceiving to service. It was estimated that the eight week in-calf rate is reduced by 0.2 of the proportion of heats missed

$$I_h = I_e - (I_e \times (HM + 0.06) \times 0.2)$$

The rule used for the eight week in-calf estimation is similar to that for the four week in-calf rate except that the appropriate estimates and corrections are substituted.

Graphical Representation

A graphical representation of the major aspects of reproductive performance is depicted in Figure 61. A summary of the expert system evaluation of herd performance could be depicted using this type of chart in a similar manner to that developed for PigFIX (Wongnarkpet, 1993). Each performance indicator could be shown on screen with a different colour for below target, warning and action levels of performance. Areas that have achieved the required targets or goals could also be displayed in an appropriate colour. The chart shown in Figure 61 could be displayed after the second stage of DairyFIX has been completed.

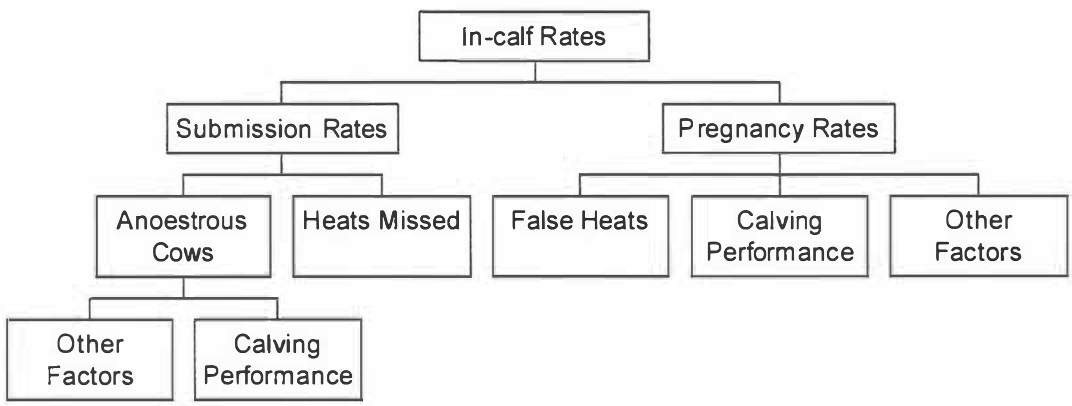

Figure 61. Suggested graphical representation of stage 1 output

Knowledge Processing Stage Three: Specific Investigations

The third stage of the DairyFIX investigation is the more detailed, specific examination of submission rates, conception rates and in-calf rates where they have been identified as problem areas or the user has identified the area as a concern.

Submission rates

Calving Pattern and Heat Detection

The effect of calving pattern and then heat detection are investigated in a similar manner to that described above. The rule calculating an expected twenty-one day submission rate is shown in Figure 62. Submission rates are modified significantly by the pattern of calving.

```
(@RULE=R_submission_exp_evaluated
        (@LHS=
                (Yes      (submission_exp_evaluated))
                (Assign   (46 - (heatmissed*46))          (sub_0.nil_missed))
                (Assign   (82) - (heatmissed*82))         (sub_1.nil_missed))
                (Assign   (95) - (heatmissed*95))         (sub_2.nil_missed))
                (Assign   (99) - (heatmissed*99))         (sub_3.nil_missed))
                        (Assign   (99) - (heatmissed*99))         (sub_4.nil_missed))
                (Assign   (((sub_0.nil_missed)/100)*calved_20.wktotal+((sub_1.nil_missed)/100)*calved20_39.\
wktotal+((sub_2.nil_missed)/100)*calved40_59.wktotal+((sub_3.nil_missed)/100)*ca\lved60_79.wktotal+((sub_4.nil_missed)/
100)*calved_79.wktotal)        (submission.WK3_expectno_nil_missed))
                (Assign
        (calved_20.wktotal+calved20_39.wktotal+calved40_59.wktotal+calved60_79.wktotal+calved_79.wktotal)
        (cows.psm))
                (Assign   ((submission.WK3_expectno_nil_missed/cows.psm)*100)
        (submission.WK3_expectpercent_nil_missed))
        )
        (@HYPO=           submission_exp_evaluated)
```

Figure 62. The DairyFIX rule for estimating the expected 21 day submission rate for the herd under investigation using the profile at the planned start of mating and the proportion of heats missed as the predictors of performance. Each of the first five assign statements calculate the expected submission numbers for each group based on the days calved. The last assign statement sums these values and this is then divided by the number of cows in the herd at the PSM to give a predicted submission rate proportion.

This rule assigns an expected submission rate to each day's calved group and multiplies this number with the number of animals in each group. The sum of these products is the total number of animals that should be submitted. Expressed as a proportion, this gives the expected submission rate for the herd. If this calculated submission rate is greater than the achieved performance then other factors affecting performance need consideration.

Table 60. Submission rates estimates from a Glimmix model with twenty-one day submission as the dependent variable, herd as a random effect and PSMCAT as the only independent fixed variable and an adjusted estimate if no heats are missed.

	Submission Estimate by 21 days	
	DairyMAN data	Nil heats missed [a]
PSMCAT 1	0.42	0.46
PSMCAT 2	0.74	0.82
PSMCAT 3	0.86	0.95
PSMCAT 4	0.90	0.99
PSMCAT 5	0.90	0.99

a Assuming 6 percent of heats missed in the population

A second rule then evaluates the effect of heat detection rates. Twenty-one day submission rates will be reduced by heat detection accuracy. The expected twenty-one day submission rate that accounts for the proportion of heats missed was assumed to be the expected twenty one day submission rate as calculated above but then multiplied by the proportion of heats missed.

Nutritional Anoestrus

If the calving pattern and heat detection do not explain the achieved herd twenty one day submission rates then DairyFIX concludes that a higher than expected proportion of the herd is not cycling. The system therefore concludes that anoestrum is a problem. As nutritional anoestrus is the most common reason for cows not cycling in New Zealand this is evaluated. A set of heuristic rules are activated under this condition and if any one of them is true then nutrition is identified as an explanation for low submission rates.

These are :

1. Average daily per cow milk production is low, before and during mating. Herds with average per cow milk production of less than 1.5 kilograms of Milksolids during mating.

2. Average condition score of the herd is below 4.5 at the start of mating.

3. Cows have lost more than 0.75 of a condition score on average between calving and mating.

4. Veterinary visits identified more than 25 percent of the herd not cycling at the start of mating or more than 8 percent at a visit 3 to 4 weeks after the PSM.

5. The proportion of cows showing pre-mating heats is less than 80 percent. The user is first queried to confirm that all cows have been observed for at least three weeks prior to the start of mating. If this is not true the proportion of cows not seen on heat prior to the PSM as reported by DairyMAN is displayed for the user who is then asked to adjust the figure taking into consideration the actual period of pre-mating heat detection. This can only be investigated for herds that record pre-mating heats. A recommendation to record pre-mating heats is made for those herds with poor submission rates not explained by the calving pattern.

If any of the above criteria are true then DairyFIX concludes that nutritional anoestrus is affecting the herd under investigation. A more detailed assessment of nutrition cannot be made within DairyFIX. The user is advised that underfeeding (of energy) rather than specific deficiencies such as trace elements is likely to be the cause of the herd problem. The user is advised to examine all production records and other information including records of pasture covers and supplemental feeding and any analyses of feed to identify the reasons for a nutritional anoestrus problem. If a solution cannot be reached then professional assistance is recommended.

Age Groups

The effect of the herd's age profile is then examined. The statistical models are again implemented but now include the data for the herd's age profile taken from DairyMAN. (Table 57). The performance of each group is compared with the model estimates taking into consideration the herds calving pattern and heat detection. Age groups that are below the estimated target are reported to the user. This analysis is not a direct comparison of different age groups but rather a comparison with an expected performance within each age group. This is because the expected performance varies with age or lactation number. Groups are only identified if they fall below the typical performance of the group in New Zealand DairyMAN herds.

Where an age group is identified as having poor performance, the number of animals in the group as a proportion of the herd, is also displayed. This is important because there could be a significant problem in older cows but they may represent only a small proportion of the herd. In this case the impact on herd performance is small.

If nutritional anoestrus has been identified as a problem and the two year olds and three year olds have reduced performance then the user is advised that attention needs to be given to the rearing of replacements and the management of the young herd between calving and mating. If the herd is larger than 200 cows a suggestion is made that these cows should be run as a separate group with improved nutrition. The user is also advised to run the specific reports in DairyMAN that analyse performance by age groups to gain more information about the problem and run the reproductive reports for the mated heifers if this data has been recorded in DairyMAN.

Health Events

Information on health events could be retrieved directly from DairyMAN, however this has not been implemented in the current version of DairyFIX for the analysis of submission rates. Reproductive disease has been previously investigated in Stage 1 as this data is directly available from the DairyMAN monitor and any problems are reported to the user at that stage.

The user is asked by the expert system to provide an estimate of the number of cows affected by lameness during the lactation. This is converted to a proportional incidence and if greater than 15 percent the user is advised that lameness may be a factor reducing submission rates. The user is reminded that the reproductive reports in DairyMAN can be processed by health event if the information has been recorded and the performance of the lame cows and non-lame cows can be compared.

As the analysis of individual cow data in Chapter 5 for calving induction shows that submission rates are not significantly different for induced cows compared with non-induced cows in the same herd this not considered as a cause of reduced submission rates in DairyFIX.

Time Frame Analysis of Submission Rates

The investigations so far have only examined the 21 day submission rates for the herd. Regardless of the findings to this point an examination of the submission rates for each week of mating is initiated. Dairy herds in New Zealand almost always have a reducing submission rate from week one to week 3. A rule asks the user to provide this data (it cannot as yet be retrieved directly from DairyMAN) and if this is found not to be true then the user is advised that the herd has an unusual submission rate pattern and there may be significant problems with the initiation of oestrus for cows in the herd and there may be a severe anoestrus problem in the herd (provided that the rule confirming anoestrus as a problem has been processed and is true).

```
(@RULE=        R_some_cows_have_delayed_oestrus
        @COMMENTS="Reducing numbers each week in first three weeks indicates a normal
pattern of submissions. If submissions in the second or third week are greater than in week one then
problems are suspected with heat detection or herd anoestrum is a significant problem
        (@LHS=
                (Yes    (submissions_week_totals_loaded))
                (<      (submission.WK1_weekly_total)   (submission.WK2_weekly_total))
                (<      (submission.WK2_weekly_total)   (submission.WK3_weekly_total))
        )
        (@HYPO=         some_cows_have_delayed_observed oestrus)
```

Figure 63. A rule examining the pattern of submissions during each of the first three weeks. This rule concludes that if submission rates are increasing each week then the herd has an anoestrus problem

The Final Rule for Submission Rate Investigation

DairyFIX will conclude that either the calving pattern or heat detection or anoestrus or any combination of these are the causes of reduced submission rates where this has been identified in stage 1. The system may however identify anoestrus as a problem without being able to provide any reasons for the problem. In this case the problem is outside the domain of DairyFIX and it is likely that a human expert (veterinary consultant) is required. In this case the user is advised that DairyFIX could not identify some of the cause(s) of the low submission rates in their herd and they should carefully check the factors analysed using DairyFIX and check that all information provided is correct. Options for seeking expert professional advice to identify other factors such as trace element deficiencies or other nutritional problems are suggested.

Investigate Conception Rate Problems

The user is asked in the initial investigation during stage 1 if the entire herd is pregnancy tested or if non-return is used. DairyMAN reports conception rates to first and subsequent services in the reproductive monitor for cows that have been pregnancy tested but the proportion of the herd is not shown. Depending on the user's response to this question the rules and models assessing conception rates by pregnancy testing or the models for non-return rates are used in all subsequent analyses of conception rates. The conception rate to first service and to subsequent services is significantly modified by the calving pattern and heat detection as previously described. For this reason these factors are again considered first if a problem is identified with herd conception rates. The model estimates for each group by days calved and the adjustment made for false heats is shown in Table 61. Again if the predicted performance is the same or less than that achieved for the herd at each step in evaluating the model then the system concludes that those factors included in the model explain the cause of reduced performance identified in Stage 1. The calving pattern is first considered and then the herd's heat detection.

Conception rates to first service or non-return rates to first service are mostly used for these investigations as they give a more accurate assessment of cow fertility. Conception rates to subsequent service are considered when attempting to establish if an undetected reproductive disease problem exists in the herd. This is discussed later in this chapter.

Table 61. Model estimates used in DairyFIX for the first service conception rates and the adjustment used for the mating of cows not on heat. Similar models are used for non-return analyses but the estimates are higher. Refer to the appendix for the detail of these other models

Days calved at PSM	Model Estimate	Lower	Upper	Adjusted for false heats
<20	38.6	32.1	45.6	37.7
20-39	46.2	42.3	50.0	43.9
40-59	54.9	51.8	57.9	52.2
60-79	61.9	59.2	64.5	58.8
>79	63.7	60.3	66.9	60.5

If there is still a residual problem then additional data is used to investigate performance problems. This aspect of the current version of DairyFIX has been advanced slightly further than for the knowledge base for submission rates. The system is still however limited by the difficulty with exporting data from the DOS version of DairyMAN. It was decided not to devote resources to developing the DOS version, but rather to implement these changes when the first version of DairyWIN (DairyMAN for Windows) becomes available (The program became generally available in March 1997). In the version of DairyFIX discussed in this chapter the system is able to retrieve data from an text file that could in the future be produced by DairyWIN. During the interim period the order of sources defined within the expert system allows for the data to be entered by the user as a set of individual questions as the knowledge base requires the data. This additional data includes the conception rates (or non-return rates) achieved by each age group, for each sire, for each technician used during the mating period, by time frame (per week) and for a number of health categories including calving induction and lameness. Breeding companies in New Zealand almost universally provide a single technician for a herd, so it is not normally possible to evaluate the performance of technicians within a herd. In this case the DairyFIX system will have identified a problem with conception rates but not the cause.

The statistical models are used to evaluate the effect of the age profile of the herd as previously described. For the investigation of health events, technicians, time frames and different sires a direct comparison of groups is made. This is possible as the performance of each group of cows for these factors should not be significantly different (This is not the case for days calved and age profiles where a pre-existing difference is expected and defined by the statistical models).

Health Events

For any herd that induces more than 2 percent of the herd and where reduced conception rates have been identified in stage 1, a comparison of the conception rates for induced and non-induced cows is made. The lactation one class is excluded because they are rarely induced and the comparison could otherwise be biased. If there is more than a 3 percent difference in the conception rates between the two groups then the effect is reported to the user as a problem. A similar comparison is made for lame cows in the herds and results are reported accordingly.

With calving induction and other factors that are subsequently shown to have reduced a herd's conception rates the number of animals in the herd that have been affected is reported to the user as well as an estimate of the change in the conception rate for the entire herd that has resulted from the poor performance for a particular group. The calculated estimate for the herd is based on the conception rate for the rest of the herd plus an expected conception rate for the affected group if the problem did not occur. The difference between this value and the achieved conception rate gives an indication of the effect on the herd.

Sires

The number of services and the conception rate outcome for each sire used during the mating period are retrieved from the text file and a conception rate (or non-return rate) is calculated. The sires are then ranked in order of performance (Figure 64) and those sires with more than 10 matings with performance more than 5 percent below the herd average are reported. Again the overall effect on herd conception rates is calculated and reported to the user (Figure 65).

```
(@RULE=R_find_poor_sires
        @COMMENTS="write info to file for storage in next herd. Need to check with sires results for other herds could
use variable for performance need to consider time frame";
        (@LHS=
                (Yes        (sires_loaded))
                (<          (pregrate_first_serve.modified)  (pregrate_first_serve.targetlevel))
                (>=         (pregrate_first_serve.modified-<|Sires|>.first_percent)  (20))
                (>          (<|Sires|>.first_number)          (10))
                (Execute    ("RankList")
        (@WAIT=TRUE;@ATOMID=<|Sires|>;@STRING="@RANKBY=first_percent,\
@RANKSET=rank,@INCREASING";))
                (Execute    ("WriteTo")          (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sires.txt,\
@TEXT=The Sires below performed significantly worse than other sires used during\
 the mating season as measured by first service pregnancy rates. @V(<sires>.firs\
t_percent),@NEW";))
                (Execute    ("WriteTo")          (@WAIT=TRUE;@ATOMID=<|Sires|>.first_percent;\
@STRING="@TRANSCRIPT,@FILE=sires.txt,@ADD";))
                (Execute    ("WriteTo")
        (@WAIT=TRUE;@ATOMID=<|Sires|>.rank;@STRING="@TRANSCRIPT,\
@FILE=sires.txt,@ADD";))
        )
        (@HYPO=         find_poor_sires)
        (@RHS=
                (Show       ("sires.txt")        (@KEEP=TRUE;@WAIT=FALSE;@RECT=100,100,300,\
300;))
        )
)
```

Figure 64. The rule in the preg.kb knowledge base that compares the conception rate achieved for each bull against target levels and displays the results for sires with more than 10 matings

```
(@RULE=R_determine_effect_on_PREGrates
        @COMMENTS="determine the effect of parameters poor performance on conception rates.";
        (@LHS=
                (Yes        (find_poor_sires))
                (<>         (<|Sires|>.rank)        (UNKNOWN))
                (Assign     ((<|Sires|>.first_number/nocows)*(pregrate_first_serve.result-<|Sires|>.first_per\
cent))      (<|Sires|>.effect))
                (Execute    ("WriteTo")
        (@WAIT=TRUE;@ATOMID=<|Sires|>.effect;@STRING="@TRANSCRIPT,\
@FILE=effect.txt,@NEW";))
        )
        (@HYPO=         determine_effect_on_PREGrates)
        (@RHS=
                (Show       ("effect.txt")        (@KEEP=FALSE;@WAIT=TRUE;))
        )
)
```

Figure 65. The rule in the preg.kb knowledge base that ranks the sires with poor performance and calculates the effect on herd performance for first service conception rates or non-return rates

Technician

The investigation to identify technicians with poor performance has a similar structure to that for sires. The only additional rule reports the options to explore if there is only one technician used in the herd where there is a reduced conception rate not explained by the factors considered by DairyFIX. The options reported are:

1. Contact the Artificial Breeding Company for a report on the technicians' performance

2. Consider using an alternative technician in the next season

3. Examine the in-calf pattern in detail with the help of a veterinarian. If the herd appears to achieve normal or above average fertility when bulls are introduced into the herd but performance during artificial breeding is poor there may be a problem with the technician. This is also considered by some rules examining in-calf rates (see below), but the complexities require a conservative approach that may prevent the rule being activated. This rule ensures that the possibility is at least reported for further consideration by human experts before other factors causing poor conception rates are investigated.

Time Frame

Conception rates over time are not examined in detail by the expert system. Weeks that have a measured performance that is more than 7 percent lower than the rest of the mating period are reported to the user with a recommendation to examine the time frame analyses in DairyMAN in more detail with the help of the herd veterinarian.

Service Number

In seasonally calving dairy herds there is generally little difference in the conception rates for first, second or third services. In many cases the trend is for a slight increase with service number because the number of days calved at service is also increasing. If the conception rates to second and subsequent services is more than 5 percent lower than the preceding service the user of DairyFIX is advised that there may be a longer term problem with the fertility of a group of cows in the herd. A recommendation to more thoroughly monitor and treat reproductive disease post calving is made. It is also suggested that the DairyMAN reports for each age group be examined in detail to see if there are any particular problems with older cows in the herd.

Final Assessment of Conception Rates

The final rule examining the conception rates in a herd lists each of the factors that has contributed to the reduced performance and that have been previously identified and reported by the specific rules.

In many cases there will be some explanation of the reduced performance, but the models may not adequately explain the complete effect. In this case the recommendation to seek professional advice to investigate other causes including trace element deficiencies is made.

In-calf Rates during the Natural Mating Period

The submission rates and conception rates to first service determine the four week in-calf rates with few other direct effects (see Chapter 7), however the eight week rates and the empty rates may be influenced directly by other factors including the eight week calving rate, age profile, heat detection and any other effects that directly modify the submission rates and conception rates. The effects observed during the period of natural mating may however be very different. Mating may be recorded to a varying level and particularly if the herd is pregnancy tested, the in-calf pattern during this period may not relate well to the calculated conception rates and submission rates. This is because unmeasured changes in heat detection may occur when bulls are introduced. For herds that use non-return analyses any interpretation of the performance of the bulls will usually not be reliable because of poor heat recording.

The expert system will initiate an investigation of the mating performance during the use of bulls under the following circumstances

The herd is pregnancy tested

The eight week in-calf rate is below the performance targets or the herd empty rate is higher that the target

The in-calf rates for the period of natural mating are examined in more detail to establish if any problems can be identified. These rules are activated if the eight week in-calf rate is below target (with or without a problem with the four week in-calf rates) and the weeks with reduced performance are identified (Figure 66). The user is asked if the bulls are rotated and if the answer is yes, it is suggested that there may be problems with some specific bulls.

```
(@RULE=R_bull_weeks_reported
        @COMMENTS="This rule looks at the weeks after the bulls have gone in and looks at those weeks with
performance less than 20 below total performance and then only those weeks with 10 or more matings. these are considered
poor weeks in need of identification. Need to look at in-calf rates and total service rates week\wk\.wkno";
        (@LHS=
                (Yes        (First_serve_periods_loading))
                (Yes        (Get_week_numbers))
                (Yes        (Total_serve_periods_loading))
                (>          (Bulls_in) (0))
                (>          (<|weeks_of_mating|>.wkno)     (Bulls_in))
                (>=         (pregrate_all_serve.modified-<|weeks_of_mating|>.Total_percent)          (20))
                (>          (<|weeks_of_mating|>.Total_number)       (10))
                (Execute    ("WriteTo")           (@WAIT=TRUE;@ATOMID=<|weeks_of_mating|>.Total_percent;\
@STRING="@TRANSCRIPT,@FILE=weeks.txt,@TEXT=Some weeks during bull mating showed \
poor performance. Recording of bull matings needs assessment before conclusions \
can be made. We will also look closely at the in calf rates during those weeks.,\
@NEW";))
                (Execute    ("WriteTo")           (@WAIT=TRUE;@ATOMID=<|weeks_of_mating|>.first_percent;\
@STRING="@TRANSCRIPT,@FILE=weeks.txt,@TEXT=Listed below are the first services p\
regnancy rates for the weeks where total serve performance was low.,\
@ADD";))
        )
        (@HYPO=          bull_weeks_reported)
        (@RHS=
                (Show       ("weeks.txt")         (@KEEP=TRUE;@WAIT=FALSE;@RECT=100,140,300,\
300;))
        )
)
```

Figure 66. The rule identifies the weeks when bulls have been used and identifies those weeks with reduced in-calf rates

The number of bulls used by the herd manager is then assessed if the eight week in-calf rate is below target (Figure 67). The required number is calculated from the estimated number of empty cows in the herd when the bulls are first introduced into the herd. The user is then asked if any of the bulls have been lame and how many have been lame during mating. For each bull reported as having a lameness event the required number of bulls is increased by 0.5. If any lameness is reported the user is also advised to consider alternative management practices including the rotation of bulls more regularly. The user is also asked if yearling bulls are used. If yearling bulls are mostly used the estimated number of bulls required is doubled if not already increased due to reported lameness events. The calculated number is then compared with the actual number and a problem reported to the user if insufficient bulls have been used.

```
(@RULE=R_evaluate_bull_power
        @COMMENTS="This rule looks at in-calf rates ";
        (@LHS=
                (Yes      (bull_weeks_reported))
                (>        (Bull.numbers)        (0))
                (Assign   ((incalf.'denom'\Bulls_in\)-(incalf.'week'\Bulls_in\)/30)(Bull.required))
                (>        (Bull.numbers)        (Bull.required))
        )
        (@HYPO=           evaluate_bull_power)
        (@RHS=
                (Execute  ("WriteTo")           (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=bulls.txt,\
@TEXT=The number of bulls used was adequate,\
@NEW";))
        )
        (@EHS=
                (Execute  ("WriteTo")           (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=bull.txt,\
@TEXT=The number of bulls used was not adequate because one bull is required for each empty cow. There were
@V(incalf.\bulls_in\) cows not pregnant when the bulls entered the herd.,@NEW";))
        )
)
```

Figure 67. Rule that compares the performance and number of bulls with recommendations. The number of bulls required is calculated from an estimate of the number of empty cows in the herd at the start of natural mating.

Predicting Performance in a Subsequent Season

A separate knowledge base within DairyFIX gives the user the option of estimating the reproductive performance in future years based on performance in the current season. The development of this section was limited by the difficulties associated with retrieving data from the DOS based version of DairyMAN. Although extracts could be created from the DOS version it required specific computer coding. The author again considered that this resource would be better used in developing the interface with DairyWIN in the release version of DairyFIX. As an interim measure the data was manually entered into test data files for retrieval into DairyFIX, as previously described in this chapter.

The intention of this module is to identify to the user, the long term problems that may be created if the reproductive management of a herd is not modified for future seasons. The system initially assumes that performance in key areas does not change and then calculates the expected in-calf rates. The calving pattern must be defined by the user, but could be retrieved from the DairyWIN predicted calving report in a release version. The user then has the option of reprocessing the data with changes made to performance. For example if the DairyFIX investigation of the current season's performance identified heat detection as a problem the user could run this knowledge base with a modified heat detection efficiency to determine the impact this has on expected performance. In this way the effect that changes which might be made to management would have on the outcome can be estimated.

Future Development of DairyFIX

The current version of DairyFIX is a development version that has been designed within an expert system shell. The program requires recoding into a final release version if it is to be successfully linked to DairyWIN (Windows version of DairyMAN). This recoding using the concepts and rules defined in the preceding chapters also provides an opportunity to create a dynamic link between DairyFIX and DairyWIN. Such a link would mean than when DairyFIX requires data the appropriate report in DairyWIN could be processed and other reports automatically run for the user when the Expert System suggests problems that may be further investigated in a specific report. The option to create a graphical user interface also exists and one suggestion for the final display is shown in Figure 68. The author experimented with the concept of storing all processed data in a database linked to DairyFIX. Such a database could allow the expert system to "learn" in a simply way from previous investigations. Target values and numerical criteria for determining if a problem exists could be modified by the system as it gains more information about the typical performance of herds that have been processed.

The inclusion of a DairyFIX module within DairyMAN (or DairyWIN) needs to meet the simple requirement of processing the appropriate reports for identified problems and briefly summarising the major causes of poor performance. It need not be as sophisticated as that described in this thesis and the Stage 1 process may be all that is required initially. In other respects there is still the potential to expand the heuristic knowledge base within DairyFIX. The implementation of a graphical interface would greatly enhance the usefulness of the program to farmers and veterinarians.

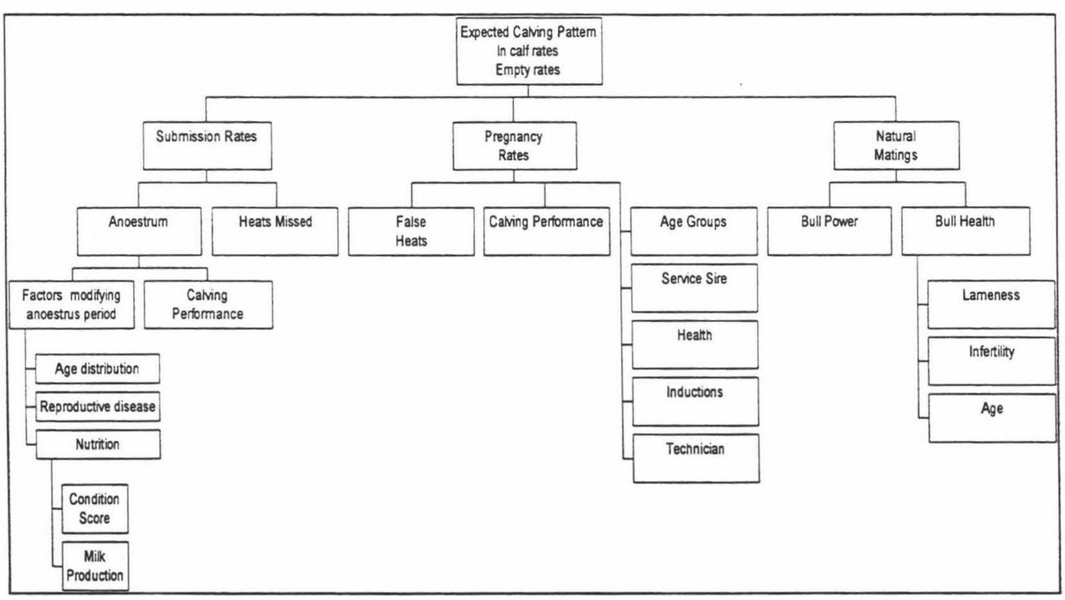

Figure 68. A suggested structure for graphically representing the DairyFIX analysis

There have been a number of recent attempts to use whole herd synchrony programs for the mating of large herds in New Zealand. The "conventional" process of investigation a reproductive problem as described in this thesis is not appropriate for these herds. At this time the number of herds using such a system is extremely small. Should such technologies advance there would be a requirement to significantly modify the DairyFIX system.

Chapter 9

Summary and Conclusion

Summary and Conclusion

This thesis aimed to develop an expert system for investigating herd reproductive problems in seasonally calving dairy herds. The author has also used the collected data to describe the performance of New Zealand dairy herds and individual cows. The data now being recorded by users of DairyMAN (now called DairyWIN) has created the opportunity for a more detailed analysis of performance that has not previously been available from other sources including the National Dairy Database. Although the thesis is divided into several key sections that were required for the final development of the DairyFIX expert system many have separate specific objectives that generally sought to describe performance of herds and groups of cows within herd. These chapters contain separate discussion and conclusions that does not require further consideration here. Where there appears to be some digression from the principal aim this has been solely to describe performance and improve the current state of knowledge using the DairyMAN on-farm information system. Where appropriate, the effects on milk yield have been also considered.

The literature review in chapter one is not intended as a comprehensive examination of expert systems and methods of monitoring dairy herd and cow reproductive performance. Rather it introduces the important concepts relating to expert systems and the methods of assessing performance that are used in the design of DairyFIX. Examples of different types of expert systems are used to illustrate the different levels of sophistication that can be used. A relatively simple approach to design has often resulted in the most successful systems. Examples including Bovid and Dairy Expert are discussed in detail. The second part of the review examined reproductive performance with an emphasis on areas that have been difficult to assess in seasonally calving dairy herds. Heat detection is covered in more detail than other equally important aspects for this reason. The limited time frames where cows are mated in seasonally calving dairy herds make the assessment of heat detection difficult and often inaccurate.

The historical points covered in the review are intended to illustrate the importance of computer systems and management information systems to the dairy industry. Expert systems such as DairyFIX are only possible because these systems are now commonly used and recognised as an integral part of many dairy farm enterprises.

Reproductive Performance of New Zealand Dairy Herds

The detailed descriptive information in Chapter 2 shows that the performance of New Zealand herds are often below those previously reported. Calving rates on average do achieve industry targets but only with a significant level of calving induction. Removal of inductions for welfare and marketing reasons will have a significant effect on the performance of many herds. If many of these herds are accepting this level of performance because calving induction is possible then there may be a compensatory response to the removal of this management tool. Detailed cost benefit analyses are beyond the scope of this thesis but are an essential component of a complete discussion of calving induction. The performance of carryover cows could not be investigated here as there it was not possible to verify that cows without a calving date were carryovers or the data was simply missing. The carryover of empty cows from one season to the next is common practice in New Zealand, but the performance of these animals has not been clearly evaluated. This may become more common if calving induction is removed as a management option as the consequence will be a more restricted mating period and more empty cows.

Submission rates are a critical determinant of the seasonal outcome, but New Zealand herds do not on average achieve the necessary targets. All measures of heat detection efficiency, although imprecise, show this is not a major problem with about 6 % of heats missed. This is however an important issue for some individual herds as the consequences of poor heat detection are dramatic. Certainly, the management of heat detection is one of the easiest aspect of performance to modify because the tools are well known, there are few unknown factors affecting performance and some improvements can be made without additional costs. Many herds may however be performing at the optimum level where increased management input may not achieve economical gains. Non cycling cows, mostly due to poor nutrition and the effects of calving pattern, are the major causes of lower submission rates. The genetic gains that have been made in recent years have resulted in higher milk yields per cows but also a requirement for a greater per cow daily feed intake. Failure to adequately meet these increasing demands by reducing stocking rates may have some negative long term effects on reproductive performance and submission rates in particular.

Conception rates of more than 60 % are commonly reported as typical for New Zealand herds, but the results reported here are lower. Much of the previous data has been taken from small study groups that may not be typical of New Zealand herds. The common use of non-return rates also provides performance indicators that do not accurately reflect true performance.

The health events such as lameness are reported here only for reference. The author's intention is to report the little data that is available, identify that this data can now be effectively recorded on-farm but also to illustrate the need for a more sophisticated monitoring system for health events. The variability in the type and degree of recording of these data is identified as a significant problem that limits the available information. Some of the health events and especially lameness may be having a significant negative effect on the reproductive performance of many herds. Herds are increasing in size and this will tend to increase the incidence of lameness.

The path models developed in chapter 3 are an essential prerequisite for the development of the DairyFIX expert system. The models have been developed from the knowledge available for the relationships between the major reproductive indices. The models statistically confirm most of the relationships and allow the use of some specific variables such as milk production as indicators of reproductive problems. In this case a low daily per cow milk yield is indicative of poor nutrition. The relationships between calving rates and submission rates and the effect of submission rates and conception rates on final in-calf rates were confirmed. The models also identify the difficulties with using non-return rates as the measure of conception. These problems are compounded if reasonably accurate measures of heat detection cannot be obtained in herds with a very restricted mating period. As herd performance increases and the efficiency of rearing replacements improves there will be a trend to shorter artificial breeding periods. Although the interactions between the various performance and diagnostic indicators have been largely understood from previous work this is the first time they have been brought together in statistically verified path models.

The next three chapters examined some aspects of performance that had important outcomes although not required for the DairyFIX expert system. The use of on-farm information systems (DairyMAN) was shown to be associated with improved herd performance including daily per cow milk yield and reproductive outcomes. These herds had cows of the same breed and genetic capacity for production but had superior performance. This finding is important because there is very little information confirming that recording systems either on-farm or as central databases give true performance gains despite the historical recognition of these systems and the rapid expansion in recent years. Justifying the use of more sophisticated tools such as expert systems would be more difficult if gains were not being achieved with the current technology

Calving induction was shown to be associated with some negative effects on milk yield and reproductive outcome. The negative impact of changing industry policies to this practise as discussed above need to be evaluated with consideration of these effects. Calving induction is typically not used as recommended in New Zealand as many of the treatments are done too late to provide sufficient economic gains through increased lactation length and number of days to the planned start of mating.

Regional differences in performance were identified, however the limited power of the herd data restricted the ability to identify any variation between regions. The reasons for the observed differences are unknown and there is a need for further investigation to more accurately define the differences and identify causes.

The performance of individual cows and groups was examined in detail and statistical models developed for use in DairyFIX. Breed, lactation number, days calved at the start of mating and some health events were all shown to have an important impact on performance. Apart from the number of days calved at the start of mating, lactation number has the most important association with the outcome variables. The mean age of New Zealand herds combined with the inferior performance of the lactation 1 and 2 groups is having a large effect on performance. The case for high culling rates including the more rapid genetic gain that is achieved are important, but the actual reasons for culling in New Zealand herds are poorly understood. Identifying the reasons for wastage is extremely important. Jersey cows tend to show superior reproductive performance and this is consistent with previous findings. Jersey heifers have however been shown to have inferior performance that may be a consequence of pregnancy loss. Milk yield is an important indicator of expected performance as it is a crude estimate of nutritional status and can be used when assessing performance.

Future Research Directions

Epidemiological investigations of the reproductive performance of New Zealand herds has been limited by the data available. This thesis has used the data from an on-farm information system for a detailed retrospective analysis. The growing use of DairyMAN is creating an opportunity to more thoroughly investigate some aspects of performance. A prospective study funded by the DRDC (Dairy Research and Development Corporation) has commenced in Australia using a select group of herds that use accurate recording systems in conjunction with local practitioners (Morton 1995). DairyMAN herds and particularly those working closely with veterinarians could provide an opportunity to evaluate the reproductive performance of New Zealand herds. These evaluations would not be disadvantaged by the use of retrospective data or from the limitations of the National Database. Standardized recording systems can be established before a study begins and closely monitored during the life of the project. A management information system provides the infrastructure to accurately record the necessary data. DairyMAN herds are not entirely representative of all New Zealand herds, but this should not exclude the resource from epidemiological investigations. In some cases it may be preferable to quantify effects in herds that are representative of industry leaders, where the information may be more applicable in the longer term. These studies would provide the infrastructure for recording detailed information that is not appropriate or possible on the National Database.

A coordinated plan that allows for the appropriate integration of an on-farm information systems such as DairyMAN and the National Dairy Database is essential. Users of DairyMAN are able to record much useful information but the data is of little use off-farm unless the methods of recording are properly coordinated. Some of the information recorded in DairyMAN should be available to the National Database if it can be accurately recorded, but will always be subject to missing data. Conversely, much of this information should only be recorded on-farm or as part of a detailed prospective study as described above. The reasons for culling dairy cows has been poorly recorded in New Zealand and there is a need for a detailed investigation if our understanding of herd reproductive performance (and other aspects of herd performance) is to be advanced.

DairyFIX

DairyFIX was developed to achieve two primary objectives. The first was to simplify the epidemiological approach to investigating a herd reproductive problem using DairyMAN by automating procedures and by using a graphical diagnostic interface. DairyFIX can provide to users of DairyMAN an automated system that interrogates the available data and quickly focuses on the important aspects of reduced performance. This simplifies the task and reduces the time required to investigate a herd problem. Although DairyMAN is comprehensive, users often find it difficult to use and may invest a considerable amount of time exploring the program rather than focusing on the task required. The second objective was to use the full expert system shell and knowledge base to utilize the expertise available within the domain of seasonal reproductive performance. This required the more sophisticated aspects of an expert system including the use of heuristic and procedural knowledge.

The statistical models including the herd reproductive path models form the basis of the DairyFIX system. Much of the discussion and documentation in Chapter 9 details the specific design requirements for each part of DairyFIX. DairyFIX consists of three sections. The first simply evaluates performance and determines if any problems exist. The second considers the effect of the major components of performance such as the calving pattern and heat detection so that the primary causes of poor performance are isolated. The third part of DairyFIX consists of several specific interrogation procedures for each area of poor performance. This section is not necessarily required for an operational system as the user can otherwise be referred to the appropriate reports in DairyMAN. Another section allows for an assessment of expected performance in future years. Most dairy herds maintain a relatively consistent level of performance because culling decisions tend to balance the level of reproductive performance (a high empty rate results is a high number of culled empty cows and the profile of the herd may vary little in the next year). However this may not always be the case if economic or other commercial limitations impose restrictions on the level of culling. In this case, it is essential to estimate performance and determine if it will be adequate. The impact of improving some aspects of performance are also illustrated using this predictive model. The models used for this purpose are similar to those that retrospectively evaluate performance.

DairyFIX is intended to be a system that simplifies the investigative task and identifies the major causes of poor reproductive performance. It is anticipated that this tool will allow more dairy farmers and veterinarians to make effective use of DairyMAN, but reduce the investment in time required to operate the computer program.

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Appendix

Appendix 1

Letter sent to all DairyMAN users in May/ June 1994

DairyMAN Data Analysis
Win Computer Software

Information on the reproductive performance of New Zealand herds has been limited to a few key parameters. The use of DairyMAN by farmers and veterinarians now makes it feasible to more accurately assess and interpret the inter relationship between the various events happening on a dairy farm that affect reproductive performance.

The developers of DairyMAN at Massey University with the support of Livestock Improvement are planning a survey of the reproductive performance of New Zealand dairy herds using the information that DairyMAN calculates. To do this we seek the support of DairyMAN users by sending us a copy of your herd's data.

Send a backup on disk now and we will include you in a draw for these educational and games programs.

1. Creative Writer. A word processor specially designed for children.
2. Wing Commander. An excellent flight simulation program.
3. Science Adventure. An educational program exploring the world of science with graphics, sound and text.

(Creative Writer requires Microsoft Windows)

Also we will return your disk with a feed budget spreadsheet file that can be loaded into most spreadsheet programs.

All users that provide us a copy of their data will receive a summary report of New Zealand herd performance and how their herd compares.

Massey University is undertaking a project to link an expert system to DairyMAN to aid in the interpretation of information produced in reports. Expert systems are computer programs that incorporate the knowledge of experts so that information can be used to reach conclusions and recommendations. The data from this survey of herd performance is necessary for such a system to operate.

Information on individual farms is totally confidential and will only be used for the purpose of this survey.

Please send your data in now. You can send your disk to:

David Hayes
Department of Veterinary Clinical Science,
Massey University,
Palmerston North.

(or to Debbie Moore at Livestock Improvement, Hamilton).

A normal or compressed backup from DairyMAN is all we need. We would appreciate if the farm profile section of data entry was as complete as possible so that background information on your herd is available. Autumn and year round calving herds should also send their data in now.

Thankyou for your interest and support. Please send a backup from DairyMAN in as soon as possible.

David Hayes B.V.M.S. (hons)

Letter sent to all Veterinarians known to be using DairyMAN in June 1994

12 June 1994
Veterinarian
Addressl,
Addrewss2,
Town

Dear "Name",

All DairyMAN users have been sent a request for copies of their herd's data with the last DairyMAN newsletter. A copy of this letter is enclosed.

The objectives of this data analysis include.

1. Determine the actual reproductive performance of New Zealand herds.

2. Evaluate relationships between different reproductive parameters using statistical analysis. (eg can the difference between non-returns and pregnancy rates be used for evaluation of heat detection. What is the relationship between previous calving pattern and the in-calf rate. Are the various parameters for measuring heat detection reliable and is there a relationship between these analyses and the outcome for a mating season.

3. Develop an expert system for evaluating reproductive performance. The normal values for reproductive performance and the inter-relationships between the reproductive indices are necessary to develop this expert system for the diagnosis of reproductive performance problems using DairyMAN information. This will ultimately give us all a better understanding of performance and how to assess results and predict outcomes for a mating season.

4. Evaluate the use of DairyMAN. This will include an assessment of users understanding of program setup (eg are PSM's set correctly for the particular herd) and the relative use of the different sections of the program.

It is essential that I collect data from as many herds as possible and particularly want data from herds where there has been veterinary involvement in the operation of the program.

All your herds will be included in the draw for the software prize however the farmers need to have given their approval for you to provide the data to Massey university.

Data is also being collected from a stratified sample of 300 herds on the National Dairy Database that will allow us to determine the relative performance of DairyMAN users to the rest of New Zealand herds and make a valid interpretation of performance parameters that can be assessed for herds using DairyMAN but cannot be evaluated for the wider population.

Data for most of your herds should now be complete for the last season. If you could post backup copies of each herds data to me I will ensure that the disks are returned and that information on the results of the data evaluation are provided. All information is confidential and will only be used for the purpose described.

Thankyou for your cooperation.

David Hayes B.V.M.S. (hons)

Appendix 2

Farming Regions and Districts

From Livestock Improvement 995/96 Dairy Statistics

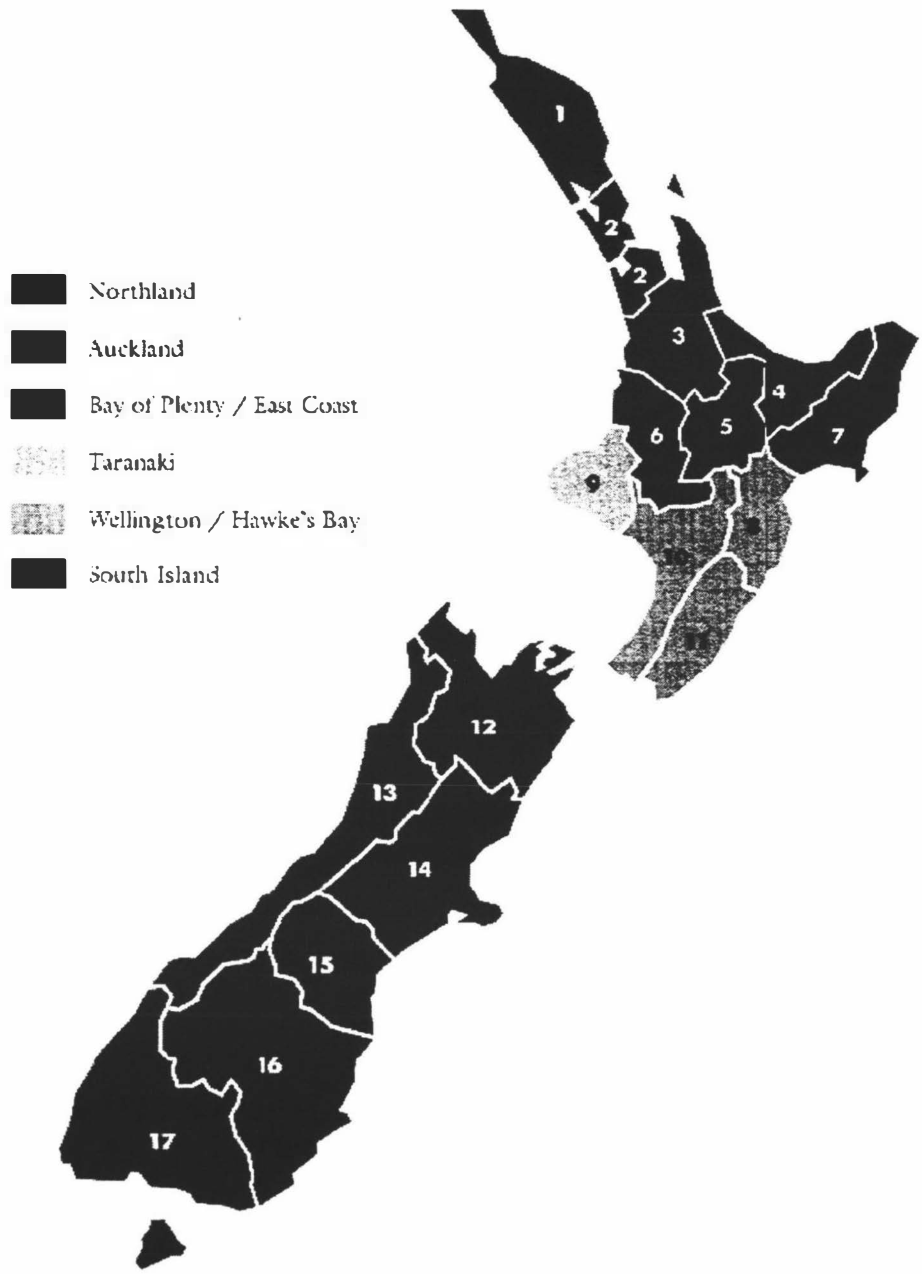

Figure 69: National Dairy Database regional classification of New Zealand Dairy Herds

1 NORTHLAND
Far North
Whangarei
Kaipara

2 CENTRAL AUCKLAND
Rodney
North Shore
Waitakere
Auckland
Manukau
Papakura
Franklin

3 SOUTH AUCKLAND
Thames/Coromandel
Hauraki
Waikato
Matamata/Piako
Hamilton
Waipa
Otorohanga
South Waikato

4 BAY OF PLENTY
Western Bay of Plenty
Tauranga
Whakatane
Kawerau
Opotiki

5 CENTRAL PLATEAU
Rotorua
Taupo

6 WESTERN UPLANDS
Waitomo
Ruapehu

7 EAST COAST
Gisborne
Wairoa

8 HAWKE'S BAY
Hastings
Napier
Central Hawke's Bay

9 TARANAKI
New Plymouth
Stratford
South Taranaki

10 WELLINGTON
Wanganui
Rangitikei
Manawatu
Palmerston North
Horo\vhenua
Kapiti
Porirua
Upper Hutt
Lower Hutt
Wellington

11 WAIRARAPA
Tararua
Masterton
Carterton
South Wairarapa

12 NELSON/MARLBOROUGH
Tasman
Nelson
Marlborough
Kaikoura

13 WEST COAST
Buller
Grey
Westland

14 NORTH CANTERBURY
Hurunui
Waimakariri
Christchurch
Banks Peninsula
Selwyn
Ashburton

15 SOUTH CANTERBURY
Timaru
MacKenzie
Waimate

16 OTAGO
Waitaki
Central Otago
Queenstown/Lakes
Dunedin
Clutha

17 SOUTHLAND
Southland
Gore
Invercargill

Appendix 3

SAS Code and Solutions to the Models for Individual Cow Reproductive Performance

Planned Start of Calving to Calving (PSC_CAL)

Model for PSC_CAL

```
/****************************************************************************/
proc access dbms=dbf;
 create work.cowcs.access; /* Create Access Descriptor */
 path='E:\cowdata\dbase\dmc.dbf';
 create work.cowscv.view; /* Create View */
 select all ;
 list view;
run;
/****************************************************************************/
TITLE "herds using DairyMAN";
proc MIXED data=work.cowscv noclprint;
class herd region laccat5 bicat C_I C_AP sex1 twin;
model PSC_CAL= region laccat5 bicat C_I C_AP sex1 twin C_I*sex1 C_I*laccat5 laccat5*bicat
            /solution;
 random herd;
 lsmeans region laccat5 bicat C_I C_AP sex1 twin C_I*sex1 C_I*laccat5 laccat5*bicat
          / adjust=bon diff cl ;
run;
/****************************************************************************/
```

Results for PSC_CAL

```
  REML Estimation Iteration History
 Iteration Evaluations Objective Criterion
 0          1 201108.82839
 1          2 199120.25051   0.00000075
 2          1 199120.17230   0.00000000
 Convergence criteria met.
 Covariance Parameter Estimates (REML)
 Cov Parm Ratio Estimate Std Error Z Pr > |Z|
 HERD            0.09697455 27.68547023 3.58524677 7.72 0.0001
 Residual        1.00000000 285.49211501 2.34276461 121.86 0.0001
 Model Fitting Information for PSC_CAL
 Description                               Value
 Observations                              29862.00
 Variance Estimate                         285.4921
 Standard Deviation Estimate               16.8965
 REML Log Likelihood                       -126979
 Akaike's Information Criterion            -126981
 Schwarz's Bayesian Criterion              -126990
 -2 REML Log Likelihood                    253958.7
```

Table 62. Parameter estimates and the standard errors for each independent variable and interaction term included in the model for PSC_CAL

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
INTERCEPT	2.154	2.168	136	0.99	0.32
REGION 1	8.067	1.960	29861	4.12	0.00
REGION 2	-2.010	1.371	29861	-1.47	0.14
REGION 3	-3.097	3.328	29861	-0.93	0.35
REGION 4	-2.445	1.607	29861	-1.52	0.13
REGION 5	-0.974	1.693	29861	-0.58	0.57
REGION 6	0.000	.	.	.	.

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
LACCAT5 1	15.088	2.211	29861	6.82	0.00
LACCAT5 2	-0.251	0.976	29861	-0.26	0.80
LACCAT5 3	1.305	1.106	29861	1.18	0.24
LACCAT5 4	-0.589	1.212	29861	-0.49	0.63
LACCAT5 5	0.000	.	.	.	.
BICAT 0	1.143	0.395	29861	2.90	0.00
BICAT 1	0.000	.	.	.	.
C_I 0	-12.590	0.765	29861	-16.46	0.00
C_I 1	0.000	.	.	.	.
C_AP 0	27.629	1.365	30000	20.24	0.00
C_AP 1	0.000	.	.	.	.
SEX1 0	-0.371	0.739	30000	-0.50	0.62
SEX1 1	0.000	.	.	.	.
TWIN 0	4.425	0.973	30000	4.55	0.00
TWIN 1	0.000	.	.	.	.
C_I*SEX1 0 0	-2.079	0.767	30000	-2.71	0.01
C_I*SEX1 0 1	0.000	.	.	.	.
C_I*SEX1 1 0	0.000	.	.	.	.
C_I*SEX1 1 1	0.000	.	.	.	.
LACCAT5*C_I 1 0	-20.655	2.203	29861	-9.38	0.00
LACCAT5*C_I 1 1	0.000	.	.	.	.
LACCAT5*C_I 2 0	2.155	0.966	29861	2.23	0.03
LACCAT5*C_I 2 1	0.000	.	.	.	.
LACCAT5*C_I 3 0	-0.054	1.096	29861	-0.05	0.96
LACCAT5*C_I 3 1	0.000	.	.	.	.
LACCAT5*C_I 4 0	0.875	1.191	29861	0.73	0.46
LACCAT5*C_I 4 1	0.000	.	.	.	.
LACCAT5*C_I 5 0	0.000	.	.	.	.
LACCAT5*C_I 5 1	0.000	.	.	.	.
LACCAT5*BICAT 1 0	2.954	0.636	29861	4.64	0.00
LACCAT5*BICAT 1 1	0.000	.	.	.	.
LACCAT5*BICAT 2 0	-0.341	0.623	29861	-0.55	0.58
LACCAT5*BICAT 2 1	0.000	.	.	.	.
LACCAT5*BICAT 3 0	0.203	0.630	29861	0.32	0.75
LACCAT5*BICAT 3 1	0.000	.	.	.	.
LACCAT5*BICAT 4 0	0.315	0.665	29861	0.47	0.64
LACCAT5*BICAT 4 1	0.000	.	.	.	.
LACCAT5*BICAT 5 0	0.000	.	.	.	.
LACCAT5*BICAT 5 1	0.000	.	.	.	.

Four Week Calving Rate (CAL4)

Model for CAL4

```
/******************************************************************************/
proc access dbms=dbf;
create work.cowcs.access; /* Create Access Descriptor */
path='e:\cowdata\dbase\dmc.dbf';
create work.cowscv.view; /* Create View */
select all ;
list view;
run;
/******************************************************************************/
%INC'e:\cowdata\glimmix.SAS';
/******************************************************************************/
```

```
run;
%glimmix(data=work.cowscv,
stmts=%str(
class herd Region Breedcat Laccat5 C_I C_AP Sex1 ;
model cal28=Region Breedcat C_AP C_I Laccat5 Sexl Laccat5*C_I C_I*SEX1
/Solution ;
random herd;
lsmeans Region Breedcat C_AP C_I Laccat5 Sex1     Laccat5*C_I C_I*SEX1
          / adjust=bon diff cl ;
))
run;
/***************************************************************************/
```

Results for CAL4

Class	Levels	Values
HERD	142	
REGION	6	1 2 3 4 5 6
BREEDCAT	5	1 2 3 4 5
LACCAT5	5	1 2 3 4 5
C_I	2	0 1
C_AP	2	0 1
SEX1	2	0 1

Covariance Parameter Estimates

HERD	0.30278561

GLIMMIX Model Statistics

Description	Value
Deviance	32737.3770
Scaled Deviance	32866.4989
Pearson Chi-Square	29771.4794
Scaled Pearson Chi-Square	29888.9033
Extra-Dispersion Scale	0.9961

Table 63. Parameter estimates and the standard errors for each independent variable and interaction terms included in the model for CAL4

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
INTERCEPT	1.797	0.497	136	3.61	0.000
REGION 1	-0.617	0.208	29874	-2.96	0.003
REGION 2	0.374	0.147	29874	2.54	0.011
REGION 3	0.464	0.356	29874	1.3	0.193
REGION 4	0.407	0.173	29874	2.36	0.019
REGION 5	0.147	0.181	29874	0.81	0.417
REGION 6	0.000	.	.	.	.
BREEDCAT 1	0.063	0.184	29874	0.34	0.732
BREEDCAT 2	-0.137	0.119	29874	-1.14	0.253
BREEDCAT 3	-0.044	0.117	29874	-0.37	0.710
BREEDCAT 4	0.061	0.120	29874	0.51	0.613
BREEDCAT 5	0.000	.	.	.	.
LACCAT5 1	-2.612	0.602	29874	-4.34	0.000
LACCAT5 2	0.038	0.114	29874	0.33	0.739
LACCAT5 3	-0.257	0.133	29874	-1.93	0.054
LACCAT5 4	-0.022	0.143	29874	-0.15	0.880
LACCAT5 5	0.000	.	.	.	.
C_I 0	1.433	0.096	29874	14.94	0.000
C_I 1	0.000	.	.	.	.
C_AP 0	-2.443	0.459	29874	-5.33	0.000

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
INTERCEPT	1.797	0.497	136	3.61	0.000
REGION 1	-0.617	0.208	29874	-2.96	0.003
C_AP 1	0.000	.	.	.	.
SEX1 0	0.064	0.094	29874	0.68	0.495
SEX1 1	0.000	.	.	.	.
LACCAT5*C_I 1 0	3.108	0.604	29874	5.15	0.000
LACCAT5*C_I 1 1	0.000	.	.	.	.
LACCAT5*C_I 2 0	-0.234	0.121	29874	-1.94	0.052
LACCAT5*C_I 2 1	0.000	.	.	.	.
LACCAT5*C_I 3 0	0.120	0.140	29874	0.86	0.390
LACCAT5*C_I 3 1	0.000	.	.	.	.
LACCAT5*C_I 4 0	-0.038	0.150	29874	-0.26	0.798
LACCAT5*C_I 4 1	0.000	.	.	.	.
LACCAT5*C_I 5 0	0.000	.	.	.	.
LACCAT5*C_I 5 1	0.000	.	.	.	.
C_I*SEX1 0 0	0.232	0.098	29874	2.37	0.018
C_I*SEX1 0 1	0.000	.	.	.	.
C_I*SEX1 1 0	0.000	.	.	.	.
C_I*SEX1 1 1	0.000	.	.	.	.

Eight Week Calving Rate (CAL8)

Model for Cal8

```
/*****************************************************************************/
proc access dbms=dbf;
create work.cowcs.access; /* Create Access Descriptor */
path='e:\cowdata\dbase\dmc.dbf';
create work.cowscv.view; /* Create View */
select all ;
list view;
run;
/*****************************************************************************/
%INC'e:\cowdata\glimmix.SAS';
/*****************************************************************************/
%glimmix(data=work.cowscv,
stmts=%str(
class herd Region Breedcat Laccat5 C_I Sex1 ;
model cal56= Region Laccat55 C_I Sex1 C_I*Laccat5
/Solution ;
random herd;
lsmeans Region Laccat5 C_I sex1 C_I*Laccat5 / adjust=bon diff cl ;
 ))
run;
/*****************************************************************************/
```

Results for CAL8

Class	Levels	Values
HERD	142	
REGION	6	1 2 3 4 5 6
BREEDCAT	5	1 2 3 4 5
LACCAT5	5	0 1
C_I	2	0 1
SEX1	2	0 1

Covariance Parameter Estimates
HERD 1.32648667

GLIMMIX Model Statistics	
Description	Value
Deviance	9048.1770
Scaled Deviance	10374.4719
Pearson Chi-Square	26081.0365
Scaled Pearson Chi-Square	29904.0325
Extra-Dispersion Scale	0.8722

Table 64. Parameter estimates and the standard errors for each independent variable and interaction terms included in the model for Cal8

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
INTERCEPT	2.26	0.30	137	7.42	0.00
REGION 1	-1.33	0.44	29879	-3.04	0.00
REGION 2	0.15	0.32	29879	0.46	0.65
REGION 3	0.49	0.80	29879	0.61	0.54
REGION 4	0.39	0.38	29879	1.02	0.31
REGION 5	-0.22	0.39	29879	-0.56	0.58
REGION 6	0.00	.	.	.	.
LACCAT5 1	-1.95	0.31	29879	-6.32	0.00
LACCAT5 2	0.18	0.19	29879	0.98	0.33
LACCAT5 3	0.03	0.21	29879	0.15	0.88
LACCAT5 4	0.13	0.23	29879	0.6	0.55
LACCAT5 5	0.00	.	.	.	.
C_I 0	1.51	0.15	29879	10.21	0.00
C_I 1	0.00	.	.	.	.
SEX1 0	0.27	0.06	29879	4.84	0.00
SEX1 1	0.00	.	.	.	.
LACCAT5*C_I 1 0	1.76	0.32	29879	5.51	0.00
LACCAT5*C_I 1 1	0.00	.	.	.	.
LACCAT5*C_I 2 0	-0.52	0.21	29879	-2.51	0.01
LACCAT5*C_I 2 1	0.00	.	.	.	.
LACCAT5*C_I 3 0	-0.15	0.23	29879	-0.66	0.51
LACCAT5*C_I 3 1	0.00	.	.	.	.
LACCAT5*C_I 4 0	-0.19	0.25	29879	-0.77	0.44
LACCAT5*C_I 4 1	0.00	.	.	.	.
LACCAT5*C_I 5 0	0.00	.	.	.	.
LACCAT5*C_I 5 1	0.00	.	.	.	.

Twenty One Day Submission Rate (Sub21)

Model for Sub21

```
/***************************************************************************/
proc access dbms=dbf;
create work.cowcs.access; /* Create Access Descriptor */
path='e:\cowdata\dbase\dm.dbf';
create work.cowscv.view; /* Create View */
select all ;
list view;
run;
/*****************************************************************************************/
%INC'e:\cowdata\glimmix.SAS';
/*****************************************************************************************/
run;
%glimmix(data=work.cowscv,
stmts=%str(
class= herd breedcat laccat5 psmcat;
```

```
model sub21= breedcat laccat5 psmcat ms2 psmcat*ms2 laccat5*ms2 /Solution;
random herd;
LSMEANS breedcat laccat5 psmcat /adjust=bon diff cl ;
))
run;
/*****************************************************************************************/
```

Results for SUB21

Class Level Information

Class	Levels	Values
HERD	126	Herd codes list here but have been deleted to retain confidentiality
BREEDCAT	5	1 2 3 4 5
LACCAT5	5	1 2 3 4 5
PSMCAT	5	1 2 3 4 5

Covariance Parameter Estimates

HERD 0.34650879

GLIMMIX Model Statistics

Description	Value
Deviance	19157.7129
Scaled Deviance	19546.3509
Pearson Chi-Square	27778.1195
Scaled Pearson Chi-Square	28341.6331
Extra-Dispersion Scale	0.9801

Table 65. Parameter estimates and the standard errors for each independent variable and interaction terms included in the model for Sub21

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
INTERCEPT	1.53	0.33	125	4.66	0.000
BREEDCAT 1	0.08	0.23	28323	0.35	0.723
BREEDCAT 2	0.13	0.16	28323	0.8	0.421
BREEDCAT 3	0.32	0.15	28323	2.1	0.036
BREEDCAT 4	0.53	0.16	28323	3.34	0.001
BREEDCAT 5	0				
LACCAT5 1	-0.74	0.23	28323	-3.2	0.001
LACCAT5 2	0.35	0.26	28323	1.35	0.179
LACCAT5 3	0.98	0.30	28323	3.31	0.001
LACCAT5 4	0.27	0.31	28323	0.85	0.394
LACCAT5 5	0				
PSMCAT 1	-2.13	0.37	28323	-5.73	0.000
PSMCAT 2	-1.01	0.31	28323	-3.25	0.001
PSMCAT 3	-0.34	0.29	28323	-1.18	0.236
PSMCAT 4	-0.33	0.28	28323	-1.21	0.227
PSMCAT 5	0.00				
MS2	0.55	0.20	28323	2.78	0.005
MS2*PSMCAT 1	-0.54	0.24	28323	-2.24	0.025
MS2*PSMCAT 2	-0.37	0.21	28323	-1.75	0.080
MS2*PSMCAT 3	-0.26	0.20	28323	-1.32	0.187
MS2*PSMCAT 4	0.10	0.20	28323	0.5	0.616
MS2*PSMCAT 5	0.00				
MS2*LACCAT5 1	0.36	0.16	28323	2.25	0.025
MS2*LACCAT5 2	-0.12	0.16	28323	-0.73	0.468
MS2*LACCAT5 3	-0.36	0.18	28323	-2.06	0.040
MS2*LACCAT5 4	0.03	0.18	28323	0.15	0.878
MS2*LACCAT5 5	0.00				

Conception Rates (Model 1)

Model 1 for Conc_1st

```
/*******************************************************************************************/
proc access dbms=dbf;
create work.cowcs.access; /* Create Access Descriptor */
path='e:\cowdata\dbase\dmpreghl.dbf';
create work.cowscv.view; /* Create View */
select all ;
list view;
run;
/*******************************************************************************************/
%INC'e:\cowdata\glimmix.SAS';
/*******************************************************************************************/
%glimmix(data=work.cowscv,
stmts=%str(
class= herd laccat5 PSMcat C_I ;
model conc_fir= laccat5 psmcat C_I Laccat5*psmcat Laccat5*C_I /solution;
lsmeans laccat5 psmcat C_I / adjust=bon diff cl ;
random herd;
))
run;
/*******************************************************************************************/
```

Results Conc_1st (Modell)

Class Level Information

Class	Levels	Values
HERD	48	Herd codes list here but have been deleted to retain confidentiality
LACCAT5	5	1 2 3 4 5
PSMCAT	5	1 2 3 4 5
C_I	2	0 1

Covariance Parameter Estimates

HERD 0.12031856

GLIMMIX Model Statistics

Description	Value
Deviance	15100.1640
Scaled Deviance	15123.7866
Pearson Chi-Square	11464.1117
Scaled Pearson Chi-Square	11482.0461
Extra-Dispersion Scale	0.9984

Table 66. Parameter estimates and the standard errors for each independent variable and interaction terms included in the model for CONC_1st for model 1

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
INTERCEPT	0.4341	0.1669	47	2.6	0.0124
LACCAT5 1	-0.8624	0.4685	11475	-1.84	0.0657
LACCAT5 2	0.0129	0.2331	11475	0.06	0.9559
LACCAT5 3	0.2994	0.2473	11475	1.21	0.226
LACCAT5 4	-0.3481	0.2854	11475	-1.22	0.2226
LACCAT5 5	0	.	.	.	.
PSMCAT 1	-1.5902	0.307	11475	-5.18	0.0001
PSMCAT 2	-0.8415	0.159	11475	-5.29	0.0001
PSMCAT 3	-0.6239	0.1298	11475	-4.81	0.0001
PSMCAT 4	-0.2666	0.1203	11475	-2.22	0.0267
PSMCAT 5	0	.	.	.	.
C_I 0	0.3092	0.1168	11475	2.65	0.0081

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
C_I 1	0	.	.	.	.
LACCAT5*PSMCAT 1 1	0.7282	0.4197	11475	1.73	0.0828
LACCAT5*PSMCAT 1 2	-0.1342	0.2416	11475	-0.56	0.5786
LACCAT5*PSMCAT 1 3	0.3591	0.1833	11475	1.96	0.0502
LACCAT5*PSMCAT 1 4	0.1575	0.1566	11475	1.01	0.3145
LACCAT5*PSMCAT 1 5	0	.	.	.	.
LACCAT5*PSMCAT 2 1	1.4362	0.4344	11475	3.31	0.0009
LACCAT5*PSMCAT 2 2	0.4028	0.2401	11475	1.68	0.0935
LACCAT5*PSMCAT 2 3	0.3389	0.2001	11475	1.69	0.0903
LACCAT5*PSMCAT 2 4	0.4529	0.1873	11475	2.42	0.0156
LACCAT5*PSMCAT 2 5	0	.	.	.	.
LACCAT5*PSMCAT 3 1	0.1115	0.5013	11475	0.22	0.824
LACCAT5*PSMCAT 3 2	0.146	0.2511	11475	0.58	0.561
LACCAT5*PSMCAT 3 3	0.2412	0.2119	11475	1.14	0.255
LACCAT5*PSMCAT 3 4	0.0448	0.1987	11475	0.23	0.8215
LACCAT5*PSMCAT 3 5	0	.	.	.	.
LACCAT5*PSMCAT 4 1	0.6564	0.5526	11475	1.19	0.2349
LACCAT5*PSMCAT 4 2	0.1181	0.2846	11475	0.42	0.678
LACCAT5*PSMCAT 4 3	0.4916	0.2366	11475	2.08	0.0378
LACCAT5*PSMCAT 4 4	0.2428	0.2205	11475	1.1	0.2709
LACCAT5*PSMCAT 4 5	0	.	.	.	.
LACCAT5*PSMCAT 5 1	0	.	.	.	.
LACCAT5*PSMCAT 5 2	0	.	.	.	.
LACCAT5*PSMCAT 5 3	0	.	.	.	.
LACCAT5*PSMCAT 5 4	0	.	.	.	.
LACCAT5*PSMCAT 5 5	0	.	.	.	.
LACCAT5*C_I 1 0	0.562	0.4495	11475	1.25	0.2112
LACCAT5*C_I 1 1	0	.	.	.	.
LACCAT5*C_I 2 0	-0.3451	0.1671	11475	-2.07	0.0389
LACCAT5*C_I 2 1	0	.	.	.	.
LACCAT5*C_I 3 0	-0.2683	0.1789	11475	-1.5	0.1336
LACCAT5*C_I 3 1	0	.	.	.	.
LACCAT5*C_I 4 0	0.2222	0.2108	11475	1.05	0.2918
LACCAT5*C_I 4 1	0	.	.	.	.
LACCAT5*C_I 5 0	0	.	.	.	.
LACCAT5*C_I 5 1	0	.	.	.	.

Conception Rates (Model 2)

Model 2 for Conc_1st

```
/*******************************************************************************************/
proc access dbms=dbf;
create work.cowcs.access; /* Create Access Descriptor */
path='e:\cowdata\dbase\dmpreghl.dbf';
create work.cowscv.view; /* Create View */
select all ;
list view;
run;
/*******************************************************************************************/
%INC'e:\cowdata\glimmix.SAS';
/*******************************************************************************************/
%glimmix(data=work.cowscv,
stmts=%str(
class= herd laccat5 PSMcat C_I Heatcase Asstcase lamecase;
```

```
model conc_fir= laccat5 psmcat C_I Heatcase Asstcase lamecase/solution;
lsmeans laccat5 psmcat C_I Heatcase Asstcase lamecase / adjust=bon diff cl ;
random herd;
))
run;
```

Results Conc_1st (Model2)

Class Level Information

Class	Levels	Values
HERD	15	Herd codes list here but have been deleted to retain confidentiality
LAMECASE	2	0 1
LACCAT5	5	1 2 3 4 5
C_I	2	0 1
HEATCASE	2	0 1
ASSTCASE	2	0 1

Covariance Parameter Estimates

HERD 0.03287811

GLIMMIX Model Statistics

Description	Value
Deviance	6159.4263
Scaled Deviance	159.0349
Pearson Chi-Square	4579.0366
Scaled Pearson Chi-Square	4578.7456
Extra-Dispersion Scale	1.0001

Table 67. Parameter estimates and the standard errors for each independent variable and interaction terms included in the model for CONC_1st for model II including some health events

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
INTERCEPT	-1.8812	0.2568	14	-7.32	0.0001
LAMECASE 0	0.2489	0.125	4574	1.99	0.0464
LAMECASE 1	0	.	.	.	.
C_I 0	0.2375	0.1013	4574	2.34	0.0191
C_I 1	0	.	.	.	.
HEATCASE 0	-0.2247	0.071	4574	-3.17	0.0016
HEATCASE 1	0	.	.	.	.
ASSTCASE 0	0.519	0.1397	4574	3.71	0.0002
ASSTCASE 1	0	.	.	.	.
LACCAT5 1	-0.0803	0.0888	4574	-0.91	0.3655
LACCAT5 2	0.1563	0.0905	4574	1.73	0.0841
LACCAT5 3	0.2011	0.0943	4574	2.13	0.033
LACCAT5 4	0.1519	0.1064	4574	1.43	0.1534
LACCAT5 5	0	.	.	.	.
CAL_SER	0.0149	0.0018	4574	8.4	0.0001

Non-Return Rates

```
proc access dbms=dbf;
create work.cowcs.access; /* Create Access Descriptor */
path='e:\cowdata\dbase\nrdm.dbf';
create work.cowscv.view; /* Create View */
select all ;
list view;
run;
/*************************************************************************************************/
%INC'e:\cowdata\glimmix.SAS';
/*************************************************************************************************/
/******* ms2 bicat region region*psmcat not significant *******/
```

```
%glimmix(data=work.cowscv,
stmts=%str(
class= herd laccat5 breedcat bicat PSMcat ;
model nr28= breedcat laccat5 psmcat
laccat5*psmcat ;
random herd;
))
run;
```

Class Level Information

Class	Levels	Values
HERD	126	
LACCAT5	5	1 2 3 4 5
BREEDCAT	5	1 2 3 4 5
BICAT	2	0 1
PSMCAT	5	1 2 3 4 5

Covariance Parameter Estimates

HERD 0.10355869

GLIMMIX Model Statistics

Description	Value
Deviance	29869.4253
Scaled Deviance	30072.5523
Pearson Chi-Square	24174.3229
Scaled Pearson Chi-Square	24338.7205
Extra-Dispersion Scale	0.9932

Table 68. Parameter estimates and the standard errors for each independent variable and interaction terms included in the model for first service non-return rates

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
INTERCEPT	0.8443	0.1381	125	6.11	0.0001
BREEDCAT 1	0.1396	0.1874	24311	0.74	0.4564
BREEDCAT 2	0.2495	0.1117	24311	2.23	0.0255
BREEDCAT 3	0.2475	0.1096	24311	2.26	0.024
BREEDCAT 4	0.126	0.1128	24311	1.12	0.2638
BREEDCAT 5	0	.	.	.	.
LACCAT5 1	-0.1625	0.1031	24311	-1.58	0.115
LACCAT5 2	-0.2889	0.1261	24311	-2.29	0.022
LACCAT5 3	-0.0595	0.1318	24311	-0.45	0.6515
LACCAT5 4	-0.0385	0.147	24311	-0.26	0.7936
LACCAT5 5	0	.	.	.	.
PSMCAT 1	-1.5396	0.2358	24311	-6.53	0.0001
PSMCAT 2	-0.9317	0.1163	24311	-8.01	0.0001
PSMCAT 3	-0.478	0.0958	24311	-4.99	0.0001
PSMCAT 4	-0.1844	0.0906	24311	-2.04	0.0418
PSMCAT 5	0	.	.	.	.
LACCAT5*PSMCAT 1 1	0.2956	0.3443	24311	0.86	0.3906
LACCAT5*PSMCAT 1 2	0.2635	0.1733	24311	1.52	0.1285
LACCAT5*PSMCAT 1 3	0.1927	0.1334	24311	1.45	0.1484
LACCAT5*PSMCAT 1 4	0.1085	0.1176	24311	0.92	0.3564
LACCAT5*PSMCAT 1 5	0	.	.	.	.
LACCAT5*PSMCAT 2 1	1.2134	0.3657	24311	3.32	0.0009
LACCAT5*PSMCAT 2 2	0.4899	0.1755	24311	2.79	0.0053
LACCAT5*PSMCAT 2 3	0.3459	0.1465	24311	2.36	0.0183
LACCAT5*PSMCAT 2 4	0.3121	0.1394	24311	2.24	0.0252
LACCAT5*PSMCAT 2 5	0	.	.	.	.
LACCAT5*PSMCAT 3 1	-0.2772	0.4086	24311	-0.68	0.4974
LACCAT5*PSMCAT 3 2	0.3982	0.1824	24311	2.18	0.029

LACCAT5*PSMCAT 3 3	0.2501	0.1529	24311	1.64	0.1019
LACCAT5*PSMCAT 3 4	0.1696	0.1453	24311	1.17	0.243
LACCAT5*PSMCAT 3 5	0	.	.	.	.
LACCAT5*PSMCAT 4 1	0.3237	0.4046	24311	0.8	0.4237
LACCAT5*PSMCAT 4 2	0.1119	0.204	24311	0.55	0.5834
LACCAT5*PSMCAT 4 3	0.2624	0.1694	24311	1.55	0.1214
LACCAT5*PSMCAT 4 4	0.0549	0.1602	24311	0.34	0.7318
LACCAT5*PSMCAT 4 5	0	.	.	.	.
LACCAT5*PSMCAT 5 1	0	.	.	.	.
LACCAT5*PSMCAT 5 2	0	.	.	.	.
LACCAT5*PSMCAT 5 3	0	.	.	.	.
LACCAT5*PSMCAT 5 4	0	.	.	.	.
LACCAT5*PSMCAT 5 5	0	.	.	.	.

In-Calf Rates for DairyMAN Pregnancy Test Herds

(Model 1)

Four week In-calf

```
proc access dbms=dbf;
create work.cowcs.access; /* Create Access Descriptor */
path='e:\cowdata\dbase\dmpreg.dbf';
create work.cowscv.view; /* Create View */
select all ;
list view;
run;
/****************************************************************************/
%INC'e:\cowdata\glimmix.SAS';
/****************************************************************************/
%glimmix(data=work.cowscv,
stmts=%str(
class= herd laccat5 psmcat sub21 conc_fir ;
model InClfp4= psmcat sub21 conc_fir /solution;
random herd;
lsmeans psmcat sub21 conc_fir /diff cl;
) ) run;
```

Class Level Information

Class	Levels	Values
HERD	4	
LACCAT5	5	1 2 3 4 5
PSMCAT	5	1 2 3 4 5
SUB21	2	0 1
CONC_FIR	2	0 1

Covariance Parameter Estimates

HERD 0.18360185

GLIMMIX Model Statistics

Description	Value
Deviance	6313.1836
Scaled Deviance	10221.2585
Pearson Chi-Square	7089.3277
Scaled Pearson Chi-Square	11477.8622
Extra-Dispersion Scale	0.6177

Table 69. Parameter estimates and the standard errors for each independent variable included in a model for four week in-calf rates that included the intermediate variables, submission and conception

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
INTERCEPT	5.8966	0.3614	47	16.32	0.0001

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
PSMCAT 1	-0.9549	0.3319	11498	-2.88	0.004
PSMCAT 2	-0.1252	0.1686	11498	-0.74	0.4576
PSMCAT 3	-0.074	0.1432	11498	-0.52	0.6052
PSMCAT 4	0.1427	0.1324	11498	1.08	0.2811
PSMCAT 5	0	.	.	.	.
SUB21 0	-6.1545	0.3602	11498	-17.09	0.0001
SUB21 1	0	.	.	.	.
CONC_FIR 0	-6.8191	0.3477	11498	-19.61	0.0001
CONC_FIR 1	0	.	.	.	.

Eight Week

```
proc access dbms=dbf;
create work.cowcs.access; /* Create Access Descriptor */
path='e:\cowdata\dbase\dmpreg.dbf';
create work.cowscv.view; /* Create View */
select all ;
list view;
run;
/*****************************************************************************/
%INC'e:\cowdata\glimmix.SAS';
/*****************************************************************************/
%glimmix(data=work.cowscv,
stmts=%str(
class= herd laccat5 psmcat sub21 conc_fir ;
model InCalfp8= laccat5 psmcat sub21 conc_fir laccat5*psmcat laccat5*sub21 laccat5*conc_fir /solution;
lsmeans laccat5 psmcat sub21 conc_fir laccat5*psmcat laccat5*sub21 laccat5*conc_fir /diff cl;
 random herd;
 ) ) run;
```

Class Level Information

Class	Levels	Values
HERD	48	
LACCAT5	5	1 2 3 4 5
PSMCAT	5	1 2 3 4 5
SUB21	2	0 1
CONC_FIR	2	0 1

Covariance Parameter Estimates

HERD 0.18360185

GLIMMIX Model Statistics

Description	Value
Deviance	6313.1836
Scaled Deviance	10221.2585
Pearson Chi-Square	7089.3277
Scaled Pearson Chi-Square	11477.8622
Extra-Dispersion Scale	0.6177

Table 70. Parameter estimates and the standard errors for each independent variable included in a model for eight week in-calf rates that included the intermediate variables, submission and conception

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
INTERCEPT	5.1311	0.2642	47	19.42	0.0001
LACCAT5 1	-0.5083	0.3294	11470	-1.54	0.1229
LACCAT5 2	-0.2303	0.3685	11470	-0.62	0.5321
LACCAT5 3	-0.0103	0.4131	11470	-0.02	0.9801
LACCAT5 4	0.8239	0.5721	11470	1.44	0.1499
LACCAT5 5	0	.	.	.	.
PSMCAT 1	-0.2819	0.2916	11470	-0.97	0.3336
PSMCAT 2	-0.3358	0.1902	11470	-1.77	0.0774
PSMCAT 3	0.0037	0.164	11470	0.02	0.9819
PSMCAT 4	0.2906	0.1581	11470	1.84	0.066
PSMCAT 5	0	.	.	.	.
SUB21 0	-0.975	0.1367	11470	-7.13	0.0001
SUB21 1	0	.	.	.	.
CONC_FIR 0	-4.466	0.2249	11470	-19.85	0.0001
CONC_FIR 1	0	.	.	.	.
LACCAT5*PSMCAT 1 1	-0.2447	0.4071	11470	-0.6	0.5477
LACCAT5*PSMCAT 1 2	0.3176	0.27	11470	1.18	0.2395
LACCAT5*PSMCAT 1 3	-0.0286	0.2273	11470	-0.13	0.8998
LACCAT5*PSMCAT 1 4	-0.0045	0.2029	11470	-0.02	0.9823
LACCAT5*PSMCAT 1 5	0	.	.	.	.
LACCAT5*PSMCAT 2 1	-0.6097	0.4645	11470	-1.31	0.1893
LACCAT5*PSMCAT 2 2	0.4188	0.2917	11470	1.44	0.1511
LACCAT5*PSMCAT 2 3	0.2388	0.2525	11470	0.95	0.3443
LACCAT5*PSMCAT 2 4	-0.0621	0.2441	11470	-0.25	0.7993
LACCAT5*PSMCAT 2 5	0	.	.	.	.
LACCAT5*PSMCAT 3 1	-0.8097	0.4952	11470	-1.63	0.1021
LACCAT5*PSMCAT 3 2	-0.0036	0.3129	11470	-0.01	0.9908
LACCAT5*PSMCAT 3 3	0.3076	0.2833	11470	1.09	0.2776
LACCAT5*PSMCAT 3 4	-0.1109	0.2706	11470	-0.41	0.6819
LACCAT5*PSMCAT 3 5	0	.	.	.	.
LACCAT5*PSMCAT 4 1	0.4599	0.6019	11470	0.76	0.4449
LACCAT5*PSMCAT 4 2	0.6561	0.3559	11470	1.84	0.0653
LACCAT5*PSMCAT 4 3	-0.0163	0.314	11470	-0.05	0.9587
LACCAT5*PSMCAT 4 4	-0.1678	0.3005	11470	-0.56	0.5767
LACCAT5*PSMCAT 4 5	0	.	.	.	.
LACCAT5*PSMCAT 5 1	0	.	.	.	.
LACCAT5*PSMCAT 5 2	0	.	.	.	.
LACCAT5*PSMCAT 5 3	0	.	.	.	.
LACCAT5*PSMCAT 5 4	0	.	.	.	.
LACCAT5*PSMCAT 5 5	0	.	.	.	.
LACCAT5*SUB21 1 0	-0.5236	0.1974	11470	-2.65	0.008
LACCAT5*SUB21 1 1	0	.	.	.	.
LACCAT5*SUB21 2 0	-0.9918	0.2266	11470	-4.38	0.0001
LACCAT5*SUB21 2 1	0	.	.	.	.
LACCAT5*SUB21 3 0	-0.3179	0.2272	11470	-1.4	0.1618
LACCAT5*SUB21 3 1	0	.	.	.	.
LACCAT5*SUB21 4 0	-0.9253	0.2984	11470	-3.1	0.0019
LACCAT5*SUB21 4 1	0	.	.	.	.
LACCAT5*SUB21 5 0	0	.	.	.	.
LACCAT5*SUB21 5 1	0	.	.	.	.
LACCAT5*CONC_FIR 1 0	0.7203	0.2975	11470	2.42	0.0155

LACCAT5*CONC_FIR 1 1	0	.	.	.	.
LACCAT5*CONC_FIR 2 0	0.398	0.3157	11470	1.26	0.2074
LACCAT5*CONC_FIR 2 1	0	.	.	.	.
LACCAT5*CONC_FIR 3 0	0.3796	0.3546	11470	1.07	0.2845
LACCAT5*CONC_FIR 3 1	0	.	.	.	.
LACCAT5*CONC_FIR 4 0	-0.5071	0.5181	11470	-0.98	0.3277
LACCAT5*CONC_FIR 4 1	0	.	.	.	.
LACCAT5*CONC_FIR 5 0	0	.	.	.	.
LACCAT5*CONC_FIR 5 1	0	.	.	.	.

Models for In-Calf Rates (Model 2)

Four Week In-Calf

```
proc access dbms=dbf;
create work.cowcs.access; /* Create Access Descriptor */
path='e:\cowdata\dbase\dmpreg.dbf';
create work.cowscv.view; /* Create View */
select all ;
list view;
run;
/*******************************************************************************************/
%INC'e:\cowdata\glimmix.SAS';
/*******************************************************************************************/
%glimmix(data=work.cowscv,
stmts=%str(
class= herd region breedcat laccat5 psmcat C_I ;
model InClfp4= region BREEDCAT LACCAT5 psmcat C_I Breedcat*laccat5
/solution;
lsmeans region BREEDCAT LACCAT5 psmcat C_I Breedcat*laccat5 /diff cl;
random herd;
/** where empty >=0** "true" model but this would exclude early cull cows/**
 /** MS not significant lsmeans psmcat sub21 conc_fir **/
) ) run;
```

Class Level Information

Class	Levels	Values
HERD	48	
REGION	5	1 2 3 4 5
BREEDCAT	5	1 2 3 4 5
LACCAT5	5	1 2 3 4 5
PSMCAT	5	1 2 3 4 5
C_I	2	0 1

GLIMMIX Model Statistics

Description	Value
Deviance	14447.0324
Scaled Deviance	14447.0324
Pearson Chi-Square	11614.0147
Scaled Pearson Chi-Square	11614.0147
Dispersion Scale	1.0000

Table 71. Parameter estimates and the standard errors for each independent variable included in a model for four week in-calf rates

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
INTERCEPT	0.3691	0.2471	11577	1.49	0.1353
REGION 1	0.0282	0.0929	11577	0.3	0.7612
REGION 2	0.1202	0.0676	11577	1.78	0.0754

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
REGION 4	0.2996	0.0712	11577	4.21	0.0001
REGION 5	-0.2033	0.0664	11577	-3.06	0.0022
REGION 6	0	.	.	.	.
BREEDCAT 1	0.4504	0.4042	11577	1.11	0.2651
BREEDCAT 2	0.2213	0.2323	11577	0.95	0.3408
BREEDCAT 3	0.3226	0.2353	11577	1.37	0.1704
BREEDCAT 4	0.0089	0.2551	11577	0.03	0.9722
BREEDCAT 5	0	.	.	.	.
LACCAT5 1	0.7956	0.4131	11577	1.93	0.0541
LACCAT5 2	0.4801	0.4118	11577	1.17	0.2437
LACCAT5 3	0.6516	0.4422	11577	1.47	0.1407
LACCAT5 4	0.2268	0.3926	11577	0.58	0.5634
LACCAT5 5	0	.	.	.	.
PSMCAT 1	-2.2851	0.1732	11577	-13.19	0.0001
PSMCAT 2	-1.0011	0.0818	11577	-12.23	0.0001
PSMCAT 3	-0.487	0.0676	11577	-7.21	0.0001
PSMCAT 4	-0.0841	0.0617	11577	-1.36	0.1728
PSMCAT 5	0	.	.	.	.
C_I 0	0.2124	0.0662	11577	3.21	0.0014
C_I 1	0	.	.	.	.
BREEDCAT*LACCAT5 1 1	-0.9633	0.711	11577	-1.35	0.1755
BREEDCAT*LACCAT5 1 2	-1.1862	0.6762	11577	-1.75	0.0794
BREEDCAT*LACCAT5 1 3	-1.1872	0.6713	11577	-1.77	0.077
BREEDCAT*LACCAT5 1 4	-0.2898	0.8067	11577	-0.36	0.7194
BREEDCAT*LACCAT5 1 5	0	.	.	.	.
BREEDCAT*LACCAT5 2 1	-1.0531	0.4196	11577	-2.51	0.0121
BREEDCAT*LACCAT5 2 2	-0.2402	0.4194	11577	-0.57	0.5668
BREEDCAT*LACCAT5 2 3	-0.3771	0.4497	11577	-0.84	0.4017
BREEDCAT*LACCAT5 2 4	-0.0337	0.4029	11577	-0.08	0.9333
BREEDCAT*LACCAT5 2 5	0	.	.	.	.
BREEDCAT*LACCAT5 3 1	-0.7893	0.425	11577	-1.86	0.0633
BREEDCAT*LACCAT5 3 2	-0.4817	0.4236	11577	-1.14	0.2555
BREEDCAT*LACCAT5 3 3	-0.1871	0.4557	11577	-0.41	0.6814
BREEDCAT*LACCAT5 3 4	0.0283	0.4122	11577	0.07	0.9454
BREEDCAT*LACCAT5 3 5	0	.	.	.	.
BREEDCAT*LACCAT5 4 1	-0.7146	0.4598	11577	-1.55	0.1202
BREEDCAT*LACCAT5 4 2	-0.2504	0.4626	11577	-0.54	0.5883
BREEDCAT*LACCAT5 4 3	-0.0528	0.4977	11577	-0.11	0.9155
BREEDCAT*LACCAT5 4 4	-0.0188	0.439	11577	-0.04	0.9658
BREEDCAT*LACCAT5 4 5	0	.	.	.	.
BREEDCAT*LACCAT5 5 1	0	.	.	.	.
BREEDCAT*LACCAT5 5 2	0	.	.	.	.
BREEDCAT*LACCAT5 5 3	0	.	.	.	.
BREEDCAT*LACCAT5 5 4	0	.	.	.	.
BREEDCAT*LACCAT5 5 5	0	.	.	.	.

Eight Week In-Calf

```
proc access dbms=dbf;
create work.cowcs.access; /* Create Access Descriptor */
path='e:\cowdata\dbase\dmpreg.dbf';
create work.cowscv.view; /* Create View */
select all ;
list view;
run;
/******************************************************************************************/
```

```
%INC'e:\cowdata\glimmix.SAS';
/******************************************************************************************/
%glimmix(data=work.cowscv,
stmts=%str(
class= herd region laccat5 psmcat C_I ;
model InCalfp8= region laccat5 psmcat C_I laccat5*C_I
/solution;
lsmeans laccat5 psmcat C_I laccat5*C_I/diff cl;
random herd;
) ) run;
```

Class Level Information

Class	Levels	Values
HERD	48	
REGION	5	1 2 4 5 6
LACCAT5	5	1 2 4 5 6
PSMCAT	5	1 2 4 5 6
C_I	2	0 1

Covariance Parameter Estimates
HERD 0.19202172

GLIMMIX Model Statistics

Description	Value
Deviance	9292.8023
Scaled Deviance	9512.8888
Pearson Chi-Square	11338.2612
Scaled Pearson Chi-Square	11606.7915
Extra-Dispersion Scale	0.9769

Table 72. Parameter estimates and the standard errors for each independent variable included in a model for eight week in-calf rates

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
INTERCEPT	1.4013	0.2306	43	6.08	0.0001
REGION 1	0.1743	0.3053	11599	0.57	0.5681
REGION 2	0.1354	0.2189	11599	0.62	0.5361
REGION 4	0.5825	0.2458	11599	2.37	0.0178
REGION 5	-0.1985	0.2317	11599	-0.86	0.3916
REGION 6	0	.	.	.	.
LACCAT5 1	0.1911	0.4052	11599	0.47	0.6372
LACCAT5 2	0.6689	0.1898	11599	3.52	0.0004
LACCAT5 3	0.5708	0.2004	11599	2.85	0.0044
LACCAT5 4	0.3343	0.2308	11599	1.45	0.1475
LACCAT5 5	0	.	.	.	.
PSMCAT 1	-1.5149	0.1549	11599	-9.78	0.0001
PSMCAT 2	-0.7672	0.1051	11599	-7.3	0.0001
PSMCAT 3	-0.2955	0.092	11599	-3.21	0.0013
PSMCAT 4	0.0731	0.0854	11599	0.86	0.3921
PSMCAT 5	0	.	.	.	.
C_I 0	0.421	0.1328	11599	3.17	0.0015
C_I 1	0	.	.	.	.
LACCAT5*C_I 1 0	-0.2878	0.4117	11599	-0.7	0.4846
LACCAT5*C_I 1 1	0	.	.	.	.
LACCAT5*C_I 2 0	-0.6217	0.2067	11599	-3.01	0.0026
LACCAT5*C_I 2 1	0	.	.	.	.
LACCAT5*C_I 3 0	-0.243	0.2191	11599	-1.11	0.2675
LACCAT5*C_I 3 1	0	.	.	.	.

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
LACCAT5*C_I 4 0	-0.0381	0.2513	11599	-0.15	0.8795
LACCAT5*C_I 4 1	0	.	.	.	.
LACCAT5*C_I 5 0	0	.	.	.	.
LACCAT5*C_I 5 1	0	.	.	.	.

In-Calf Rates for Herds Using DairyMAN (Non-Return Analysis)

Four Week In-Calf Rate

```
proc access dbms=dbf;
create work.cowcs.access; /* Create Access Descriptor */
path='e:\cowdata\dbase\dm.dbf';
create work.cowscv.view; /* Create View */
select all ;
list view;
run;
/*****************************************************************************/
%INC'e:\cowdata\glimmix.SAS';
/*****************************************************************************/
%glimmix(data=work.cowscv,
stmts=%str(
class= herd laccat5 psmcat sub21 nr28 ;
model IC4NR= laccat5 psmcat sub21 nr28 laccat5*nr28 psmcat*nr28 sub21*nr28 /solution;
lsmeans laccat5 psmcat sub21 nr28 laccat5*nr28 psmcat*nr28 sub21*nr28/diff cl;
/***C_I not sig removed laccat*heatcase and heat case laccat5*psmcat laccat5*sub21 psmcat*sub21**/
random herd;
) ) run;
```

Class	Levels	Values
HERD	143	
LACCAT5	5	1 2 3 4 5
PSMCAT	5	1 2 3 4 5
SUB21	2	0 1
NR28	2	0 1

Covariance Parameter Estimates

HERD 0.14486989

GLIMMIX Model Statistics

Description	Value
Deviance	28530.4602
Scaled Deviance	29257.5871
Pearson Chi-Square	31869.5151
Scaled Pearson Chi-Square	32681.7411
Extra-Dispersion Scale	0.9751

Table 73 Parameter estimates and the standard errors for each independent variable included in a model for four week in-calf rates that included the intermediate variables, submission and non-return

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
INTERCEPT	2.2550	0.0757	142	29.78	0.0001
LACCAT5 1	-0.1650	0.0551	32654	-2.99	0.0028
LACCAT5 2	0.1087	0.0584	32654	1.86	0.0628
LACCAT5 3	0.2381	0.0626	32654	3.8	0.0001
LACCAT5 4	0.3597	0.0700	32654	5.14	0.0001
LACCAT5 5	0.0000	.	.	.	.
PSMCAT 1	-1.3068	0.1301	32654	-10.05	0.0001
PSMCAT 2	-0.8107	0.0818	32654	-9.91	0.0001
PSMCAT 3	-0.3668	0.0706	32654	-5.2	0.0001
PSMCAT 4	-0.0811	0.0660	32654	-1.23	0.2196

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
PSMCAT 5	0.0000	.	.	.	.
SUB21 0	-2.6468	0.0491	32654	-53.85	0.0001
SUB21 1	0.0000	.	.	.	.
NR28 0	-2.9301	0.1000	32654	-29.31	0.0001
NR28 1	0.0000	.	.	.	.
LACCAT5*NR28 1 0	0.3058	0.0835	32654	3.66	0.0003
LACCAT5*NR28 1 1	0.0000	.	.	.	.
LACCAT5*NR28 2 0	0.1004	0.0863	32654	1.16	0.2444
LACCAT5*NR28 2 1	0.0000	.	.	.	.
LACCAT5*NR28 3 0	-0.0215	0.0920	32654	-0.23	0.8152
LACCAT5*NR28 3 1	0.0000	.	.	.	.
LACCAT5*NR28 4 0	-0.2998	0.1011	32654	-2.97	0.0030
LACCAT5*NR28 4 1	0.0000	.	.	.	.
LACCAT5*NR28 5 0	0.0000	.	.	.	.
LACCAT5*NR28 5 1	0.0000	.	.	.	.
PSMCAT*NR28 1 0	0.8349	0.2067	32654	4.04	0.0001
PSMCAT*NR28 1 1	0.0000	.	.	.	.
PSMCAT*NR28 2 0	0.6135	0.1206	32654	5.09	0.0001
PSMCAT*NR28 2 1	0.0000	.	.	.	.
PSMCAT*NR28 3 0	0.2613	0.1028	32654	2.54	0.0110
PSMCAT*NR28 3 1	0.0000	.	.	.	.
PSMCAT*NR28 4 0	0.0570	0.0961	32654	0.59	0.5527
PSMCAT*NR28 4 1	0.0000	.	.	.	.
PSMCAT*NR28 5 0	0.0000	.	.	.	.
PSMCAT*NR28 5 1	0.0000	.	.	.	.
SUB21*NR28 0 0	-1.2385	0.3360	32654	-3.69	0.0002
SUB21*NR28 0 1	0.0000	.	.	.	.
SUB21*NR28 1 0	0.0000	.	.	.	.
SUB21*NR28 1 1	0.0000	.	.	.	.

Eight Week In-Calf Rate

```
proc access dbms=dbf;
create work.cowcs.access; /* Create Access Descriptor */
path='e:\cowdata\dbase\dm.dbf';
create work.cowscv.view; /* Create View */
select all ;
list view;
run;
/***************************************************************************/
%INC'e:\cowdata\glimmix.SAS';
/***************************************************************************/
%glimmix(data=work.cowscv,
stmts=%str(
class= herd laccat5 psmcat sub21 nr28 C_I ;
model IC8NR= laccat5 psmcat sub21 nr28 C_I laccat5*sub21 psmcat*nr28 /solution ;
/******* not significant **laccat5*psmcat**laccat5*nr28 psmcat*sub21 sub21*nr28***/
lsmeans laccat5 psmcat sub21 nr28 C_I laccat5*sub21 psmcat*nr28/diff cl;
random herd;
))
run;
```

Class Level Information

Class	Levels	Values
HERD	143	
LACCAT5	5	1 2 3 4 5
PSMCAT	5	1 2 3 4 5

SUB21	2	0 1
NR28	2	0 1
C_I	2	0 1

Covariance Parameter Estimates
HERD 0.41915420
GLIMMIX Model Statistics

Description	Value
Deviance	21916.6922
Scaled Deviance	23082.9607
Pearson Chi-Square	31020.6471
Scaled Pearson Chi-Square	32671.3709
Extra-Dispersion Scale	0.9495

Table 74. Parameter estimates and the standard errors for each independent variable included in a model for eight week in-calf rates that included the intermediate variables, submission and non-return

Parameter	Estimate	Std Error	DDF	T	Pr > |T|
INTERCEPT	2.6847	0.1118	142	24.02	0.0001
LACCAT5 1	0.0795	0.0546	32654	1.46	0.1454
LACCAT5 2	0.2506	0.0566	32654	4.43	0.0001
LACCAT5 3	0.3359	0.0604	32654	5.56	0.0001
LACCAT5 4	0.3923	0.0666	32654	5.89	0.0001
LACCAT5 5	0	.	.	.	.
PSMCAT 1	-1.0832	0.1292	32654	-8.38	0.0001
PSMCAT 2	-0.7436	0.0971	32654	-7.66	0.0001
PSMCAT 3	-0.3547	0.0861	32654	-4.12	0.0001
PSMCAT 4	-0.101	0.0813	32654	-1.24	0.2141
PSMCAT 5	0	.	.	.	.
SUB21 0	-0.9776	0.081	32654	-12.07	0.0001
SUB21 1	0	.	.	.	.
NR28 0	-1.2372	0.1031	32654	-12	0.0001
NR28 1	0	.	.	.	.
C_I 0	0.1149	0.0578	32654	1.99	0.047
C_I 1	0	.	.	.	.
LACCAT5*SUB21 1 0	-0.2961	0.1131	32654	-2.62	0.0089
LACCAT5*SUB21 1 1	0	.	.	.	.
LACCAT5*SUB21 2 0	-0.1494	0.124	32654	-1.21	0.2281
LACCAT5*SUB21 2 1	0	.	.	.	.
LACCAT5*SUB21 3 0	-0.1528	0.138	32654	-1.11	0.2682
LACCAT5*SUB21 3 1	0	.	.	.	.
LACCAT5*SUB21 4 0	-0.3903	0.1531	32654	-2.55	0.0108
LACCAT5*SUB21 4 1	0	.	.	.	.
LACCAT5*SUB21 5 0	0	.	.	.	.
LACCAT5*SUB21 5 1	0	.	.	.	.
PSMCAT*NR28 1 0	0.5104	0.1801	32654	2.83	0.0046
PSMCAT*NR28 1 1	0	.	.	.	.
PSMCAT*NR28 2 0	0.4767	0.1354	32654	3.52	0.0004
PSMCAT*NR28 2 1	0	.	.	.	.
PSMCAT*NR28 3 0	0.2252	0.1213	32654	1.86	0.0634
PSMCAT*NR28 3 1	0	.	.	.	.
PSMCAT*NR28 4 0	0.1567	0.1162	32654	1.35	0.1774
PSMCAT*NR28 4 1	0	.	.	.	.
PSMCAT*NR28 5 0	0	.	.	.	.
PSMCAT*NR28 5 1	0	.	.	.	.

Appendix 4

DairyFIX.kb Computer Code in Text Format

This code is include here because it contains the message text for the report output for stage one of the DairyFIX investigation.

```
(@RULE= abortions_abovetarget
	@COMMENTS=".";
	(@LHS=
		(=	(COMPARE(abortions.result,abortions.targetlevel))	(1))
		(<=	(COMPARE(abortions.result,abortions.warninglevel))	(0)))
	(@HYPO= abortions_abovetarget)
	(@RHS=
		(Execute	("writeTo")
	(@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=incalf.txt,\
@TEXT=@V(t.line),@ADD";))
		(Execute	("WriteTo")
	(@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=incalf.txt,\
@TEXT=The percentage of abortions is @V(abortions.result) percent. This exceeds the target
level and requires investigation. Additional veterinary investigations will be required to
identify the cause of the problem. You should also carefully exam the records for cows that
were expected to calve but did not at the start of the season This may indicate problems also
existed in the previous season. Also you should examine the abortion reports in detail for
this and previous seasons where you have pregnancy tested the herd (DairyMAN will only record
an abortion if a cow has been confirmed in-calf by pregnancy diagnosis,@ADD";))
		(Execute	("WriteTo")
	(@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=incalf.txt,\
@TEXT=@V(t.bl),@ADD";))
	))
(@RULE= abortions_actionlevel
	@COMMENTS="c";
	(@LHS=
		(=	(COMPARE(abortions.result,abortions.actionlevel))	(1))
		(>	(abortions.result)	(0)))
	(@HYPO= abortions_actionlevel)
	(@RHS=
		(Execute	("writeTo")
	(@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=incalf.txt,\
@TEXT=@V(t.line),@ADD";))
		(Execute	("WriteTo")
	(@WAIT=TRUE;@ATOMID=abortions.result;@STRING="@TRANSCRIPT,\
@FILE=incalf.txt,@TEXT=The number of recorded abortions is @V(abortions.result) \
percent. The recorded abortion rate is in the action range and requires urgent investigation.
There is an unusually high abortion rate recorded in this herd. Additional veterinary
investigations will be required to identify the cause of the problem. You should also
carefully exam the records for cows that were expected to calve but did not at the start of
the season This may indicate problems also existed in the previous season. Also you should
examine the abortion reports in detail for this and previous seasons where you have pregnancy
tested the herd (DairyMAN will only record an abortion if a cow has been confirmed in-calf by
pregnancy diagnosis,\
@ADD";))
		(Execute	("writeTo")
	(@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=incalf.txt,\
@TEXT=@V(T.bl),@ADD";))
	))
(@RULE= abortions_belowtarget
	@COMMENTS="a";
	(@LHS=
		(<=	(COMPARE(abortions.result,abortions.targetlevel))	(0))
		(>	(abortions.result)	(0)))
	(@HYPO= abortions_belowtarget)
	(@RHS=
		(Execute	("writeTo")
	(@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=incalf.txt,\
@TEXT=@V(t.line),@ADD";))
		(Execute	("WriteTo")
	(@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=incalf.txt,\
@TEXT=The abortion rate is @V(abortions.result) percent and is below the level of concern.
This means performance is adequate but it is often difficult to calculate an accurate estimate
of abortions. Many abortions in dairy herds may go un-noticed. Carefully examine the records
for cows that failed to calve. Abortions are only recorded in DairyMAN for cows that have been
confirmed in-calf by pregnancy testing. A large difference in the number of cows that actually
calved compared with the number expected to calve may indicate an abortion problem in your
herd. If there is no great difference in the number of cows expected and actually calved then
it is not likely that abortions are of concern in your herd,\@ADD";))
	))
(@RULE= abortions_belowtarget__1
	@COMMENTS="a";
	(@LHS=
```

```
            (<=     (COMPARE(abortions.result,abortions.targetlevel))    (0))
            (=      (abortions.result)     (0)))
        (@HYPO= abortions_belowtarget)
        (@RHS=
            (Execute       ("writeTo")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=incalf.txt,\
@TEXT=@V(t.line),@ADD";))
            (Execute       ("WriteTo")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=incalf.txt,\
@TEXT=There were NO abortions recorded during the period being analysed. If you pregnancy
tested your herd this indicated that abortions are not of concern. However abortions are only
recorded for cows that have been confirmed in-calf by pregnancy testing. If you do not use
herd pregnancy testing this figure will always be low. Carefully examine the difference
between the number of cows expected to calve and the number of cows that actually calved. If
there is little difference then abortions are not likely to be a problem. If the difference is
of concern then abortions may be a problem in your herd (or the cows were never actually
pregnant). You should consider pregnancy testing your herd next season and carefully examine
other aspects of your herds performance. If heat detection is not ideal or does not continue
during the period of natural mating then expected calving rates may overestimate the "true
picture" \
@ADD";))
        ))
(@RULE= abortions_loaded1
        (@LHS=
            (Yes    (abortions_abovetarget)))
        (@HYPO= abortions_loaded))
(@RULE= abortions_loaded2
        (@LHS=
            (Yes    (abortions_belowtarget)))
        (@HYPO= abortions_loaded))
(@RULE= abortions_loaded3
        (@LHS=
            (Yes    (abortions_warninglevel)))
        (@HYPO= abortions_loaded))
(@RULE= abortions_loaded4
        (@LHS=
            (Yes    (abortions_actionlevel)))
        (@HYPO= abortions_loaded))
(@RULE= abortions_warninglevel
        (@LHS=
            (=      (COMPARE(abortions.result,abortions.warninglevel))    (1))
            (>=     (COMPARE(abortions.result,abortions.actionlevel))    (0)))
        (@HYPO= abortions_warninglevel)
        (@RHS=
            (Execute       ("writeto")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=incalf.txt,\
@TEXT=@V(t.line),@ADD";))
            (Execute       ("WriteTo")
        (@WAIT=TRUE;@ATOMID=abortions.result;@STRING="@TRANSCRIPT,\
@FILE=incalf.txt,@TEXT=The number of abortions is in the warning range. This indicates a
severe abortion problem exists in your herd and requires investigation. Additional veterinary
investigations will be required to identify the cause of the problem. You should also
carefully exam the records for cows that were expected to calve but did not at the start of
the season This may indicate problems also existed in the previous season. Also you should
examine the abortion reports in detail for this and previous seasons where you have pregnancy
tested the herd (DairyMAN will only record an abortion if a cow has been confirmed in-calf by
pregnancy diagnosis,\
,@ADD";))
        ))
(@RULE= Calving_end_date_too_close
        (@LHS=
            (No     (enddate_acceptable)))
        (@HYPO= data_fault)
        (@RHS=
            (Execute       ("Message")     (@WAIT=TRUE;@STRING="@TEXT=The date to end the
Calving analysis is less than 10\
 weeks after the planned start of calving. Data is therefore likely to be inaccurate and
therefore will not proceed for some analyses. You will be advised when this is so.,@OK";))
            (Execute       ("WriteTo")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=data.txt,\
@TEXT=The date to end the calving analysis is less than 10 weeks after the planned start of
calving. Some analyses will therefore be inaccurate and will not proceed. You will be advised
when this is so,\
,@NEW";))
            (Execute       ("ControlSession")     (@WAIT=TRUE;@STRING="@STOP";))
        ))
(@RULE= cows_calved_less_40_days_abovetarget
        (@LHS=
            (=
        (COMPARE(cows_calved_less_40_days.result,cows_calved_less_40_days.targetlevel))    (1))
```

```
            (<=
        (COMPARE(cows_calved_less_40_days.result,cows_calved_less_40_days.warninglevel))
        (0)))
        (@HYPO= cows_calved_less_40_days_abovetarget)
        (@RHS=
            (Execute        ("writeTo")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
@TEXT=@V(t.line),@ADD";))
            (Execute        ("WriteTo")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
@TEXT=The percent of cows calved less than 40 days is @V(cows_calved_less_40_days.result)
percent. This an extremely important factor that will affect the subsequent mating
performance. It is above target and therefore could affect the reproductive performance of the
herd. This will be investigated further
,\
@ADD";))
        ))
(@RULE= cows_calved_less_40_days_actionlevel
        (@LHS=
            (=
        (COMPARE(cows_calved_less_40_days.result,cows_calved_less_40_days.actionlevel))
        (1)))
        (@HYPO= cows_calved_less_40_days_actionlevel)
        (@RHS=
            (Execute        ("WriteTo")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
@TEXT=@V(t.line),@ADD";))
            (Execute        ("WriteTo")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
,@TEXT=The number of cows calved less than 40 days is @V(cows_calved_less_40_days.result)
percent and is in the action range. The calving pattern in relation to mating start will have
a significant effect on the reproductive performance or your herd.,
@ADD";))
        ))
(@RULE= cows_calved_less_40_days_belowtarget
        (@LHS=
            (<=
        (COMPARE(cows_calved_less_40_days.result,cows_calved_less_40_days.targetlevel))
        (0)))
        (@HYPO= cows_calved_less_40_days_belowtarget)
        (@RHS=
            (Execute        ("writeTo")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
@TEXT=@V(t.line),@ADD";))
            (Execute        ("WriteTo")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
@TEXT=The cows calved less than forty days is @V(cows_calved_less_40_days.result\
) percent and is equal to or below the recommended level. This means performance is adequate
and not likely to affect reproductive performance adversely. This will be further
assessed.,@ADD";))
        ))
(@RULE= cows_calved_less_40_days_loaded
        (@LHS=
            (Yes    (cows_calved_less_40_days_abovetarget)))
        (@HYPO= cows_calved_less_40_days_loaded))
(@RULE= Cows_calved_less_40_days_loaded__1
        (@LHS=
            (Yes    (cows_calved_less_40_days_actionlevel)))
        (@HYPO= cows_calved_less_40_days_loaded))
(@RULE= cows_calved_less_40_days_warningrangee
        (@LHS=
            (=
        (COMPARE(cows_calved_less_40_days.result,cows_calved_less_40_days.warninglevel))   (1))
            (>=
        (COMPARE(cows_calved_less_40_days.result,cows_calved_less_40_days.actionlevel))
        (0)))
        (@HYPO= cows_calved_less_40_days_warninglevel)
        (@RHS=
            (Execute        ("writeTo")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
@TEXT=@V(t.line),@ADD";))
            (Execute        ("WriteTo")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
,@TEXT=The number of cows calved less than 40 days is @V(cows_calved_less_40_day.results)
percent and is in the warning range. It is likely that the calving pattern has affected
reproductive performance. This will be investigated further.,@ADD";))
        ))
(@RULE= dates_for_calving_analysis_ok
        @COMMENTS="This sets files for reporting to blank with header. Over writes any pre
existing files in path ";
        (@LHS=
            (Yes    (update_date_acceptible))
            (Yes    (enddate_acceptable))
            (Execute        ("writeTo")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=calve.txt,\
@TEXT=DairyFIX analysis of basic information.,\
@NEW";))
            (Execute        ("WriteTo")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=Calve.txt,\
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@TEXT=DairyFIX. Calving Performance,@ADD";))
               (Execute        ("writeTO")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
@TEXT=DairyFIX analysis of basic information,\
,@NEW";))
               (Execute        ("WriteTo")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
@TEXT=Submission Performance,@ADD";))
               (Execute        ("writeTo")
       (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=heats.txt,\
@TEXT=DairyFIX analysis of basic information,\
@NEW";))
               (Execute        ("WriteTo")
       (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=heats.txt,\
@TEXT=Heat Detection Performance ,@ADD";))
               (Execute        ("writeTo")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
@TEXT=DairyFIX reproductive analysis of basic data.,\
@NEW";))
               (Execute        ("WriteTo")
       (@WAIT=TRUE;@STRING="@FILE=preg.txt,@TEXT=Conception Performance,\
@ADD";))
               (Execute        ("writeTo")
       (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=incalf.txt,\
@TEXT=DairyFIX analysis of basic information,\
@NEW";))
               (Execute        ("WriteTo")
       (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=incalf.txt,\
@TEXT=Incalf Rates,@ADD";)))
       (@HYPO= dates_for_calving_analysis_ok))
(@RULE= eight_week_calve_rate_below_target
       (@LHS=
               (Yes    (four_week_calve_analysed))
               (=
       (COMPARE(eight_week_calving_rate.result,eight_week_calving_rate.targetlevel))      ((0-
1)))
               (>=
       (COMPARE(eight_week_calving_rate.result,eight_week_calving_rate.warninglevel))
       (0)))
       (@HYPO= eight_week_calve_rate_belowtarget)
       (@RHS=
               (Execute        ("writeto")
       (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=calve.txt,\
@TEXT=@v(t.line),@ADD";))
               (Execute        ("WriteTo")
       (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=calve.txt,\
@TEXT=The eight week calving rate is @V(eight_week_calving_rate.result) percent and is below
target. The reduced calving performance will have a negative effect on the outcome or the
mating season. The analysis to follow will consider this performance. ,@ADD";))
       ))
(@RULE= eight_week_calving_actionlevel
       (@LHS=
               (Yes    (four_week_calve_analysed))
               (<=
       (COMPARE(eight_week_calving_rate.result,eight_week_calving_rate.actionlevel))
       (0)))
       (@HYPO= eight_week_calving_actionlevel)
       (@RHS=
               (Execute        ("writeto")
       (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=calve.txt,\
@TEXT=@V(t.line),@ADD";))
               (Execute        ("WriteTo")     (@WAIT=TRUE;@STRING="@FILE=calve.txt,@TEXT=the
eight week calving is @V(eight_w\
eek_calving_rate.result) percent and is in action level. It is likely that the calving pattern
has had a significant effect on reproductive performance. This effect will be evaluated
,@ADD";))
       ))
(@RULE= eight_week_calving_rate_abovetarget
       (@LHS=
               (Yes    (four_week_calve_analysed))
               (>=
       (COMPARE(eight_week_calving_rate.result,eight_week_calving_rate.targetlevel))
       (0)))
       (@HYPO= eight_week_calve_rate_abovetarget)
       (@RHS=
               (Execute        ("writeTO")
       (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=calve.txt,\
@TEXT=@V(t.line),@ADD";))
               (Execute        ("WriteTo")
       (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=calve.txt,\
@TEXT=The eight week calving rate is @V(eight_week_calving_rate.result) percent and meets
performance standards. Good calving performance will have a positive effect on the potential
outcome or the mating season. The analysis to follow will consider this performance. A poor
eight week calving rate may also indicate an abortion or pregnancy loss problem prior to
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calving. If the number of cows that fail to calve is high this should be considered.
,,@ADD";))
        ))
(@RULE= eight_week_calving_warninglevel
        (@LHS=
                (Yes    (four_week_calve_analysed))
                (=
        (COMPARE(eight_week_calving_rate.result,eight_week_calving_rate.warninglevel))     ((0-
1)))
                (>=
        (COMPARE(four_week_calving_rate.result,four_week_calving_rate.actionlevel))
        (0)))
        (@HYPO= eight_week_calving_warninglevel)
        (@RHS=
                (Execute       ("writeto")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=calve.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute       ("WriteTo")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=calve.txt,\@TEXT=The eight week calving rate is
@V(eight_week_calving_rate.result) percent and is in the warning range. The reduced calving
performance will have a negative effect on the potential outcome or the mating season. The
analysis to follow will consider this performance. A poor eight week calving rate may also
indicate an abortion or pregnancy loss problem prior to calving. If the number of cows that
fail to calve is high this should be considered,@ADD";))
        ))
(@RULE= eight_week_incalf_rate_above_targets__1
        (@LHS=
                (Yes    (four_week_incalf_rate_loaded))
                (>=
        (COMPARE(eight_week_incalf_rate.result,eight_week_incalf_rate.targetlevel))
        (0)))
        (@HYPO= eight_week_incalf_rate_abovetarget)
        (@RHS=
                (Execute       ("writeto")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=incalf.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute       ("WriteTo")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=incalf.txt,\
@TEXT=the eight week incalf rate is @v(eight_week_incalf_rate.result) percent \
and indicates good overall performance.,@ADD";))
        ))
(@RULE= eight_week_incalf_rate_actionlevel
        (@LHS=
                (Yes    (four_week_incalf_rate_loaded))
                (=
        (COMPARE(eight_week_incalf_rate.result,eight_week_incalf_rate.actionlevel))       ((0-
1))))
        (@HYPO= eight_week_incalf_rate_actionlevel)
        (@RHS=
                (Execute       ("writeto")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=incalf.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute       ("WriteTo")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=incalf.txt,\
@TEXT=The eight week incalf rate is @V(eight_week_incalf_rate.result) percent requires action.
The analysis of factors affecting this result of reproductive performance need examination and
will be evaluated. A poor eight week calving rate may also indicate an abortion or pregnancy
loss problem prior to calving. If the number of cows that fail to calve is high this should be
considered,\
@ADD";))
        ))
(@RULE= eight_week_incalf_rate_belowtarget
        (@LHS=
                (Yes    (four_week_incalf_rate_loaded))
                (<
        (COMPARE(eight_week_incalf_rate.result,eight_week_incalf_rate.targetlevel))       (0))
                (>=
        (COMPARE(eight_week_incalf_rate.result,eight_week_incalf_rate.warninglevel))
        (0)))
        (@HYPO= eight_week_incalf_rate_belowtarget)
        (@RHS=
                (Execute       ("writeto")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=incalf.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute       ("WriteTo")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=incalf.txt,\
@TEXT=The eight week incalf rate is @v(eight_week_incalf_rate.result) percent and below
target. Performance could be improved. The effect the calving pattern has had on reproductive
peroformance will be examined. A poor eight week calving rate may also indicate an abortion or
pregnancy loss problem prior to calving. If the number of cows that fail to calve is high this
should be considered @ADD";))
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        ))
(@RULE= eight_week_incalf_rate_warninglevel
        (@LHS=
                (Yes    (four_week_incalf_rate_loaded))
                (<
        (COMPARE(eight_week_incalf_rate.result,eight_week_incalf_rate.warninglevel))        (0))
                (>=
        (COMPARE(eight_week_incalf_rate.result,eight_week_incalf_rate.actionlevel))
        (0)))
        (@HYPO= eight_week_incalf_rate_warninglevel)
        (@RHS=
                (Execute        ("writeto")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=incalf.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=incalf.txt,\
@TEXT=The eight week incalf rate is @V(eight_week_incalf_rate.result) percent is in warning
range. The analysis of factors affecting this result of reproductive performance need
examination and will be evaluated. A poor eight week calving rate may also indicate an
abortion or pregnancy loss problem prior to calving. If the number of cows that fail to calve
is high this should be considered.";))
        ))
(@RULE= end_calving_date_acceptible
        @COMMENTS="checking if end of calving date is at least 10 weeks after the planned
start of calving";
        (@LHS=
                (>=     ((pec.number-PSC.number)/(60*60*24))  (70)))
        (@HYPO= enddate_acceptable)
        (@RHS=
                (Assign (pec.number-PSC.number/60*60*24)      (|days|.calving))
        ))
(@RULE= four_week_calve_analysed
        (@LHS=
                (Yes    (four_week_calve_rate_abovetarget)))
        (@HYPO= four_week_calve_analysed))
(@RULE= four_week_calve_analysed_2
        (@LHS=
                (Yes    (four_week_calve_rate_belowtarget)))
        (@HYPO= four_week_calve_analysed))
(@RULE= four_week_calve_rate_above_targets
        (@LHS=
                (Yes    (induced_analysed))
                (>=
        (COMPARE(four_week_calving_rate.result,four_week_calving_rate.targetlevel))
        (0)))
        (@HYPO= four_week_calve_rate_abovetarget)
        (@RHS=
                (Execute        ("writeto")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=calve.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=calve.txt,\
@TEXT=The four week calving rates is @V(four_week_calving_rate.result) percent and is above
target. Good calving performance will have a positive effect on the potential outcome or the
mating season. The analysis to follow will consider this performance.,@ADD";))
                (Assign (TRUE)  (four_week_calve_analysed))
        ))
(@RULE= four_week_calve_rate_belowtarget
        (@LHS=
                (Yes    (induced_analysed))
                (=
        (COMPARE(four_week_calving_rate.result,four_week_calving_rate.targetlevel))        ((0-
1)))
                (>=
        (COMPARE(four_week_calving_rate.result,four_week_calving_rate.warninglevel))
        (0)))
        (@HYPO= four_week_calve_rate_belowtarget)
        (@RHS=
                (Execute        ("WRITETO")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=calve.txt,\
@TEXT=@V(T.LINE),@ADD";))
                (Execute        ("WriteTo")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=calve.txt,\
@TEXT=The four week calving rate is @V(four_week_calving_rate.result) percent and is below
target. The reduced calving performance may have a negative effect on the potential outcome or
the mating season. The analysis to follow will consider this performance.,@ADD";))
                (Assign (TRUE)  (four_week_calve_analysed))
        ))
(@RULE= four_week_calving_actionevel
        (@LHS=
                (Yes    (induced_analysed))
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                (<=
        (COMPARE(four_week_calving_rate.result,four_week_calving_rate.actionlevel))
        (0)))
        (@HYPO= four_week_calving_actionlevel)
        (@RHS=
                (Execute        ("writeto")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=calve.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=calve.txt,\
@TEXT=The four week calving rates is @V(four_week_calving_rate.result) percent and very poor.
Action must be implemented this mating season to improve the result next year This will have a
severe effect on potential results this season. The analysis to follow will consider this
performance.@OK,\
@ADD";))
                (Assign (TRUE)  (four_week_calve_analysed))
        ))
(@RULE= four_week_calving_warninglevel
        (@LHS=
                (Yes    (induced_analysed))
                (=
        (COMPARE(four_week_calving_rate.result,four_week_calving_rate.warninglevel))       ((0-
1)))
                (>=
        (COMPARE(four_week_calving_rate.result,four_week_calving_rate.actionlevel))
        (0)))
        (@HYPO= four_week_calving_warninglevel)
        (@RHS=
                (Execute        ("writeto")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=calve.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=calve.txt,\
@TEXT=The four week calving rate is @v(four_week_calving_rate.result) percent and in the
warning range. The reduced calving performance will have a negative effect on the potential
outcome or the mating season. The analysis to follow will consider this performance.,@OK";))
                (Assign (TRUE)  (four_week_calve_analysed))
        ))
(@RULE= four_week_incalf_rate_abovetargets__1
        (@LHS=
                (Yes    (loadtxtfile_conception))
                (>=
        (COMPARE(four_week_incalf_rate.result,four_week_incalf_rate.targetlevel))  (0)))
        (@HYPO= four_week_incalf_rate_abovetarget)
        (@RHS=
                (Execute        ("writeto")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=incalf.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=incalf.txt,\
@TEXT=The four week incalf rate is @v(four_week_incalf_rate.result) percent and is above
target. Reproductive performance early in the mating season was good. Use caution interpreting
these results if the herd is not pregnancy tested. Record all heats and returns and enter into
DairyMAN. Re run the analysis if necessary. If cows fail to calve in the following season
carefully consider the need for pregnancy testing\
,@ADD";))
        ))
(@RULE= four_week_incalf_rate_actionlevel
        (@LHS=
                (Yes    (loadtxtfile_conception))
                (=
        (COMPARE(four_week_incalf_rate.result,four_week_incalf_rate.actionlevel))  ((0-1))))
        (@HYPO= four_week_incalf_rate_actionlevel)
        (@RHS=
                (Execute        ("writeto")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=incalf.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=incalf.txt,\
@TEXT=The four week incalf rate is @v(four_week_incalf_rate.result) percent and requires
action. Performance next season may be seriously compromised. We will predict next years
performance,@ADD";))
        ))
(@RULE= four_week_incalf_rate_belowtarget
        (@LHS=
                (Yes    (loadtxtfile_conception))
                (<
        (COMPARE(four_week_incalf_rate.result,four_week_incalf_rate.targetlevel))  (0))
                (>=
        (COMPARE(four_week_incalf_rate.result,four_week_incalf_rate.warninglevel)) (0)))
        (@HYPO= four_week_incalf_rate_belowtarget)
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        (@RHS=
                (Execute        ("writeto")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=incalf.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=incalf.txt,\
@TEXT=The four week incalf rate is @v(four_week_incalf_rate.result) percent and is below
target. We will evaluate the reasons for this and predict performance next year.,@ADD";))
        ))
(@RULE= four_week_incalf_rate_warninglevel
        (@LHS=
                (Yes    (loadtxtfile_conception))
                (<
        (COMPARE(four_week_incalf_rate.result,four_week_incalf_rate.warninglevel)) (0))
                (>=
        (COMPARE(four_week_incalf_rate.result,four_week_incalf_rate.actionlevel))  (0)))
        (@HYPO= four_week_incalf_rate_warninglevel)
        (@RHS=
                (Execute        ("writeto")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=incalf.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=incalf.txt,\
@TEXT=The four week incalf rate is @v(four_week_incalf_rate.result) percent and is in warning
range. We will assess the reasons for this and evaluate next years performance.";))
        ))
(@RULE= induced_abovetarget
        (@LHS=
                (Yes    (warning_action_target_levels_loaded))
                (=      (COMPARE(induced.result,induced.targetlevel))       (1))
                (<=     (COMPARE(induced.result,induced.warninglevel))      (0)))
        (@HYPO= induced_abovetarget)
        (@RHS=
                (Execute        ("writeto")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=calve.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=calve.txt,\
@TEXT=The number of cows induced is @v(induced.result) percent and is above the accepted
target for your herd. How this relates to your calving pattern will be evaluated. You should
aim to reduce the need to induce cows through improved management during the mating period.
Induction does not necessarily improve reproductive performance. Induced cows should be in
above average body condition and induced to calve as early as possible. Late inductions will
not contribute to an improved herd performance. ,@ADD";))
        ))
(@RULE= Induced_actionlevel
        (@LHS=
                (Yes    (warning_action_target_levels_loaded))
                (=      (COMPARE(induced.result,induced.actionlevel))       (1)))
        (@HYPO= Induced_actionlevel)
        (@RHS=
                (Execute        ("writeto")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=calve.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=calve.txt,\
@TEXT=The percentage cows inducecd is @v(induced.result) percent and very high. Action should
be taken to reduce the need for this number of inductions. We will evaluate those areas of
reproductive performance that can be improved to reduce the need for inductions. You should
aim to reduce the need to induce cows through improved management during the mating period.
Induction does not necessarily improve reproductive performance. Induced cows should be in
above average body condition and induced to calve as early as possible. Late inductions will
not contribute to an improved herd performance.,@ADD";))
        ))
(@RULE= induced_analysed
        (@LHS=
                (Yes    (induced_abovetarget)))
        (@HYPO= induced_analysed))
(@RULE= induced_analysed_2
        (@LHS=
                (Yes    (Induced_warninglevel)))
        (@HYPO= induced_analysed))
(@RULE= induced_analysed__3
        (@LHS=
                (Yes    (Induced_belowtarget)))
        (@HYPO= induced_analysed))
(@RULE= induced_analysed__4
        (@LHS=
                (Yes    (Induced_actionlevel)))
        (@HYPO= induced_analysed))
(@RULE= Induced_belowtarget
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        (@LHS=
                (Yes    (warning_action_target_levels_loaded))
                (<=     (COMPARE(induced.result,induced.targetlevel))       (0)))
        (@HYPO= Induced_belowtarget)
        (@RHS=
                (Execute        ("writeto")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=calve.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("writeto")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=calve.txt,\
@TEXT=The percentage induced is @v(induced.result) percent and below the industry accepted
level. We will evaluate this in relation to your herds calving pattern as increased or reduced
inductions may be indicated depending on the expected calving pattern. You should aim to
reduce the need to induce cows through improved management during the mating period. Induction
does not necessarily improve reproductive performance. Induced cows should be in above average
body condition and induced to calve as early as possible. Late inductions will not contribute
to an improved herd performance.,@ADD";))
        ))
(@RULE= Induced_belowtarget__1
        (@LHS=
                (Yes    (warning_action_target_levels_loaded))
                (<=     (COMPARE(induced.result,induced.targetlevel))       (0))
                (=      (induced.result)       (0)))
        (@HYPO= Induced_belowtarget)
        (@RHS=
                (Execute        ("writeto")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=calve.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("writeto")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=calve.txt,\
@TEXT=There were NO cows induced during the calving period prior to the mating season being
analysed,@ADD";))
        ))
(@RULE= Induced_warninglevel
        (@LHS=
                (Yes    (warning_action_target_levels_loaded))
                (=      (COMPARE(induced.result,induced.warninglevel))      (1)))
        (@HYPO= Induced_warninglevel)
        (@RHS=
                (Execute        ("writeto")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=calve.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=calve.txt,\
@TEXT=The percentage cows induced is @v(induced.result) percent and high. You should aim to
reduce the need to induce cows through improved management during the mating period. Induction
does not necessarily improve reproductive performance. Induced cows should be in above average
body condition and induced to calve as early as possible. Late inductions will not contribute
to an improved herd performance. We will evaluate the number of inductions needed if the
information is complete for this season,@ADD";))
        ))
(@RULE= nonreturn_all_loaded
        (@LHS=
                (Yes    (nonreturn_all_serve_abovetarget)))
        (@HYPO= nonreturn_all_loaded))
(@RULE= nonreturn_all_loaded2
        (@LHS=
                (Yes    (nonreturn_all_serve_actionlevel)))
        (@HYPO= nonreturn_all_loaded))
(@RULE= nonreturn_all_loaded3
        (@LHS=
                (Yes    (nonreturn_all_serve_belowtarget)))
        (@HYPO= nonreturn_all_loaded))
(@RULE= nonreturn_all_loaded4
        (@LHS=
                (Yes    (nonreturn_all_serve_warninglevel)))
        (@HYPO= nonreturn_all_loaded))
(@RULE= nonreturn_all_serve_abovetarget
        (@LHS=
                (>=     (COMPARE(nonreturn_all_serve.result,nonreturn_all_serve.targetlevel))
        (0)))
        (@HYPO= nonreturn_all_serve_abovetarget)
        (@RHS=
                (Execute        ("writeto")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
@TEXT=the nonreturn rate for all matings is @v(nonreturn_all_serve.result) percent and above
target. Non return rates are influenced by heat detection efficiency. We will eveluate this to
determine if the expected calving rates based on nonreturn rates are reliable.,@ADD";))
        ))
(@RULE= nonreturn_all_serve_actionlevel
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        (@LHS=
                (=      (COMPARE(nonreturn_all_serve.result,nonreturn_all_serve.actionlevel))
        ((0-1))))
        (@HYPO= nonreturn_all_serve_actionlevel)
        (@RHS=
                (Execute        ("writeto")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
@TEXT=The non-return rate all services is @v(nonreturn_all_serve.result) percent\
 and suggests conception rates are very poor. Investigation required will follow,@ADD";))
        ))
(@RULE= nonreturn_all_serve_belowtarget
        (@LHS=
                (<      (COMPARE(nonreturn_all_serve.result,nonreturn_all_serve.targetlevel))
        (0))
                (>=     (COMPARE(nonreturn_all_serve.result,nonreturn_all_serve.warninglevel))
        (0)))
        (@HYPO= nonreturn_all_serve_belowtarget)
        (@RHS=
                (Execute        ("writeto")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("writeto")     (@WAIT=TRUE;@ATOMID=nonreturn_all_serve.result;\
@STRING="@TRANSCRIPT,@FILE=preg.txt,@TEXT=The nonreturn rate for all serves is @\
V(nonreturn_all_serve.result) percent and is below target.,\
@ADD";))
        ))
(@RULE= nonreturn_all_serve_warninglevel
        (@LHS=
                (<      (COMPARE(nonreturn_all_serve.result,nonreturn_all_serve.warninglevel))
        (0))
                (>=     (COMPARE(nonreturn_all_serve.result,nonreturn_all_serve.actionlevel))
        (0)))
        (@HYPO= nonreturn_all_serve_warninglevel)
        (@RHS=
                (Execute        ("writeto")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
@TEXT=The non return rate for all serves is @v(nonreturn_all_serve.result) percent and in the
warning range. Further investigation will determine how heat detection has influenced this
result and evaluate the expected in-calf rates.,\
@ADD";))
        ))
(@RULE= nonreturn_first_serve_abovetarget
        (@LHS=
                (>=
        (COMPARE(nonreturn_first_serve.result,nonreturn_first_serve.targetlevel))  (0)))
        (@HYPO= nonreturn_first_serve_abovetarget)
        (@RHS=
                (Execute        ("writeto")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
@TEXT=the nonreturn_first_serve is above target,\
@ADD";))
        ))
(@RULE= nonreturn_first_serve_actionlevel
        (@LHS=
                (=
        (COMPARE(nonreturn_first_serve.result,nonreturn_first_serve.actionlevel))  ((0-1))))
        (@HYPO= nonreturn_first_serve_actionlevel)
        (@RHS=
                (Execute        ("writeto")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
@TEXT=The first services non-return rate is @v(nonreturn_first_serve.result) percent percent
and is in the action range.,\
@ADD";))
        ))
(@RULE= nonreturn_first_serve_belowtarget
        (@LHS=
                (Yes    (calve_analysed))
                (<=
        (COMPARE(nonreturn_first_serve.result,nonreturn_first_serve.targetlevel))  (0))
                (>=
        (COMPARE(nonreturn_first_serve.result,nonreturn_first_serve.warninglevel)) (0)))
        (@HYPO= nonreturn_first_serve_belowtarget)
        (@RHS=
                (Execute        ("writeto")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
@TEXT=The first service non return rate is @v(nonreturn_first_serve.result) percent and is
below target.,@ADD";))
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        ))
(@RULE= nonreturn_first_serve_warninglevel
        (@LHS=
                (Yes    (calve_analysed))
                (<
        (COMPARE(nonreturn_first_serve.result,nonreturn_first_serve.warninglevel)) (0))
                (>=
        (COMPARE(nonreturn_first_serve.result,nonreturn_first_serve.actionlevel))  (0)))
        (@HYPO= nonreturn_first_serve_warninglevel)
        (@RHS=
                (Execute        ("writeto")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
@TEXT=The nonreturn rate for fist service is @v(nonreturn_first_serve) percent and is in the
warning range.,@ADD";))
        ))
(@RULE= Not_in_calf_rate_abovetarget
        (@LHS=
                (Yes    (loadtxtfile_conception))
                (=      (COMPARE(not_in_calf_rate.result,not_in_calf_rate.targetlevel))     (1))
                (<=     (COMPARE(not_in_calf_rate.result,not_in_calf_rate.warninglevel))
        (0)))
        (@HYPO= Not_in_calf_rate_abovetarget)
        (@RHS=
                (Execute        ("writeto")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=incalf.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=incalf.txt,\
@TEXT=The percentage of cows not in calf at aaa is @V(not_in_calf_rate.result) percent and
above the normal accetable level. ,@ADD";))
        ))
(@RULE= not_in_calf_rate_actionlevel
        (@LHS=
                (Yes    (eight_week_incalf_rate_loaded))
                (=      (COMPARE(not_in_calf_rate.result,not_in_calf_rate.actionlevel))
        (1)))
        (@HYPO= not_in_calf_rate_actionlevel)
        (@RHS=
                (Execute        ("WriteTo")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=incalf.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=incalf.txt,\
@TEXT=The percentage of cows not in calf at xxx is @v(not_in_calf_rate.result) percent and in
the actionrange.,@ADD";))
        ))
(@RULE= not_in_calf_rate_belowtarget
        (@LHS=
                (Yes    (eight_week_incalf_rate_loaded))
                (<=     (COMPARE(not_in_calf_rate.result,not_in_calf_rate.targetlevel))
        (0)))
        (@HYPO= not_in_calf_rate_belowtarget)
        (@RHS=
                (Execute        ("writeto")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=incalf.txt,\
@TEXT=The empty rate is @v(not_incalf_rate.result) and performance is good.Use caution
interpreting these results if they are based on non-return rates,@ADD";))
                (Execute        ("WriteTo")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=incalf.txt,\
@TEXT=The percentage of cows not in calf is xxx and performance is good, Use caution
interpreting these results if they are based on non-return rates., @ADD";))
        ))
(@RULE= not_in_calf_rate_warninglevel
        (@LHS=
                (Yes    (eight_week_incalf_rate_loaded))
                (=      (COMPARE(not_in_calf_rate.result,not_in_calf_rate.warninglevel))    (1))
                (<=     (COMPARE(not_in_calf_rate.result,not_in_calf_rate.actionlevel))
        (0)))
        (@HYPO= not_in_calf_rate_warninglevel)
        (@RHS=
                (Execute        ("writeto")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=incalf.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=incalf.txt,\
@TEXT=The percentage of cows not in calf at xxx days is @v(not_incalf_rate.resul\
t) and is in the warning range.The herd empty rate is considerably higher than achievable
targets,@ADD";))
        ))
(@RULE= pregrate_all_serve_abovetarget
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        (@LHS=
                (Yes    (preg_test_all_herd))
                (Yes    (pregrate_first_serve_loaded))
                (>=     (COMPARE(pregrate_all_serve.result,pregrate_all_serve.targetlevel))
        (0)))
        (@HYPO= pregrate_all_serve_abovetarget)
        (@RHS=
                (Execute        ("writeto")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
@TEXT=The first service pregnancy rate is @v(pregrate_all_serve.result) percent  is above
target. Conceptions rates overall are giood and not reducing herd performance. Improvements in
this area may be possible but gains will be small. ,@ADD";))
        ))
(@RULE= pregrate_all_serve_abovetarget__1
        (@LHS=
                (No     (preg_test_all_herd)))
        (@HYPO= pregrate_all_serve_loaded)
        (@RHS=
                (Execute        ("writeto")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
@TEXT=Because you did not pregnancy test ALL cows we cannot use the pregnancy rate or serves
per conception analysis. We will use the NON-RETURN analysis,\
@ADD";))
        ))
(@RULE= pregrate_all_serve_abovetarget__1__1
        (@LHS=
                (Yes    (preg_test_all_herd)))
        (@HYPO= pregrate_all_serve_loaded)
        (@RHS=
                (Execute        ("writeto")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
@TEXT=You have pregnancy tested ALL cows. The pregnancy rate information will be more accurate
than NON-RETURN analysis. Non-return information is reported but will usually be excluded from
the analysis.,\
@ADD";))
        ))
(@RULE= pregrate_all_serve_actionlevel
        (@LHS=
                (Yes    (preg_test_all_herd))
                (Yes    (pregrate_first_serve_loaded))
                (=      (COMPARE(pregrate_all_serve.result,pregrate_all_serve.actionlevel)) ((0-
1))))
        (@HYPO= pregrate_all_serve_actionlevel)
        (@RHS=
                (Execute        ("writeto")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
@TEXT=The pregnancy rate for all services is @v(pregrate_all_serve.result) percent and
performance is very poor. We will examine some of the reasons why conception rates may be
low.,@ADD";))
        ))
(@RULE= pregrate_all_serve_belowtarget
        (@LHS=
                (Yes    (preg_test_all_herd))
                (Yes    (pregrate_first_serve_loaded))
                (<      (COMPARE(pregrate_all_serve.result,pregrate_all_serve.targetlevel)) (0))
                (>=     (COMPARE(pregrate_all_serve.result,pregrate_all_serve.warninglevel))
        (0)))
        (@HYPO= pregrate_all_serve_belowtarget)
        (@RHS=
                (Execute        ("writeto")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
@TEXT=The pregnancy rate for all serves is below target at @V(pregrate_all_serve.result)
percent. We will examine some of the reasons why conception rates could be lower than
target,@ADD";))
        ))
(@RULE= pregrate_all_serve_warninglevel
        (@LHS=
                (Yes    (preg_test_all_herd))
                (Yes    (pregrate_first_serve_loaded))
                (<      (COMPARE(pregrate_all_serve.result,pregrate_all_serve.warninglevel))
        (0))
                (>=     (COMPARE(pregrate_all_serve.result,pregrate_all_serve.actionlevel))
        (0)))
        (@HYPO= pregrate_all_serve_warninglevel)
        (@RHS=
                (Execute        ("writeto")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
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@TEXT=@v(t.line),@ADD";))
            (Execute        ("WriteTo")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
@TEXT=The pregnancy rate for all services is @v(pregrate_all_serve.result) percent and is in
warning range. We will examine some of the reasons why conception rates could be low.,@ADD";))
        ))
(@RULE= pregrate_first_serve_abovetarget_1
        (@LHS=
            (Yes    (preg_test_all_herd))
            (Yes    (loadtxtfile_heats))
            (>=     (COMPARE(pregrate_first_serve.result,pregrate_first_serve.targetlevel))
        (0)))
        (@HYPO= pregrate_first_serve_abovetarget)
        (@RHS=
            (Execute        ("writeto")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
@TEXT=@v(t.line),@ADD";))
            (Execute        ("WriteTo")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
@TEXT=the pregnancy rate for first services is @v(pregrate_first_serves.result) percent and is
above target.Performance is very good and is not likely to be adversely affecting herd
reproductive performance. ,@ADD";))
        ))
(@RULE= pregrate_first_serve_actionlevel
        (@LHS=
            (Yes    (preg_test_all_herd))
            (=      (COMPARE(pregrate_first_serve.result,pregrate_first_serve.actionlevel))
        ((0-1))))
        (@HYPO= pregrate_first_serve_actionlevel)
        (@RHS=
            (Execute        ("writeto")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
@TEXT=@v(t.line),@ADD";))
            (Execute        ("WriteTo")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
@TEXT=The pregnancy rate for first services is @v(pregrate_first_serve.result) percent and is
in the action range. First service conception rates may be reduced by many factors. We will
examine some of the major causes. ,@ADD";))
        ))
(@RULE= pregrate_first_serve_belowtarget
        (@LHS=
            (Yes    (preg_test_all_herd))
            (<      (COMPARE(pregrate_first_serve.result,pregrate_first_serve.targetlevel))
        (0))
            (>=
        (COMPARE(pregrate_first_serve.result,pregrate_first_serve.warninglevel))   (0)))
        (@HYPO= pregrate_first_serve_belowtarget)
        (@RHS=
            (Execute        ("writeto")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
@TEXT=@v(t.line),@ADD";))
            (Execute        ("WriteTo")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
@TEXT=The first service pregnancy rate is below target at @v(pregrate_first_se\
rve.result) percent,@ADD";))
        ))
(@RULE= pregrate_first_serve_warninglevel
        (@LHS=
            (Yes    (preg_test_all_herd))
            (<
        (COMPARE(pregrate_first_serve.result,pregrate_first_serve.warninglevel))   (0))
            (>=     (COMPARE(pregrate_first_serve.result,pregrate_first_serve.actionlevel))
        (0)))
        (@HYPO= pregrate_first_serve_warninglevel)
        (@RHS=
            (Execute        ("writeto")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
@TEXT=@v(t.line),@ADD";))
            (Execute        ("WriteTo")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
@TEXT=The pregnancy rate for first serves is in warning range at
@v(pregrate_first_serves.result)  percent. First service conception rates may be reduced by
many factors. We will examine some of the major causes.,@ADD";))
        ))
(@RULE= R54
        (@LHS=
            (Yes    (four_week_calving_actionlevel)))
        (@HYPO= four_week_calve_analysed))
(@RULE= R55
        (@LHS=
            (Yes    (four_week_calving_warninglevel)))
        (@HYPO= four_week_calve_analysed))
(@RULE= R57
        (@LHS=
            (Yes    (eight_week_calve_rate_belowtarget)))
        (@HYPO= calve_data_analysed))
(@RULE= R58
        (@LHS=
            (Yes    (eight_week_calving_actionlevel)))
        (@HYPO= calve_data_analysed))
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(@RULE= ratio_heats_abovetarget
        (@LHS=
                (Yes    (loadtxtfile_submissions))
                (>=     (COMPARE(ratio_heats.result,ratio_heats.targetlevel))       (0))
                (Yes    (heats_recorded_long_enough_to_evaluate)))
        (@HYPO= ratio_heats_abovetarget)
        (@RHS=
                (Execute        ("writeto")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=heats.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=heats.txt,\
@TEXT=the ratio of 18 to 24 day returns to 39 to 45 day returns is above targe\
t at @v(ratio_heats.result) and indicates few heats are being missed. (We are assuming that
heat detection has continued at the same level for most of the mating period),\
@ADD";))
        ))
(@RULE= ratio_heats_actionlevel
        (@LHS=
                (Yes    (loadtxtfile_submissions))
                (=      (COMPARE(ratio_heats.result,ratio_heats.actionlevel))       ((0-1)))
                (Yes    (heats_recorded_long_enough_to_evaluate)))
        (@HYPO= ratio_heats_actionlevel)
        (@RHS=
                (Execute        ("writeto")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=heats.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=heats.txt,\
@TEXT=The ratio of 18 to 24 day returns to 39 to 45 day returns heats is
@v(ratio_heats.result) and requires action for next season as many heats are being missed.This
is because most cows with return intervals of 39-45 days have probably been missed on heat.
Poor heat detection can have a dramatic effect on the performance of seasonal herds.Consider
using additional aids or other options that have been well described to help with detecting
cows on heat ,@ADD";))
        ))
(@RULE= ratio_heats_belowtarget
        (@LHS=
                (Yes    (loadtxtfile_submissions))
                (<      (COMPARE(ratio_heats.result,ratio_heats.targetlevel))       (0))
                (>=     (COMPARE(ratio_heats.result,ratio_heats.warninglevel))      (0))
                (Yes    (heats_recorded_long_enough_to_evaluate)))
        (@HYPO= ratio_heats_belowtarget)
        (@RHS=
                (Execute        ("writeto")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=heats.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=heats.txt,\
@TEXT=The ratio of 18 to 24 day cycles to 39 to 45 day cycles is below target a\
t @v(ratio_heats.result) and indicates that a considerable number of heats are being missed.
This is because most cows with return intervals of 39-45 days have probably been missed on
heat. Poor heat detection can have a dramatic effect on the performance of seasonal
herds.Consider using additional aids or other options that have been well described to help
with detecting cows on heat,@ADD";))
        ))
(@RULE= ratio_heats_warninglevel
        (@LHS=
                (Yes    (loadtxtfile_submissions))
                (<      (COMPARE(ratio_heats.result,ratio_heats.warninglevel))      (0))
                (>=     (COMPARE(ratio_heats.result,ratio_heats.actionlevel))       (0))
                (Yes    (heats_recorded_long_enough_to_evaluate)))
        (@HYPO= ratio_heats_warninglevel)
        (@RHS=
                (Execute        ("writeto")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=heats.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=heats.txt,\
@TEXT=The ratio of normal to double cycles is in warning range at @v(ratio_heats\
.result) percent. This indicates that a significant number of heats are being missed. Poor
heat detection can have a dramatic effect on the performance of seasonal herds.Consider using
additional aids or other options that have been well described to help with detecting cows on
heat. ,@ADD";))
        ))
(@RULE= reproductive_disorders_abovetarget
        (@LHS=
                (=      (COMPARE(reprodisorders.result,reprodisorders.targetlevel)) (1))
                (>=     (COMPARE(reprodisorders.result,reprodisorders.warninglevel))
        (0)))
        (@HYPO= reproductive_disorders_abovetarget)
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        (@RHS=
                (Execute        ("writeto")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
@TEXT=The number of reproductive disorders is @v(reprodisorders.result) percent
\and is above target. This is unusual in a New Zealand dairy herd. Discuss the problem with
your veterinarian. Calculated figures can vary depending on wwhat type of information is being
recorded. Veterinary advise will be needed to reduce the level of reproductive problems. Not
all treatements for reproductive disease are appropriate. Some do considerable damage. Poor
body condition may also be associated with these problems. A high proportion of retained
membranes required special investiagtions to identfy the causes,@ADD";))
        ))
(@RULE= reproductive_disorders_actionlevel
        (@LHS=
                (=      (COMPARE(reprodisorders.result,reprodisorders.actionlevel)) (1)))
        (@HYPO= reproductive_disorders_actionlevel)
        (@RHS=
                (Execute        ("writeto")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
@TEXT=The number of reproductive disorders is in the action range at @v(reprodi\
sorders.result) percent. This is very unusual in a New Zealand dairy herd. Discuss the problem
with your veterinarian. Calculated figures can vary depending on what type of information is
being recorded. Veterinary advise will be needed to reduce the level of reproductive problems.
Not all treatements for reproductive disease are appropriate. Some do considerable damage.
Poor body condition may also be associated with these problems. A high proportion of retained
membranes required special investiagtions to identfy the causes Ch,@ADD";))
        ))
(@RULE= reproductive_disorders_belowtarget
        (@LHS=
                (<=     (COMPARE(reprodisorders.result,reprodisorders.targetlevel)) (0))
                (>      (reprodisorders.result)         (0)))
        (@HYPO= reproductive_disorders_Belowtarget)
        (@RHS=
                (Execute        ("writeto")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
@TEXT=The number of reproductive disorders is equal or below a level considered to affect
reproductive performance at @v(reprodisorders.result) percent. If you are not recording this
type of information look carefully at the conception rate reports. If conception rates are
reducing during the mating period then this may indicate there is a group of cows that have a
very low chance of becoming pregnant due to severe reproductive disorders. Consider recording
this information next season. ,\
@ADD";))
        ))
(@RULE= reproductive_disorders_belowtarget__1
        (@LHS=
                (<=     (COMPARE(reprodisorders.result,reprodisorders.targetlevel)) (0))
                (=      (reprodisorders.result)         (0)))
        (@HYPO= reproductive_disorders_Belowtarget)
        (@RHS=
                (Execute        ("writeto")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
@TEXT=There were no cows recorded as having reproductive problems during the mating season
being analysed. This suggests they were not being recorded. If you are not recording this type
of information look carefully at the conception rate reports. If conception rates are reducing
during the mating period then this may indicate there is a group of cows that have a very low
chance of becoming pregnant due to severe reproductive disorders. Consider recording this
information next season,\
@ADD";))
        ))
(@RULE= reproductive_disorders_warninglevel
        (@LHS=
                (=      (COMPARE(reprodisorders.result,reprodisorders.warninglevel))        (1))
                (>=     (COMPARE(reprodisorders.result,reprodisorders.actionlevel)) (0)))
        (@HYPO= reproductive_disorders_warninglevel)
        (@RHS=
                (Execute        ("writeto")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
@TEXT=The number of reproductive disorders is @v(reprodisorders.result) percen\
t and is in the warning range.,@ADD";))
        ))
(@RULE= returns_18_24_days_abovetarget
        (@LHS=
                (>=     (COMPARE(returns_18_24_days.result,returns_18_24_days.targetlevel)) (0))
                (Yes    (warning_action_target_levels_loaded)))
        (@HYPO= returns_18_24_days_abovetarget)
        (@RHS=
```

```
                (Execute        ("writeto")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=heats.txt,\
@TEXT=@v(t.line)";))
                (Execute        ("WriteTo")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=heats.txt,\
@TEXT=the 18 to 24 day returns is above target at @v(returns_18_24_days.result) \
percent,@ADD";))
        ))
(@RULE= returns_18_24_days_actionlevel
        (@LHS=
                (=      (COMPARE(returns_18_24_days.result,returns_18_24_days.actionlevel)) ((0-
1))))
        (@HYPO= returns_18_24_days_actionlevel)
        (@RHS=
                (Execute        ("writeto")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=heats.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=heats.txt,\
@TEXT=The 18 to 24 days returns is @v(returns_18_24_days.result) percent.,\
@ADD";))
        ))
(@RULE= returns_18_24_days_belowtarget
        (@LHS=
                (<      (COMPARE(returns_18_24_days.result,returns_18_24_days.targetlevel)) (0))
                (>=     (COMPARE(returns_18_24_days.result,returns_18_24_days.warninglevel))
        (0)))
        (@HYPO= returns_18_24_days_belowtarget)
        (@RHS=
                (Execute        ("writeto")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=heats.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=heats.txt,\
@TEXT=The 18 to 24 day returns is below target at @v(returns_18_24_days.result)\
 percent.,@ADD";))
        ))
(@RULE= returns_18_24_day_warninglevel
        (@LHS=
                (<      (COMPARE(returns_18_24_days.result,returns_18_24_days.warninglevel))
        (0))
                (>=     (COMPARE(returns_18_24_days.result,returns_18_24_days.actionlevel))
        (0)))
        (@HYPO= returns_18_24_days_warninglevel)
        (@RHS=
                (Execute        ("writeto")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=heats.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=heats.txt,\
@TEXT=The 18 to 24 day returns is @v(returns_18_24_days.result) percent and is\
 in the warning range,@ADD";))
        ))
(@RULE= returns_2_17_days_abovetarget
        (@LHS=
                (=      (COMPARE(returns_2_17_days.result,returns_2_17_days.targetlevel))   (1))
                (<=     (COMPARE(returns_2_17_days.result,returns_2_17_days.warninglevel))
        (0)))
        (@HYPO= returns_2_17_days_abovetarget)
        (@RHS=
                (Execute        ("writeto")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=heats.txt,\
@TEXT=@V(t.line),@ADD";))
                (Execute        ("WriteTo")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=heats.txt,\
@TEXT=The number of returns 2 to 17 days is in above targets. Ie Too high,\
,@ADD";))
        ))
(@RULE= returns_2_17_days_actionlevel
        (@LHS=
                (=      (COMPARE(returns_2_17_days.result,returns_2_17_days.actionlevel))
        (1)))
        (@HYPO= returns_2_17_days_actionlevel)
        (@RHS=
                (Execute        ("writeto")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=heats.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=heats.txt,\
```

```
@TEXT=The number of returns between 2 and 17 days is @v(returns_2_17_days.result) percent and
is in the action range. A high proportion of short returns is caused either by a poor calving
pattern, poor nutrition or bad heat detection.,@ADD";))
        ))
(@RULE= returns_2_17_days_belowtarget
        (@LHS=
                (<=     (COMPARE(returns_2_17_days.result,returns_2_17_days.targetlevel))
        (0)))
        (@HYPO= returns_2_17_days_belowtarget)
        (@RHS=
                (Execute        ("writeto")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=heats.txt,\
,@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=heats.txt,\
@TEXT=The 2 to 17 day returns is @v(returns_2_17_days.result) percent and is below the upper
acceptible limit. This mean performance is adequate and suggests few cows are being mated that
are not on heat and that the nutritional energy status of the herd is good.,@ADD";))
        ))
(@RULE= returns_2_17_days_warninglevel
        (@LHS=
                (=      (COMPARE(returns_2_17_days.result,returns_2_17_days.warninglevel)) (1))
                (<=     (COMPARE(returns_2_17_days.result,returns_2_17_days.actionlevel))
        (0)))
        (@HYPO= returns_2_17_days_warninglevel)
        (@RHS=
                (Execute        ("writeTo")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=heats.txt,\
,@TEXT=@V(t.line),@ADD";))
                (Execute        ("WriteTo")     (@WAIT=TRUE;@STRING="@FILE=heats.txt,@TEXT=The
number of returns between 2 and 17 days is in the warning range at
@v(returns_2_17_days.result) percent. A high proportion of short returns is caused either by a
poor calving pattern, poor nutrition or bad heat detection.,@,\
@ADD";))
        ))
(@RULE= returns_39_45_days_abovetarget
        (@LHS=
                (Yes    (heats_recorded_long_enough_to_evaluate))
                (=      (COMPARE(returns_39_45_days.result,returns_39_45_days.targetlevel)) (1))
                (>=     (COMPARE(returns_39_45_days.result,returns_39_45_days.warninglevel))
        (0)))
        (@HYPO= returns_39_45_days_abovetarget)
        (@RHS=
                (Execute        ("writeto")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=heats.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=heats.txt,\
@TEXT=The number of return intervals of 39 to 45 days is high at @v(returns_3\
9_45_days.result) percent.,@ADD";))
        ))
(@RULE= returns_39_45_days_actionlevel
        (@LHS=
                (Yes    (heats_recorded_long_enough_to_evaluate))
                (=      (COMPARE(returns_39_45_days.result,returns_39_45_days.actionlevel))
        (1)))
        (@HYPO= returns_39_45_days_actionlevel)
        (@RHS=
                (Execute        ("writeto")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=heats.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=heats.txt,\
@TEXT=The number of return intervals of 39 to 45 days is high at @v(returns_39_4\
5_days.result) percent and is in the action range.,\
@ADD";))
        ))
(@RULE= returns_39_45_days_belowtarget
        (@LHS=
                (Yes    (heats_recorded_long_enough_to_evaluate))
                (<=     (COMPARE(returns_39_45_days.result,returns_39_45_days.targetlevel))
        (0)))
        (@HYPO= returns_39_45_days_belowtarget)
        (@RHS=
                (Execute        ("writeto")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=heats.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=heats.txt,\
@TEXT=The 39 to 45 day returns is adequate at @v(returns_39_45_days.result) per\
cent.,@ADD";))
```

```
        ))
(@RULE= returns_39_45_days_warninglevel
        (@LHS=
               (Yes    (heats_recorded_long_enough_to_evaluate))
               (=      (COMPARE(returns_39_45_days.result,returns_39_45_days.warninglevel))
        (1))
               (>=     (COMPARE(returns_39_45_days.result,returns_39_45_days.actionlevel))
        (0)))
        (@HYPO= returns_39_45_days_warninglevel)
        (@RHS=
               (Execute       ("writeto")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=heats.txt,\
@TEXT=@v(t.line),@ADD";))
               (Execute       ("WriteTo")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=heats.txt,\
@TEXT=The number of returns 39 to 45 days is in the warning range at @v(returns\
_39_45_days.result) percent,@ADD";))
        ))
(@RULE= R_A_loadtxtfile
       @INFCAT=100;
       @COMMENTS="createreport";
        (@LHS=
               (Yes    (loadtxtfile_incalf))
               (Show   ("calve.txt")   (@KEEP=TRUE;@WAIT=FALSE;))
               (Show   ("sub.txt")     (@KEEP=TRUE;@WAIT=FALSE;))
               (Show   ("preg.txt")    (@KEEP=TRUE;@WAIT=FALSE;))
               (Show   ("incalf.txt")  (@KEEP=TRUE;@WAIT=FALSE;)))
        (@HYPO= A_loadtxtfile))
(@RULE= R_calve_data_analysed
        (@LHS=
               (Yes    (eight_week_calve_rate_abovetarget)))
        (@HYPO= calve_data_analysed))
(@RULE= R_calve_data_analysed__1
        (@LHS=
               (Yes    (eight_week_calving_warninglevel)))
        (@HYPO= calve_data_analysed))
(@RULE= R_cows_calved_less_40_days_loaded__2
        (@LHS=
               (Yes    (cows_calved_less_40_days_warninglevel)))
        (@HYPO= cows_calved_less_40_days_loaded))
(@RULE= R_cows_calved_less_40_days_loaded__6
        (@LHS=
               (Yes    (cows_calved_less_40_days_belowtarget)))
        (@HYPO= cows_calved_less_40_days_loaded))
(@RULE= R_eight_week_incalf_rate_loaded
        (@LHS=
               (Yes    (eight_week_incalf_rate_abovetarget)))
        (@HYPO= eight_week_incalf_rate_loaded))
(@RULE= R_eight_week_incalf_rate_loaded__1
        (@LHS=
               (Yes    (eight_week_incalf_rate_belowtarget)))
        (@HYPO= eight_week_incalf_rate_loaded))
(@RULE= R_eight_week_incalf_rate_loaded__2
        (@LHS=
               (Yes    (eight_week_incalf_rate_warninglevel)))
        (@HYPO= eight_week_incalf_rate_loaded))
(@RULE= R_eight_week_incalf_rate_loaded__3
        (@LHS=
               (Yes    (eight_week_incalf_rate_actionlevel)))
        (@HYPO= eight_week_incalf_rate_loaded))
(@RULE= R_four_week_incalf_rate_loaded
        (@LHS=
               (Yes    (four_week_incalf_rate_actionlevel)))
        (@HYPO= four_week_incalf_rate_loaded))
(@RULE= R_four_week_incalf_rate_loaded__1
        (@LHS=
               (Yes    (four_week_incalf_rate_warninglevel)))
        (@HYPO= four_week_incalf_rate_loaded))
(@RULE= R_four_week_incalf_rate_loaded__2
        (@LHS=
               (Yes    (four_week_incalf_rate_belowtarget)))
        (@HYPO= four_week_incalf_rate_loaded))
(@RULE= R_four_week_incalf_rate_loaded__3
        (@LHS=
               (Yes    (four_week_incalf_rate_abovetarget)))
        (@HYPO= four_week_incalf_rate_loaded))
(@RULE= R_heat_specificity_loaded
        (@LHS=
               (Yes    (returns_2_17_days_loaded))
               (Yes    (returns_18_24_days_loaded)))
        (@HYPO= heat_specificity_loaded))
```

```
(@RULE= R_loadtxtfile_conception
        @COMMENTS="stop comes from the predictions of next mating season.";
        (@LHS=
                (=      (serves_per_conception_loaded)        (KNOWN))
                (Yes    (nonreturn_all_loaded))
                (Yes    (nonreturn_first_serve_loaded))
                (=      (pregrate_all_serve_loaded)    (KNOWN))
                (=      (pregrate_first_serve_loaded)  (KNOWN))
                (<>     (stop)  (TRUE)))
        (@HYPO= loadtxtfile_conception))
(@RULE= R_loadtxtfile_heats
        (@LHS=
                (Yes    (ratio_heats_loaded))
                (Yes    (returns_39_45_days_loaded))
                (Yes    (heat_specificity_loaded)))
        (@HYPO= loadtxtfile_heats))
(@RULE= R_loadtxtfile_incalf
        (@LHS=
                (Yes    (abortions_loaded))
                (Yes    (eight_week_incalf_rate_loaded))
                (Yes    (four_week_incalf_rate_loaded))
                (Yes    (Not_in_calf_rate_loaded)))
        (@HYPO= loadtxtfile_incalf))
(@RULE= R_loadtxtfile_submissions
        (@LHS=
                (Yes    (two_year_olds_loaded))
                (Yes    (cows_calved_less_40_days_loaded))
                (Yes    (reproductive_disorders_loaded))
                (Yes    (submission21_loaded))
                (Yes    (submission28_loaded)))
        (@HYPO= loadtxtfile_submissions))
(@RULE= R_loadtxtfile__1
        (@LHS=
                (Yes    (calve_data_analysed))
                (Yes    (four_week_calve_analysed))
                (Yes    (induced_analysed)))
        (@HYPO= loadtxtfile_calving))
(@RULE= R_nonreturn_first_serve_loaded
        (@LHS=
                (Yes    (nonreturn_first_serve_abovetarget)))
        (@HYPO= nonreturn_first_serve_loaded))
(@RULE= R_nonreturn_first_serve_loaded__1
        (@LHS=
                (Yes    (nonreturn_first_serve_belowtarget)))
        (@HYPO= nonreturn_first_serve_loaded))
(@RULE= R_nonreturn_first_serve_loaded__2
        (@LHS=
                (Yes    (nonreturn_first_serve_warninglevel)))
        (@HYPO= nonreturn_first_serve_loaded))
(@RULE= R_nonreturn_first_serve_loaded__3
        (@LHS=
                (Yes    (nonreturn_first_serve_actionlevel)))
        (@HYPO= nonreturn_first_serve_loaded))
(@RULE= R_Not_in_calf_rate_loaded
        (@LHS=
                (Yes    (Not_in_calf_rate_abovetarget)))
        (@HYPO= Not_in_calf_rate_loaded))
(@RULE= R_Not_in_calf_rate_loaded__1
        (@LHS=
                (Yes    (not_in_calf_rate_belowtarget)))
        (@HYPO= Not_in_calf_rate_loaded))
(@RULE= R_Not_in_calf_rate_loaded__2
        (@LHS=
                (Yes    (not_in_calf_rate_warninglevel)))
        (@HYPO= Not_in_calf_rate_loaded))
(@RULE= R_Not_in_calf_rate_loaded__3
        (@LHS=
                (Yes    (not_in_calf_rate_actionlevel)))
        (@HYPO= Not_in_calf_rate_loaded))
(@RULE= R_pregrate_all_serve_loaded
        (@LHS=
                (Yes    (pregrate_all_serve_abovetarget)))
        (@HYPO= pregrate_all_serve_loaded))
(@RULE= R_pregrate_all_serve_loaded__1
        (@LHS=
                (Yes    (pregrate_all_serve_belowtarget)))
        (@HYPO= pregrate_all_serve_loaded))
(@RULE= R_pregrate_all_serve_loaded__2
        (@LHS=
                (Yes    (pregrate_all_serve_warninglevel)))
        (@HYPO= pregrate_all_serve_loaded))
```

```
(@RULE= R_pregrate_all_serve_loaded__3
        (@LHS=
                (Yes    (pregrate_all_serve_actionlevel)))
        (@HYPO= pregrate_all_serve_loaded))
(@RULE= R_pregrate_first_serve_loaded
        (@LHS=
                (Yes    (pregrate_first_serve_abovetarget)))
        (@HYPO= pregrate_first_serve_loaded))
(@RULE= R_pregrate_first_serve_loaded__1
        (@LHS=
                (Yes    (pregrate_first_serve_belowtarget)))
        (@HYPO= pregrate_first_serve_loaded))
(@RULE= R_pregrate_first_serve_loaded__2
        (@LHS=
                (Yes    (pregrate_first_serve_actionlevel)))
        (@HYPO= pregrate_first_serve_loaded))
(@RULE= R_pregrate_first_serve_loaded__3
        (@LHS=
                (Yes    (pregrate_first_serve_warninglevel)))
        (@HYPO= pregrate_first_serve_loaded))
(@RULE= R_ratio_heats_can_be_evaluated
        @COMMENTS="there is probably a relationship betwen weeks observing and these
parameters that wil need to be used";
        (@LHS=
                (Yes    (mating_long_enough)))
        (@HYPO= heats_recorded_long_enough_to_evaluate))
(@RULE= R_ratio_heats_loaded
        (@LHS=
                (Yes    (ratio_heats_abovetarget)))
        (@HYPO= ratio_heats_loaded))
(@RULE= R_ratio_heats_loaded__1
        (@LHS=
                (Yes    (ratio_heats_belowtarget)))
        (@HYPO= ratio_heats_loaded))
(@RULE= R_ratio_heats_loaded__2
        (@LHS=
                (Yes    (ratio_heats_actionlevel)))
        (@HYPO= ratio_heats_loaded))
(@RULE= R_ratio_heats_loaded__3
        (@LHS=
                (Yes    (ratio_heats_warninglevel)))
        (@HYPO= ratio_heats_loaded))
(@RULE= R_reproductive_disorders_loaded
        (@LHS=
                (Yes    (reproductive_disorders_abovetarget)))
        (@HYPO= reproductive_disorders_loaded))
(@RULE= R_reproductive_disorders_loaded__1
        (@LHS=
                (Yes    (reproductive_disorders_Belowtarget)))
        (@HYPO= reproductive_disorders_loaded))
(@RULE= R_reproductive_disorders_loaded__2
        (@LHS=
                (Yes    (reproductive_disorders_actionlevel)))
        (@HYPO= reproductive_disorders_loaded))
(@RULE= R_reproductive_disorders_loaded__3
        (@LHS=
                (Yes    (reproductive_disorders_warninglevel)))
        (@HYPO= reproductive_disorders_loaded))
(@RULE= R_returns_18_24_days_loaded
        (@LHS=
                (Yes    (returns_18_24_days_abovetarget)))
        (@HYPO= returns_18_24_days_loaded))
(@RULE= R_returns_18_24_days_loaded__1
        (@LHS=
                (Yes    (returns_18_24_days_belowtarget)))
        (@HYPO= returns_18_24_days_loaded))
(@RULE= R_returns_18_24_days_loaded__2
        (@LHS=
                (Yes    (returns_18_24_days_warninglevel)))
        (@HYPO= returns_18_24_days_loaded))
(@RULE= R_returns_18_24_days_loaded__3
        (@LHS=
                (Yes    (returns_18_24_days_actionlevel)))
        (@HYPO= returns_18_24_days_loaded))
(@RULE= R_returns_2_17_days_loaded
        (@LHS=
                (Yes    (returns_2_17_days_abovetarget)))
        (@HYPO= returns_2_17_days_loaded))
(@RULE= R_returns_2_17_days_loaded__1
        (@LHS=
                (Yes    (returns_2_17_days_belowtarget)))
```

```
        (@HYPO= returns_2_17_days_loaded))
(@RULE= R_returns_2_17_days_loaded__2
        (@LHS=
                (Yes    (returns_2_17_days_warninglevel)))
        (@HYPO= returns_2_17_days_loaded))
(@RULE= R_returns_2_17_days_loaded__3
        (@LHS=
                (Yes    (returns_2_17_days_actionlevel)))
        (@HYPO= returns_2_17_days_loaded))
(@RULE= R_returns_39_45_days_loaded
        (@LHS=
                (Yes    (returns_39_45_days_abovetarget)))
        (@HYPO= returns_39_45_days_loaded))
(@RULE= R_returns_39_45_days_loaded__1
        (@LHS=
                (Yes    (returns_39_45_days_belowtarget)))
        (@HYPO= returns_39_45_days_loaded))
(@RULE= R_returns_39_45_days_loaded__2
        (@LHS=
                (Yes    (returns_39_45_days_warninglevel)))
        (@HYPO= returns_39_45_days_loaded))
(@RULE= R_returns_39_45_days_loaded__3
        (@LHS=
                (Yes    (returns_39_45_days_actionlevel)))
        (@HYPO= returns_39_45_days_loaded))
(@RULE= R_serves_per_conception_loaded
        (@LHS=
                (Yes    (serves_per_conception_abovetarget)))
        (@HYPO= serves_per_conception_loaded))
(@RULE= R_serves_per_conception_loaded__1
        (@LHS=
                (Yes    (serves_per_conception_belowtarget)))
        (@HYPO= serves_per_conception_loaded))
(@RULE= R_serves_per_conception_loaded__2
        (@LHS=
                (Yes    (serves_per_conception_warninglevel)))
        (@HYPO= serves_per_conception_loaded))
(@RULE= R_serves_per_conception_loaded__3
        (@LHS=
                (Yes    (serves_per_conception_actionlevel)))
        (@HYPO= serves_per_conception_loaded))
(@RULE= R_submission21_loaded
        (@LHS=
                (Yes    (submission21_abovetarget)))
        (@HYPO= submission21_loaded))
(@RULE= R_submission21_loaded__1
        (@LHS=
                (Yes    (submission21_belowtarget)))
        (@HYPO= submission21_loaded))
(@RULE= R_submission21_loaded__2
        (@LHS=
                (Yes    (submission21_warninglevel)))
        (@HYPO= submission21_loaded))
(@RULE= R_submission21_loaded__3
        (@LHS=
                (Yes    (submission21_actionlevel)))
        (@HYPO= submission21_loaded))
(@RULE= R_submission28_loaded
        (@LHS=
                (Yes    (submission28_actionlevel)))
        (@HYPO= submission28_loaded))
(@RULE= R_submission28_loaded__1
        (@LHS=
                (Yes    (submission28_warninglevel)))
        (@HYPO= submission28_loaded))
(@RULE= R_submission28_loaded__2
        (@LHS=
                (Yes    (submission28_belowtarget)))
        (@HYPO= submission28_loaded))
(@RULE= R_submission28_loaded__3
        (@LHS=
                (Yes    (submission28_abovetarget)))
        (@HYPO= submission28_loaded))
(@RULE= R_two_year_olds_loaded
        (@LHS=
                (Yes    (two_year_olds_abovetarget)))
        (@HYPO= two_year_olds_loaded))
(@RULE= R_two_year_olds_loaded__1
        (@LHS=
                (Yes    (two_year_olds_belowtarget)))
        (@HYPO= two_year_olds_loaded))
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```
(@RULE= R_two_year_olds_loaded__2
        (@LHS=
                (Yes    (two_year_olds_actionlevel)))
        (@HYPO= two_year_olds_loaded))
(@RULE= R_two_year_olds_loaded__3
        (@LHS=
                (Yes    (two_year_olds_warninglevel)))
        (@HYPO= two_year_olds_loaded))
(@RULE= R_warning_action_target_levels_loaded
        @COMMENTS="This rule is a focus. We must load the data files before backward chaining
to retrieve dates. These dates will need expanding to include dates for other reports.";
        (@LHS=
                (<>     (herd)  ("Enter_your_herd_please"))
                (Retrieve       ("goals.txt")  (@TYPE=NXPDB;@UNKNOWN=TRUE;@NAME="!object!";\
@PROPS=warninglevel,actionlevel,targetlevel;\
@FIELDS="warninglev","actionleve","targetleve";))
                (Retrieve       ("@V(herd).mon")        (@TYPE=NXPDB;@FILL=ADD;@NAME="!object!";\
@PROPS=result;@FIELDS="result";))
                (Retrieve       ("@V(herd).mon")        (@TYPE=NXPDB;@FILL=ADD;@NAME="!object!";\
@PROPS=datel;@FIELDS="date";))
                (Yes    (dates_for_calving_analysis_ok)))
        (@HYPO= warning_action_target_levels_loaded)
        (@EHS=
                (Reset  (warning_action_target_levels_loaded))
                (Reset  (herd))
        ))
(@RULE= serves_per_conception_abovetarget
        (@LHS=
                (Yes    (preg_test_all_herd))
                (=
        (COMPARE(serves_per_conception.result,serves_per_conception.targetlevel))  (1))
                (<=
        (COMPARE(serves_per_conception.result,serves_per_conception.warninglevel)) (0)))
        (@HYPO= serves_per_conception_abovetarget)
        (@RHS=
                (Execute        ("writeto")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
@TEXT=the serves per conception is high at @v(serves_per_conception.result) per\
cent,@ADD";))
        ))
(@RULE= serves_per_conception_actionlevel
        (@LHS=
                (Yes    (preg_test_all_herd))
                (=
        (COMPARE(serves_per_conception.result,serves_per_conception.actionlevel))  (1)))
        (@HYPO= serves_per_conception_actionlevel)
        (@RHS=
                (Execute        ("writeto")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
@TEXT=The number of serves per conception is in the action range at
@v(serves_per_conception.result) percent.,@ADD";))
        ))
(@RULE= serves_per_conception_belowtarget
        (@LHS=
                (Yes    (preg_test_all_herd))
                (<=
        (COMPARE(serves_per_conception.result,serves_per_conception.targetlevel))  (0)))
        (@HYPO= serves_per_conception_belowtarget)
        (@RHS=
                (Execute        ("writeto")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
@TEXT=The serves per conception is good at @v(serves_per_conception.result) percent.,@ADD";))
        ))
(@RULE= serves_per_conception_warninglevel
        (@LHS=
                (Yes    (preg_test_all_herd))
                (=      (COMPARE(serves_per_conception.result,serves_per_conception
warninglevel)) (1))
                (<=
        (COMPARE(serves_per_conception.result,serves_per_conception.actionlevel))  (0)))
        (@HYPO= serves_per_conception_warninglevel)
        (@RHS=
                (Execute        ("writeto")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=preg.txt,\
@TEXT=the serves per conception is in the warning range at @v(serves_per_conception.result)
percent. ,@ADD";))
        ))
```

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(@RULE= submission21_actionlevel
	(@LHS=
		(=	(COMPARE(submission21.result,submission21.actionlevel))	((0-1))))
	(@HYPO= submission21_actionlevel)
	(@RHS=
		(Execute	("writeto")	(@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
@TEXT=@v(t.line),@ADD";))
		(Execute	("WriteTo")	(@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
@TEXT=The 21 day submission requires action. Low submission rates will result in a poor mating
performance. Low submissions are either due to poor heat detection or cows not cycling
properly. We will examine these issues. ,@ADD";))
	))
(@RULE= submission21_rate_abovetarget
	@COMMENTS="load the submission file if performance below target";
	(@LHS=
		(>=	(COMPARE(submission21.result,submission21.targetlevel))	(0)))
	(@HYPO= submission21_abovetarget)
	(@RHS=
		(Execute	("writeto")	(@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
@TEXT=@v(t.line),@ADD";))
		(Execute	("WriteTo")	(@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
@TEXT=the 21 day submission rate is above target at @v(submission21.result) percent.
Submission rates will not be affecting herd mating performance adversely. ,@ADD";))
	))
(@RULE= submission21_rate_belowtarget
	(@LHS=
		(<	(COMPARE(submission21.result,submission21.targetlevel))	(0))
		(>=	(COMPARE(submission21.result,submission21.warninglevel))	(0)))
	(@HYPO= submission21_belowtarget)
	(@RHS=
		(Execute	("writeto")	(@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
@TEXT=@v(t.line),@ADD";))
		(Execute	("WriteTo")	(@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
@TEXT=The 21 day submissions below target at @v(submission21.result) percent. Low submission
rates will result in a poor mating performance. Low submissions are either due to poor heat
detection or cows not cycling properly. We will examine these issues.,@ADD";))
	))
(@RULE= submission21_warninglevel
	(@LHS=
		(<	(COMPARE(submission21.result,submission21.warninglevel))	(0))
		(>=	(COMPARE(submission21.result,submission21.actionlevel))	(0)))
	(@HYPO= submission21_warninglevel)
	(@RHS=
		(Execute	("writeto")	(@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
@TEXT=@v(t.line),@ADD";))
		(Execute	("writeto")	(@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
@TEXT=The 21 day submission rate is in the warning range at @v(submission21.result) percent.
Low submission rates will result in a poor mating performance. Low submissions are either due
to poor heat detection or cows not cycling properly. We will examine these issues.,@ADD";))
	))
(@RULE= submission28_abovetarget
	(@LHS=
		(>=	(COMPARE(submission28.result,submission28.targetlevel))	(0)))
	(@HYPO= submission28_abovetarget)
	(@RHS=
		(Execute	("writeto")	(@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
@TEXT=@v(t.line),@ADD";))
		(Execute	("WriteTo")	(@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
@TEXT=the 28 day submission rate is above target at @v(submission28.result) perc\
ent.,@ADD";))
	))
(@RULE= submission28_actionlevel
	(@LHS=
		(=	(COMPARE(submission28.result,submission28.actionlevel))	((0-1))))
	(@HYPO= submission28_actionlevel)
	(@RHS=
		(Execute	("writeto")	(@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
@TEXT=@v(t.line),@ADD";))
		(Execute	("WriteTo")	(@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
@TEXT=The 28 day submission is in the action range at @v(submission28.result) pe\
rcent.,@ADD";))
	))
(@RULE= submission28_belowtarget
	(@LHS=
		(<	(COMPARE(submission28.result,submission28.targetlevel))	(0))
		(>=	(COMPARE(submission28.result,submission28.warninglevel))	(0)))
	(@HYPO= submission28_belowtarget)
	(@RHS=
		(Execute	("writeto")	(@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
@TEXT=@v(t.line),@ADD";))
		(Execute	("WriteTo")	(@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
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@TEXT=The 28 day submissions below target at @v(submission28.result) percent,\
@ADD";))
        ))
(@RULE= submission28_warninglevel
        (@LHS=
                (<      (COMPARE(submission28.result,submission28.warninglevel))     (0))
                (>=     (COMPARE(submission28.result,submission28.actionlevel))      (0)))
        (@HYPO= submission28_warninglevel)
        (@RHS=
                (Execute        ("writeto")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
@TEXT=The 28 day submission rate is in the warning range at @v(submission28.resu\
lt),@ADD";))
        ))
(@RULE= two_year_olds_abovetarget
        (@LHS=
                (Yes    (loadtxtfile_calving))
                (=      (COMPARE(two_year_olds.result,two_year_olds.targetlevel))    (1))
                (<=     (COMPARE(two_year_olds.result,two_year_olds.warninglevel))   (0)))
        (@HYPO= two_year_olds_abovetarget)
        (@RHS=
                (Execute        ("writeto")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
@TEXT=The number of two year olds calved is above target at @v(two_year_olds.r\
esult) percent. Two and three year old cows have relatively poor reproductive peroformances.
This will reduce the overall herd performance.,@ADD";))
        ))
(@RULE= two_year_olds_actionlevel
        (@LHS=
                (=      (COMPARE(two_year_olds.result,two_year_olds.actionlevel))    (1)))
        (@HYPO= two_year_olds_actionlevel)
        (@RHS=
                (Execute        ("writeto")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
@TEXT=The number of two year olds calved is in action range at @v(two_year_olds.result)
percent. Two and three year old cows have relatively poor reproductive performances. This will
reduce the overall herd performance.,@ADD";))
        ))
(@RULE= two_year_olds_belowtarget
        (@LHS=
                (<=     (COMPARE(two_year_olds.result,two_year_olds.targetlevel))    (0)))
        (@HYPO= two_year_olds_belowtarget)
        (@RHS=
                (Execute        ("writeto")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
@TEXT=The number of two year olds calved is at an acceptible level and not likely to affect
reproductive performance at @v(two_year_olds.result) percent. A very low number of two year
olds may indicate problems for the future. Do not allow replacement numbers to drop or the age
of the herd will increase. Reproductive performance will not be dramatically affected by an
increasing herd age until there are asignificant number of old cows in the herd. ,\
@ADD";))
        ))
(@RULE= two_year_olds_warninglevel
        (@LHS=
                (=      (COMPARE(two_year_olds.result,two_year_olds.warninglevel))   (1))
                (<=     (COMPARE(two_year_olds.result,two_year_olds.actionlevel))    (0)))
        (@HYPO= two_year_olds_warninglevel)
        (@RHS=
                (Execute        ("writeto")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
@TEXT=@v(t.line),@ADD";))
                (Execute        ("WriteTo")     (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=sub.txt,\
@TEXT=The number of two year olds calved is in warning range at @v(two_year_olds.result)
percent This means the age profile of the herd is likely to reduce reproductive performance.
Two and three year old cows have relatively poor reproductive peroformances. This will reduce
the overall herd performance.,@ADD";))
        ))
(@RULE= Update_date
        @COMMENTS="checking if update is after the end calving date";
        (@LHS=
                (Assign (DATE2FLOAT(<|alldates|>.datel))        (<|alldates|>.number))
                (>=     ((update.number-pec.number))  (0)))
        (@HYPO= update_date_acceptible)
        (@RHS=
                (Assign (update.number-PSC.number/60*60*24)   (|days|.update))
        ))
(@RULE= Update_date_before_enddate
        (@LHS=
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                (No     (update_date_acceptible)))
        (@HYPO= data_fault)
        (@RHS=
                (Execute        ("Message")     (@WAIT=TRUE;@STRING="@TEXT=The update is before
the date you want to end the ca\
lving analysis. Information will not be complete,\
@OK";))
                (Execute        ("WriteTo")
        (@WAIT=TRUE;@STRING="@TRANSCRIPT,@FILE=output.txt,\
@TEXT=The update date is before the date to end the calving analysis.,\
@ADD";))
                (Execute        ("ControlSession")      (@WAIT=TRUE;@STRING="@STOP";))
        ))
```