Current practices and future possibilities of performance recording extensively-grazed commercial beef herds in New Zealand

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There is little evidence that the productivity of New Zealand beef herds has improved over time. Data from the NZ Meat and Wool Board's Economic Service (2006) suggest that the average national calving percentage has declined over the last two decades. During the same period cattle carcass weights have increased but so too has the average cow live-weight which has resulted in increased maintenance costs of the cow herds. It is unclear whether production efficiency in the industry has improved or declined over time. The aim of this research was to develop means of improving productivity in commercial beef herds through practical methods of performance recording. The objectives were firstly to establish current management practices in commercial herds and secondly to develop an objective system for cow selection and culling which would have practical application in commercial herds.

Beef management survey

Ninety two commercial beef producers with more than 100 breeding cows from the greater Canterbury region of New Zealand were surveyed.

Pasture control was the main reason given for owning a beef herd. Size and conformation were the main selection criteria for choosing replacement heifers and bulls. Over 80% of herds retained their own heifers as replacements and >60% mated yearling heifers to first calve at two years of age.

Fertility was poor in the surveyed herds. In-calf rates at pregnancy testing averaged 88% for maiden heifers, 92% for rising second calvers and 93% for mixed age (m.a.) cows. There was no significant difference between in-calf rates of maiden heifers mated to first calve at two or three years of age; nor was there any significant difference between the re-breeding success of the two groups. Heifers mated at least one week earlier than m.a. cows, achieved a re-breeding success 4.7% greater ($P<.01$) than those mated at the same time.

Reasons for cows not weaning a calf included wet dry (9.3% of pregnant cows wintered), pregnancy tested not-in-calf (7.4%) and dam death (2.6%). Only 87.9% of pregnant females wintered weaned a calf (89.4% of m.a. cows and 84.9% of heifers). Reasons

why cows exited the herds included diagnosed empty (37.2% of all exits), involuntary culls (25.4%), sold wet dry (16.2%), deaths (13.1%) and poor calf production (5.1%).

Vaccination was infrequent with clostridial vaccines the most common in m.a. cows (15.2%) and in calves (40.7%); vaccination against Leptospirosis was much less common.

Very few of the surveyed farms used any system of performance recording; as a result there was very little performance-based selection or culling practiced.

Evaluation of alternative measures of cow productivity

Data from four performance recording beef herds were used to compare alternative measures of cow productivity with the industry standard which is calf weaning weight adjusted for sex (SOC) and age of calf and age of dam (AOD), i.e. the "200 day weight." None of the alternative measures evaluated required knowledge of calving date and all were relatively easily obtainable in extensively managed beef herds. The assessment of cows was based not on their estimated breeding values but instead on their most probable producing ability which, as the sum of all of the permanent, repeatable aspects of the calf-rearing ability of the cow, explains considerably more of the variance of weaning weight than does breeding value alone.

SOC and AOD-adjusted marking weight, weaning weight and average daily gain (ADG) between marking and weaning were the traits mostly highly correlated with the 200d wt of calves (r = 0.68, 0.90 and 0.74. respectively). An Extensively- Grazed-Cow-Weaning-Index of these three indicator traits was found to be more highly correlated than any of the individual traits on their own (r = 0.94).

Index weights for the three indicator traits were calculated within each herd and then those within-herd index weights were regressed on readily obtainable herd descriptive variables to obtain a regression equation that could predict index weights for any herd. When the model was applied to data from two additional herd years not included in the original model, the EGCW Index was highly correlated with the 200d weights (r>0.90).

Performance-based culling of previously unselected commercial beef herds based on the EGCW Index will result in improved productivity due to the moderately high repeatability of calf weaning weight. Objective data from extensively grazed commercial herds will also make possible the use of commercial herd data in genetic evaluations of herd sires.

Key words: beef cows, performance recording, extensively grazed, 200 day weight,
weaning weight, marking weight, average daily gain

Preface

Twenty-five years farming on our own account and twenty years in farm animal veterinary practice have convinced me of the huge contribution beef cows make to the New Zealand pastoral industry. No other animal has the ability to convert rank pasture of low nutritional value into high quality animal protein human food and do so while being treated like the ugly stepsister. Beef cows demonstrate an enviable ability to cope with adversity and still deliver; perhaps that is the reason why they are often given so little attention.

Early on in my time in NZ I was struck by the tendency of beef and sheep farmers to describe themselves as sheep farmers. When asked about their beef herd, the usual reply was that they only had the cows to keep the grass right for the sheep. The noble beef cow deserves better than that! Several unfavourable and possibly unfair comparisons of the gross margins of different classes of livestock have caused beef cows to be regarded by many as one of the least attractive options. Sadly beef cow numbers have declined and Friesian bulls have spread across the landscape.

For reasons that have always escaped me the amount and volume of animal breeding advice to the beef industry has been but a faint whisper of that offered to the sheep industry. Largely that advice has consisted of recommendations to buy bulls (often sight-unseen off the internet) based on Estimated Breeding Values (EBV's) and index values. Advice regarding female selection and culling has been nearly non-existent. Quantitative geneticists with ever more elaborate formulas have captured the beef advisory industry. Estimated Breeding Values for more traits than one could possibly ever use have proliferated (75 at last count for Brazilian beef cattle). Many of these EBV's are for traits that appear to be of dubious economic value to producers, e.g. marbling and eye muscle area. Others are of such low accuracy that a "shot-in-the-dark" would be a flattering description. The breed societies have refused to require reporting of a reproductive result from every female every year so few fertility EBV's are available to bull buyers. We have tended to measure and calculate what is easy (and possibly insignificant) and ignore what is difficult (and possibly more important).

On the other hand there are many traditionalists who continue to choose cattle on the spring of their rib, the shape of their head or whether the bull actually looks like the assessor's preconceived idea of what a bull should look like. If only we were paid for looks!

The practicalities of NZ beef production rule out close monitoring of individual cow performance such as that practiced in NZ dairy herds. Nevertheless even a cursory observation of beef production will reveal considerable diversity of production. Some cows are larger than others, some retain more condition and some raise better calves than their herd-mates. Experience in commercial dairy herds suggests considerable improvements in herd productivity could be achieved if poor producers were identified and removed from the herd.

I began this project, more years ago that I like to remember, with two goals. First I wanted to determine what criteria farmers used to choose their culls and replacements. Secondly, in what I was fairly confident would be the absence of any objective, justifiable selection criteria, I wanted to determine if an objective selection system could be devised that was practical in the reasonably extensive production systems of hill country sheep and beef properties. There was no need, as I saw it, to produce another performance recording system that required management inputs that are not practical and will never be implemented in the post-Roger Douglas farming environment of most hill country properties.

So I began the project, watched it evolve from what I imagined it would be and eventually am now submitting it as part of a Masters of Agriculture Science degree.

I am grateful to those responsible for the management of the herds involved in this project. Dr. Chris Morris supplied historical data from five herd-years at Whatawhata, John Harrington of Te Mania weighed four hundred calves at marking especially for the project and Terry Shepherd of Toshi Farm began performance recording his herd a year or two before he had intended to so he could contribute data to the project.

The Sustainable Farming Fund of the Ministry of Agriculture and Forestry provided financial support for the bench marking survey.

Professor Tony Bywater has been tolerant of my part-time study, my flights of fancy, my total absence for months on end and occasionally my bursts of enthusiasm. I thank you Tony for your support and endurance. So too must I record my thanks to my wife, Angela, who not only laid a gourmet’s delight before me every night but also for a number of years wound up the strings and fed the hay on our farm at Windwhistle. She also with only the occasional complaint tolerated a veterinarian husband who wasn’t veterinarianing in order to follow an academic dream. Thank you all.

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Glossary

industry term	definition
marking	ear marking, ear tagging, castration, drenching and vaccination of calves, most often at between 60 and 120 days of age
weaning	weaning of calves off their mothers in the autumn when calves are more or less 200 days of age
rising	an animal approaching a birth day, e.g. a R 2yr heifer is between 1 and 2 years of age
m.a.	mixed age cow, i.e. has had at least one calf
maiden heifer	a heifer mated for the first time which will calve at either 2 or 3 years
wet dry	a cow or heifer diagnosed pregnant but which fails to wean a calf
pregnant weaning percentage	calves weaned per 100 pregnant cows wintered
"true" weaning percentage	calves weaned per 100 cows mated less pregnant cows sold
involuntary culls	cows either not thought likely to survive another year (age, teeth, cancer eye or condition), wean a live calf for physical reasons(udder) be a danger to humans (temperament) cows diagnosed non-pregnant and wet dries are not included in this category
voluntary culls	cows capable of surviving another year and producing a calf but sold
CD	calving date
AOD	age of dam at time of calving in years
SOC	sex of calf at weaning: bull, heifer or steer
birth wt	weight within 24 hours of birth, unadjusted
adjusted birth weight	birth wt adjusted for sex of calf and age of dam
marking weight	weight at marking, unadjusted
adjusted marking weight	weight at marking, adjusted for sex of calf and age of dam
weaning weight	weight at weaning, unadjusted
adjusted weaning weight	weight at weaning, adjusted for sex of calf and age of dam
200d wt	weaning weight of the calf adjusted to the equivalent of a 200 day old bull calf out of a 5 year old cow
ADG	averag daily gain between two dates in kgs/day
ADG b/mk	average daily gain between birth and marking
ADG mk/wn	average daily gain between marking and weaning
ADG b/wn	average daily gain between birth and weaning

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Introduction and Literature review

Little is known of the efficiency of beef production in New Zealand. The Economic Service of Meat and Wool New Zealand conducts an annual survey of a limited number of herds which includes limited production and financial data but there are few other published reports of many other important characteristics of beef production including mating practices, selection and culling practices or animal health policies.

A 1959 report on beef cow performance in Poverty Bay found an average pregnancy rate (cows diagnosed pregnant over cows mated) of 83%, a true marking percentage (calves marked over cows mated) of 76% and the most common age at first calving of 3 years (Fielden & McFarlane, 1959). A 1960’s study, also in Gisborne, reported a true calving percentage of 75% (Young, 1965).

In the 1970’s two veterinarians reported on beef production from a total of 140,000 cows over four years in the Wairoa district (Hanley & Mossman, 1977). The pregnancy rate was 90.1% in cows and 89.2% in heifers with a true calving percentage of 82.5%. The Wairoa study found dystocia was virtually a non-existent problem in cows and caused the loss of only 1-2% of heifers’ calves although only 5% of heifers first calved at two years of age.

Hanley and Mossman, like Fielden and Young before them, concluded low reproductive efficiency made most beef herds unprofitable.

Over the years beef cows have been primarily seen as less important than sheep and have been farmed mainly as a means of controlling rank summer pasture growth and restoring the paddocks to “sheep-friendly” status. With the increased efficiencies demanded of Post-Rogernomics pastoral farming, labour availability on farms has declined. Beef cows in particular are seen by many farmers as low-labour-input animals. With the minimal focus on beef cows, selection and culling have apparently consisted of annual culling of cows pregnancy tested empty and those with physical infirmities.

There is little to suggest that beef cow herds have become more efficient over time. Over the last twelve years the national beef calving percentage has declined (Meat & Wool New Zealand Economic Service, 2006) (Figure 1).

Over the same period the sheep industry has dramatically lifted production with the national lambing percentage rising from around 105% in the mid 1990’s to just over 125% in early 2005 (Meat & Wool New Zealand Economic Service, 2006) (Figure 2).

Figure 1

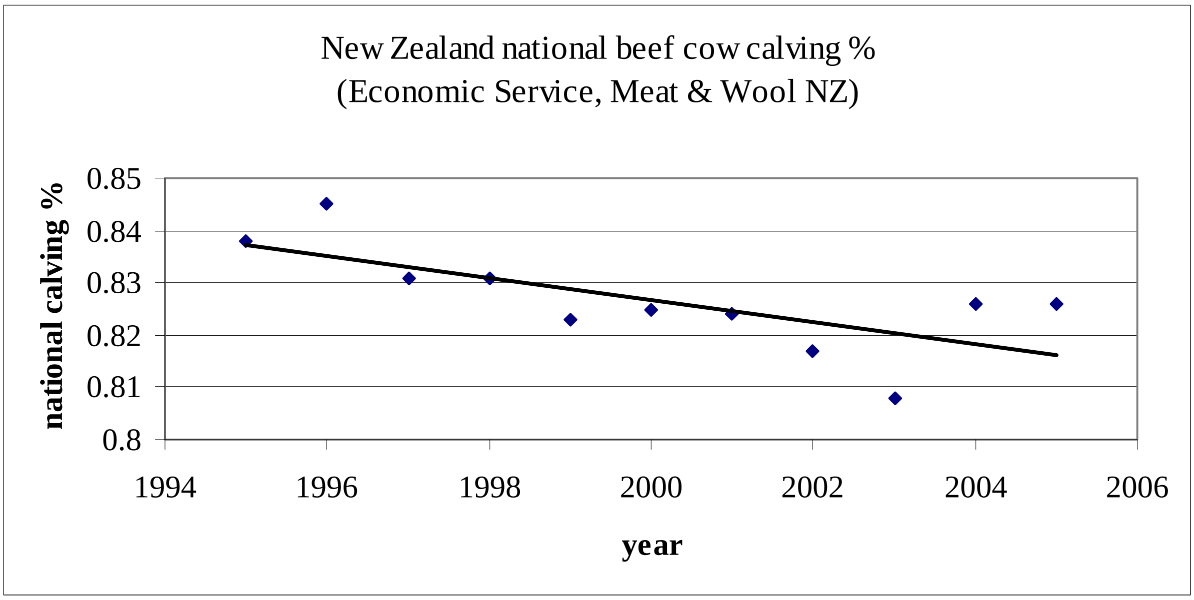
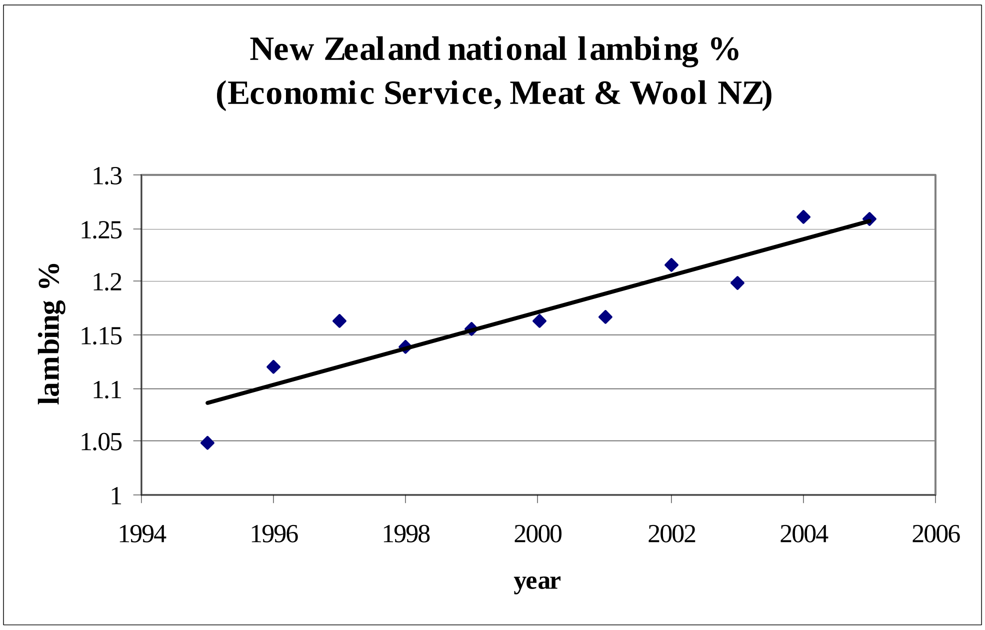
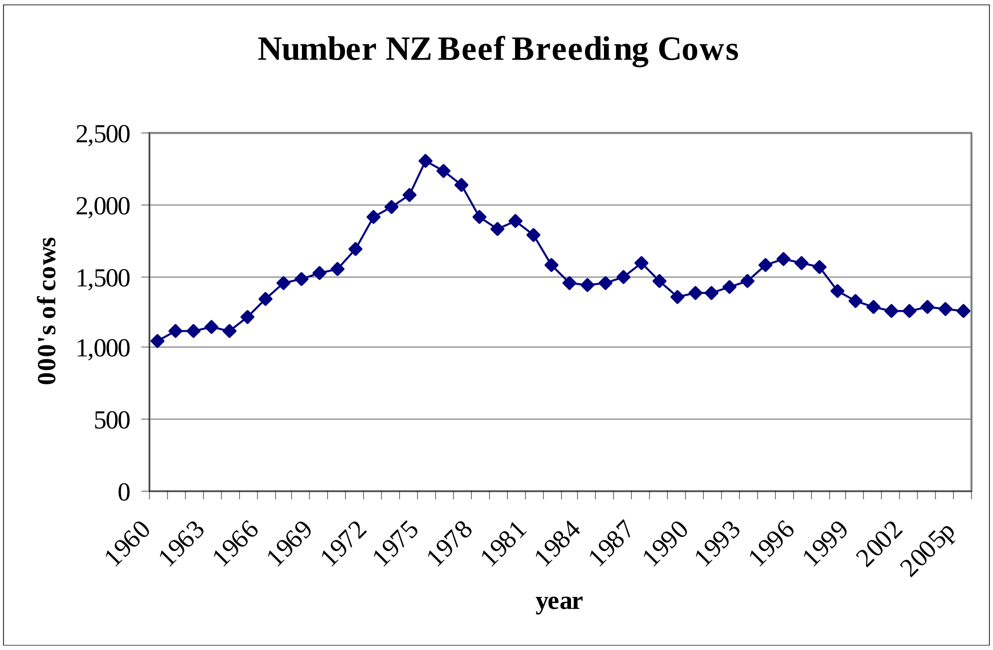


Figure 2



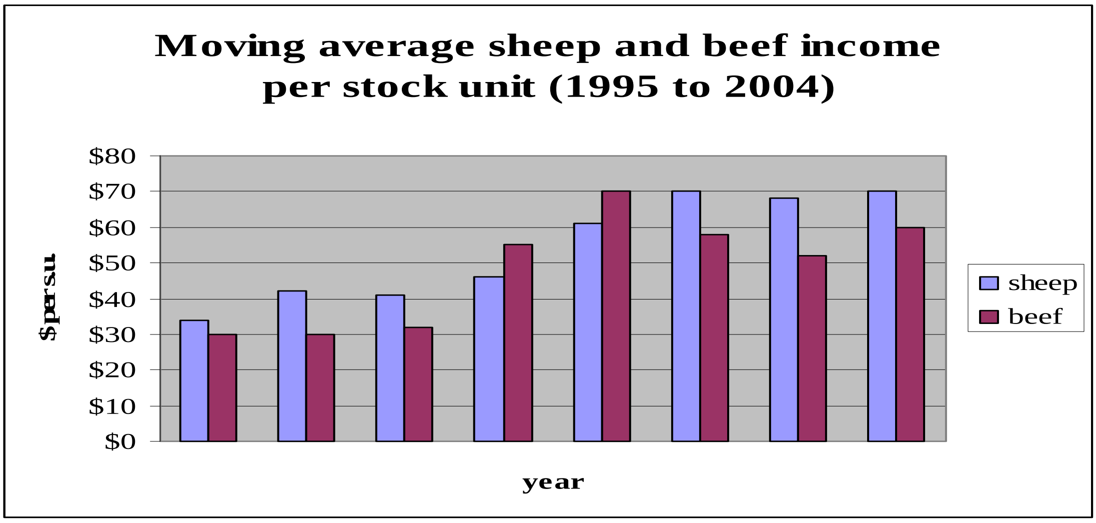
Cow numbers have declined steadily from their peak in mid 1970's (Figure 3) (Meat & Wool New Zealand Economic Service, 2006) for a variety of reasons. In the early 1990's large areas of hill country, particularly on the east coast of the North Island, that had previously been beef and sheep farms were converted to pine plantations reducing the area available to beef cows. Intensified tuberculosis control programs have required annual testing of beef herds in many areas in which beef cows were previously rarely yarded and have added substantially to the labour requirements of beef production. Increased sub-divisional fencing of larger blocks on many breeding properties has also reduced the perceived need for pasture-tidying cows.

Figure 3



Finally several economic comparisons have ranked beef cows relatively poorly compared to other grazing options (Crawford & Lowe, 1994; McCall, 1994). Economic Service data, too, suggests the profitability of beef is lagging behind that of sheep (Figure 4) (Meat & Wool New Zealand Economic Service, 2006).

Figure 4



Critical to the comparison of the gross margins per stock unit of the different pastoral options, of course, is the number of stock units assigned to each class of animal. Beef cows have traditionally been said to be the equivalent of six stock units and the traditional ewe one stock unit. Some have argued that the number assigned to cows is too high (Crawford & Lowe, 1994; McCall, 1994; Pleasants *et al.*, 1994) Although the traditional six stock units per breeding cow may accurately reflect the total annual energy requirements of beef cows the system may not accurately indicate the economic cost of the feed consumed. If the number of stock units per breeding cow was less than six then their profitability per stock unit would be more favourable relative to other livestock options. A current AgResearch project is attempting to more accurately estimate the economics of beef production.

For all these reasons cattle production has for many pastoral farmers been a low priority and there has been little attention directed at efforts to increase the efficiency and profitability of beef production.

Bull selection has largely been focused on growth and size. A study of sale prices achieved at auction by Angus bulls in Canterbury in 2004 (Thomas, 2005) found bigger size and faster growth estimated by any physical measure or estimated breeding value was associated with higher sale prices.

Cattle live-weight and carcass weights have increased over time (Meat & Wool New Zealand Economic Service, 2006) and the genetic trends for growth and live-weight of the major breed societies have steadily trended upwards. Since 1980 the Australasian Angus breed average estimated breeding values (EBV's) for birth weight, 200 day, 400 day and 600 day weight have increased by 4.3, 33, 62, and 80kgs respectively(Angus Society of Australia, January 2003). Unfortunately due to genetic correlations, mature cow weight has increased by 70 kgs as well (Angus Society of Australia, January 2003) which has resulted in higher maintenance costs per cow and greater feed costs for the entire production system. One commentator has questioned whether the production efficiency of the beef industry (kilograms meat produced per kg of dry matter consumed) has improved or declined over time (Macfarlane, 2003) .

However technology advances by some meat companies and new marketing efforts by at least two of the cattle breed societies (Hereford Prime® and Angus Pure®) have resulted in an increased proportion of beef carcasses being sold in the form of chilled, vacuum-packed, individually-packaged higher priced cuts that attempt to capitalize on New Zealand's "clean green" image. The increased retail value of the improved processing has increasingly been returned to producers resulting in sustained higher farm gate prices for beef. BSE, foot and mouth and E coli scares in overseas countries have also offered new opportunities for NZ beef. One reasonable size feedlot has also been established in the South Island and has not only supported calf prices but led to an increased awareness of the desirability of producing quality carcasses. The recent (2006) decline in the lamb schedule has also contributed to an increased interest in beef.

Accordingly there is renewed interest in improving the efficiency of beef production. One North Island farm adviser (M Walshe, 2005, personal communication) has reported that variation in overall farm profitability among his clients is primarily due to variations in cattle productivity with sheep profitability reasonably constant.

Anecdotal evidence from veterinarians, stud breeders and commercial herd managers suggests very few herds practice any performance recording.

The objectives of this research are firstly to establish current management practices in commercial herds, particularly with respect to recording, selection and culling of cows, and secondly to develop an objective system for cow selection and culling that would be practical in largely un-shepherded commercial herds and which would result in improved productivity.

Extension efforts in the NZ beef industry have focused on improving the genetics of commercial herds through the purchase of breeding bulls from registered studs on the basis of their EBV's and index values (Baker & Morris, 1981; Baker *et al.*, 1987; Meat and Wool New Zealand, 2000; New Zealand Beef Council, 1989, 1991; Thomson, 1987).

Current extension advice places little importance on objective selection of female beef cattle and has largely been confined to comments such as "grow the heifers well to achieve critical breeding weights" (Vermunt, 1994).

There are a number of reasons, however, to question this dependence on male selection for improving cattle production in commercial herds.

1. **The proportion of the variance of calf weaning weight attributed to the sire of the calf is less than one quarter of that attributed to the dam** (Table 1)

The only contribution a bull makes to the performance of individual calf is one half of the direct additive genetic effect. Contributions of the dam to the phenotype of the calf include an equal direct additive effect, all of the maternal genetic effects, gene combination value and the dam's permanent environmental effect. The latter, largely due to the cow's own rate of growth to 8 months of age, has been shown to be responsible for up to 30 kgs difference in weaning weight (Johnsson & Morant, 1984);(Johnsson & Obst, 1984).

According to the literature (Table 1) the sire of a calf explains on average only 10.6% of the phenotypic variance of calf weaning weight after adjustments for known environmental effects while the dam is responsible for on average 46.4%. Selection methods focusing exclusively on bulls ignore the opportunity to lift production by devoting some attention to dam factors. Most Probable Producing Ability (MPPA) estimates are a mathematical expression of these repeatable aspects of the calf producing ability of cows and "are particularly important to commercial producers" (Bourdon, 1997).

2. **Accuracies associated with the Estimated Breeding Values (EBV's) of sale bulls are quite low** (Angus Society of Australia, January 2003) with accordingly large standard errors of prediction. EBV's are the best estimate of the value of a bull's genes to his offspring and for marketing purposes EBV's are expressed as specific numbers. More accurately EBV's and their associated standard errors are confidence limits within which

there is a given probability that the true breeding value (BV) of the animal can be found. For example a 2001-born Angus bull with a 200 day weight EBV of +28 (breed average)

Table 1

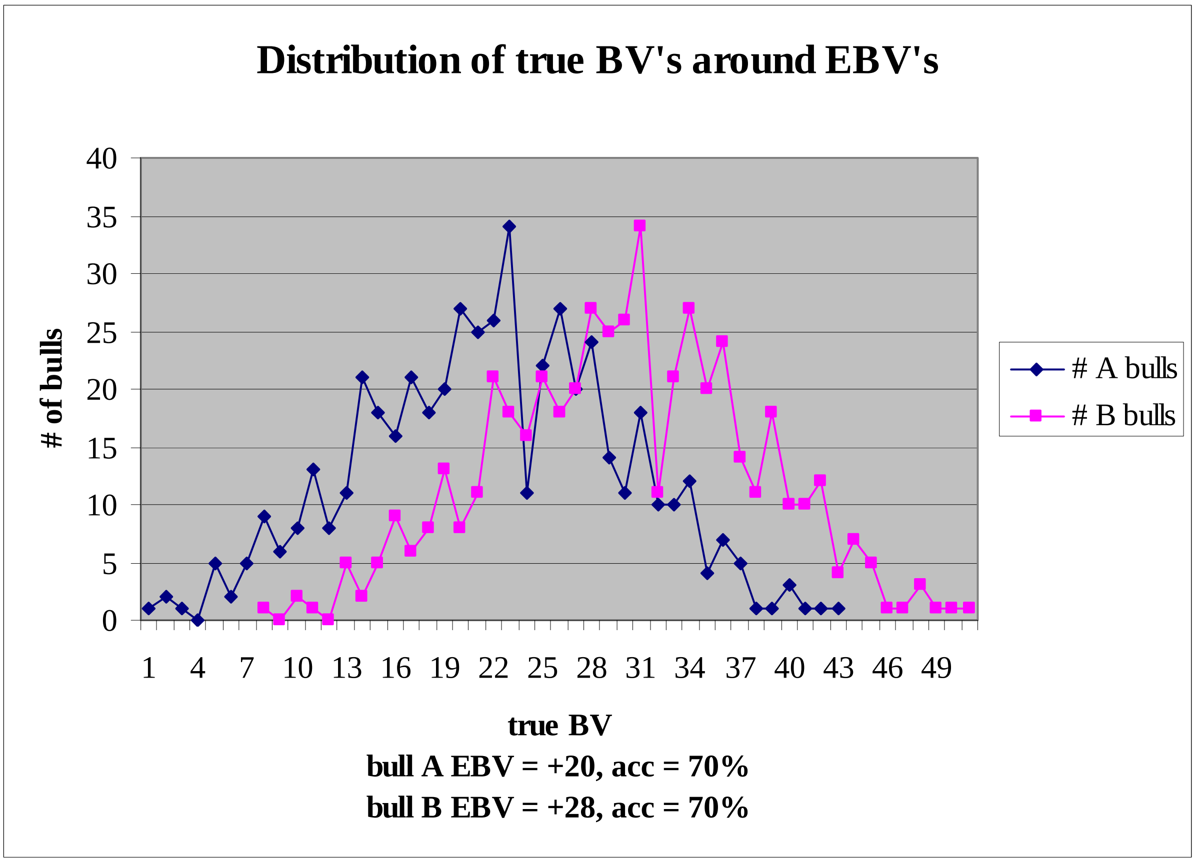
Partitioning of phenotypic variance of calf weaning weight

reference	# records	direct additive	genetic maternal	permanent environmental	residual VE	comment
Waldron 1993	2,000	14.2%	11.4%	15.3%	60.8%	Angus, 150 d
Koch 1972	4,000	19.9%	13.5%	3.5%	59.5%	Angus, 200d
Herd 1990	220					Angus, gain to wn
Van Vleck 1996	486	35.0%	17.0%	10.0%	36.0%	Angus 2yr
Van Vleck 1996	459	24.0%	14.0%	28.0%	37.0%	Angus 3yr
Van Vleck 1996	966	23.0%	14.0%	29.0%	41.0%	Angus ≥4yr
Van Vleck 1996	285	19.0%	20.0%	38.0%	32.0%	Here, 2yrs
Van Vleck 1996	332	26.0%	31.0%	39.0%	14.0%	Here,3yrs
Van Vleck 1996	778	21.0%	12.0%	30.0%	43.0%	Here ≥ 4yrs
Koch 1972	4,000	35-45% of VP due to total maternal				Hereford
				26.0%		Hereford
Meyer 1992	5,000	13.7%	13.2%	23.0%	57.9%	Hereford, 200d
Meyer 1992				20.0%		Hereford
Souza 1996		14.0%	16.9%	5.2%	65.5%	Nelore
Souza 1996	108,000	6.0%				Nelore
Bertrand 1987	50,000	16.0%	15.4%	5.9%	67.4%	Limosin
Bertrand 1987	25,000	28.0%	19.8%	4.1%	54.9%	Brangus
average		**20.0%**	**16.5%**	**19.8%**	**47.4%**	

and a typical accuracy of 70% has a standard error of prediction of 7 kgs and therefore the 95% confidence limit for his true breeding value is within the range of 2 standard errors either side of the estimate or between +14 and +42 kgs in this example. A similar bull with an EBV of only +20 and an accuracy of 70% would have a 95% confidence limit of between +6 and +34. A simulation based on random number generation and standard errors (Figure 5) demonstrates that there is considerable overlap of true breeding values of bulls having different EBV's: many of the "better" bulls actually have true breeding values below those of some of the "poorer" bulls.

One leading geneticist has suggested that differences of EBV for weaning weight of as much as 10-20 kgs will not be noticeable on most commercial farms (Bourdon et al., 1997)

Figure 5



Because EBV's are descriptions of the genotype of the bull and because progeny receive only half of their genes from their sire (and the other half from their dam), the difference between the EBV's of two bulls is twice the likely difference of performance of their progeny. By way of contrast North American genetic estimates are expressed in expected progeny differences (EPD's) which describe the expected difference in progeny. Hence the Australasian use of EBV's instead of EPD's exaggerates the difference individual bulls will have on a herd and possibly misleads bull buyers about the importance of minor differences in EBV's.

3. Genetic x environmental interactions may further reduce the accuracy of many EBV's in commercial herds. EBV's in New Zealand are calculated almost exclusively from data provided by stud breeders who in most cases farm in relatively favourable environmental conditions of minimal stress. Most commercial beef herds on the other hand are run on tussock hill country and are routinely exposed to significant nutritional stress.

There is mounting evidence that EBV's generated in environments of minimal stress may not be accurate in more stressful environments. Bourdon (1998) has suggested that stud-based <u>fertility</u> EBV's are very often not relevant in commercial herds. Charteris *et al.* (1997)

found carcass EBV's calculated from feedlot-finished cattle were not reliable for predicting performance in grass finishing conditions and vice versa.

Bourdon (1998) also suggested significant G x E interactions exist for growth traits. Earlier Falconer (1977) had demonstrated that genetic gains achieved by mice in ad lib feed situations were not transferable to more restricted nutritional environments. Frisch (1981) later confirmed Falconer's results in Queensland cattle.

A recent addition to the available EBV's, net feed conversion efficiency, has been developed in Australian feedlots by comparing actual feed consumption with that predicted from size and performance of the animal. Richardson *et al*. (1999) reported that less active bulls that spent much of their time sitting down were found to be more efficient than more active bulls. Whether hill country beef breeders who expect a bull (and his daughters) to climb to the top of the hill would agree is debatable.

The failure of bulls to always leave progeny compatible with their EBV's has been postulated (Bourdon, 1998; Bourdon *et al.*, 1997) to be due to the fact that some bulls lack genes associated with adaptability.

The United States Department of Agriculture has recently established a national task force on the adaptability (or more accurately the absence of adaptability) of genetic predictions in beef cattle in an attempt to better understand and minimize G x E interactions (Pollack, 2005).

Therefore it is highly possible, if infrequently stated, that stud-generated EBV's available in bull sale catalogues may be of limited relevance for many hill country bull buyers.

4. Fertility traits have been shown to be considerably more important economically to commercial beef producers than either growth or carcass traits (Melton, 1995; Melton *et al.*, 1994; Trenkle & Willham, 1977), **but few fertility EBV's appear in bull catalogues** (Hargreaves, 2005; Jenkins, 2005; Wilding, 2005)**.** Most NZ maternal breed cattle studs offer at most one (scrotal circumference) of the four fertility EBV's internationally available. Two of the other fertility EBV's (heifer pregnancy (Doyle *et al.*, 2000; Evans *et al.*, 1999) and stayability (Hyde *et al.*, 1996)) are rarely available in New Zealand catalogues largely because most breed societies do not require whole (as opposed to partial) herd reporting (Snelling, 1998).

At the same time most studs provide their clients with up to five EBV's for growth and four for carcass traits (Hargreaves, 2005; Jenkins, 2005; Wilding, 2005). There is currently in New Zealand no financial reward for superior carcass characteristics. Carcass traits are, however easier to measure than fertility or reproductive traits.

Grasser (1994) demonstrated that inclusion of fertility traits in a genetic selection index had a substantial effect on herd profitability.

5. The standard formula for predicting genetic change suggests female selection may compare more than favourably with male selection.

$$\frac{\text{genetic change}}{\text{year}} = \frac{\text{selection intensity} * \text{accuracy} * \text{phenotypic variation}}{\text{average age of parents}}$$

a. Selection intensity in bulls is quite low and arguably no better than is possible in female selection programs

Selection intensity (Bourdon, 1997) is an expression of the proportion of those available for breeding that are used to produce the next generation.

An individual farmer using artificial insemination (AI) has the opportunity to purchase semen from any of the many bulls whose semen is commercially available and would have a very high selection intensity. In reality very few commercial cattlemen in NZ use AI .

An individual beef farmer using registered bulls for natural mating theoretically has the choice of any one of the registered bulls offered for sale, e.g. 1 out of the approximately 8,000 registered Angus bulls born each year (Charteris, 1996); again a very high selection intensity.

Viewed from an industry perspective, however, selection intensity is much less. Assuming, as is usually the case, neither AI nor unregistered bulls are used (Charteris, 1996), the pool from which potential sires are chosen by the industry consists of registered bull calves. Again using the Angus breed as an example approximately 2,500 Angus bulls are purchased each year by the beef industry out of pool of 8,000 registered bull calves resulting in a selection proportion of approximately 1 in 3.

A one in three selection intensity is also possible for female selection in commercial herds if most of the yearling heifers are mated and heifer calves out of first calving heifers are retained as possible replacements as well as those out of mixed age cows.

It has been argued that a lower selection intensity in a stud herd of greater mean genetic merit may produce greater genetic progress than a higher selection intensity in a commercial herd of lesser genetic merit. This will depend on the extent of the difference between stud herds and commercial herds in terms of genetic merit for commercial herd production which as noted earlier is uncertain.

b. **Accuracy of selection favours females** Genetic by environmental (G x E) interactions between the favourable environment in which bulls are measured and the less favourable environment in which they are expected to perform possibly reduces the accuracy of male selection. Commercial females can be selected on the basis of their performance in their own environment.

c. **Phenotypic variation may well be at least as large in unselected commercial herds** as it is in (possibly line-bred) stud herds

d. **Average age of parents may favour females** Nationally a large proportion of heifers produce their first calf at two years of age. Most bulls are purchased at 22 months, used for mating at 27 months and have their first calves on the ground at three years of age. The only redeeming feature of the generation interval of bulls is the shortness of the average bull life span; high rates of bull wastage mean there are not many old bulls around leaving calves. The short productive life of many bulls may be attractive from a rate of genetic change perspective but is not necessarily viewed as favourably by the bull buyer.

A great deal of time and money is invested in the prediction of genetic worth of bulls but if the result of that effort over the past 20 years is larger cows with higher maintenance feed costs and lower reproductive rates (Golden et al., 2000; Holmes et al., 1999) then one has to question whether the time and money have been well spent.

For all of the above reasons complete reliance on stud-generated EBV-based bull selection for herd improvement is a questionable practice. It may well be that commercial beef producers could profitably devote some effort to objective female selection based on Most Probable Producing Ability predictions of individual cows.

Currently available performance recording systems in commercial beef herds

Objective female culling is based on the repeatability of a cow's ability to produce a calf which is usually expressed as either the 200d weight of the calf or the average daily gain(ADG) of the calf to weaning. Repeatability estimates generally range between 0.3 – 0.6 for weaning weight and 0.3 – 0.7 for ADG (Table 2).

Records of adjacent years are more highly correlated (more repeatable) than those more distant. Lee & Henderson (1971) claimed failure to remove the effects of culling from calculations of repeatability lowered estimates by up to 20%. Whether the repeatability estimates listed in Table 2 are corrected for culling was not stated.

Table 2

Repeatability estimates of adjusted calf weaning weight^

	Angus	Hereford	comment
Weaning weight			
Koger & Knox 1947		0.49-.57	
Koch 1951		0.52	
Botkin & Whatly 1953		0.43-.49	
		0.66	between 1st and 2nd calves
Rollins and Guilbert, 1954		0.48	
Koch and Clark, 1955		0.34	
Brown et al., 1954	0.65	0.42	240 day
Taylor et al., 1960	0.36	0.50	
Lueker et al., 1963	0.45	0.45	
Boston et al., 1975		0.52	
Brinks 1964		0.45	
Cunningham and Henderson, 1965		0.48	adjacent records
Minyard and Dinkel, 1965	0.52	0.42	
Drewry and Hazel, 1966	0.45		205 day
Hohenboken and Brinks, 1969		0.25	
Sellers et al., 1970	0.19	0.27	
Hohenboken and Brinks, 1971		0.33-.40	
Kress and Burfening, 1972		0.44	
Boston et al., 1973	0.27	0.50	
Pre-weaning ADG			
Turner and Shrode, 1986	0.35	0.49	
Gregory et al., 1950		0.50	
Botkin and Whatley, 1953		0.38	
		0.69	between 1st & 2nd ADG
Taylor et al., 1960		0.37	

^ adjusted for sex of calf, age of dam and age of calf

Identification and culling of poorer calf producers will lift subsequent production from the herd. Frey (1972) has suggested that a heifer's first calving record is by far the most useful indication of life time productivity, far more reliable than any measure of size, type or weight.

The opportunities for herd improvement in commercial operations have been recognised for some time. A number of cow evaluation methods have been developed and promoted over the years (Baker, 1973; Baker & Morris, 1981; Morris, 1980; Newman *et al.*, 1992). All of these attempt to remove the non-repeatable influences on calf growth in order to estimate, as accurately as possible, the most likely future production of individual cows. In most cases comparison is made on the basis of the equivalent of a 200 day bull calf out of a five year old dam (Cardellino & Frahm, 1971; Cundiff & Willham, 1966; Lehmann *et al.*, 1962; Minyard & Dinkel, 1965; Nicoll & Rae, 1977; Pell & Thayne, 1978; Vernon *et al.*, 1964).

In New Zealand initially Beef Plan (Nicoll & Rae, 1977) and more latterly Breedplan (Graser *et al.*, 1987; Johnston *et al.*, 1999) have been well received and widely, if sometimes grudgingly, adopted by stud breeders. Very few commercial beef farmers appear to have adopted the technology. Most herd managers pay little attention to their cows at calving and have no knowledge of the calving date of individual cows or consequently the ages of individual calves at weaning. Since correction for age of calf has been shown to be the most important of all the corrections (Nicoll & Rae, 1977), performance recording has not been possible within the constraints of commercial beef production.

If a method of accurately estimating the productivity of individual beef cows could be developed that did not require knowledge of age of calf, performance recording would be practical in many commercial beef herds. Within existing beef herd management practices calves can easily be weighed on at least two occasions. Most beef calves are brought to cattle yards at between 2-4 months of age in order to castrate the male calves and ear mark/ear tag the calves. Practically this is usually either at the time the bulls are introduced to the herd (approximately 80 days after the start of calving) or when the bulls are removed from the herd some 40-80 days later. Weighing calves at calf marking would not add significantly to the labour requirement of commercial cattlemen. It is also possible to identify dam parentage for the great majority of calves as they are released from the yards after marking. Calves are also yarded at weaning and could be weighed again at that time.

If individual calf weights could be collected at marking and at weaning and dam parentage established after marking, it might be possible to use either of those measures or some combination of them to accurately estimate adjusted 200 d weight. A farmlet trial in Western Australia (Meyer & Graser, 1994) demonstrated a favourable genetic correlation ($r>0.90$) between the ADG between marking and weaning and 200 day weight. The maternal heritability and permanent environmental effects of the two traits were very highly correlated with the coefficients approaching 1.0.

Meyer suggested pre-weaning ADG could be used as an alternative to 200 day weight in performance recording programs and concluded that use of pre-weaning ADG data from extensive situations could be used to substantially increase the size and accuracy of the Breedplan database (Meyer & Graser, 1994). Meyer’s study was based on a farmlet trial with relatively constant feeding levels from calving to weaning. She questioned whether pre-weaning ADG would be equally reliable as an indicator of 200d weight in situations in which ADG declined markedly in the later portion of lactation due to summer drought and reduced feed supply available to the dam and the calf.

If the relative calf rearing ability of cows can be accurately estimated without knowledge of calving date then a practical method of estimating most likely future calf rearing ability would be available for calf producers in extensive situations.

Benchmarking Survey

Materials and methods

A list of beef herds with more than 100 breeding cows in the greater Canterbury region was purchased from Agri-Quality NZ. An effort was made to contact most of the herds on Banks Peninsula and in Mid Canterbury between the Waimakariri and Waitaki Rivers. Farm managers were contacted by telephone and whenever possible an appointment was made to visit the farm and conduct the survey.

A questionnaire was prepared and during the autumn/winter of 2005 the farms were visited. In most instances farmers consulted their annual accounts, notebooks and/or pocket diaries. Occasionally the author telephoned the respondents later to clarify survey details.

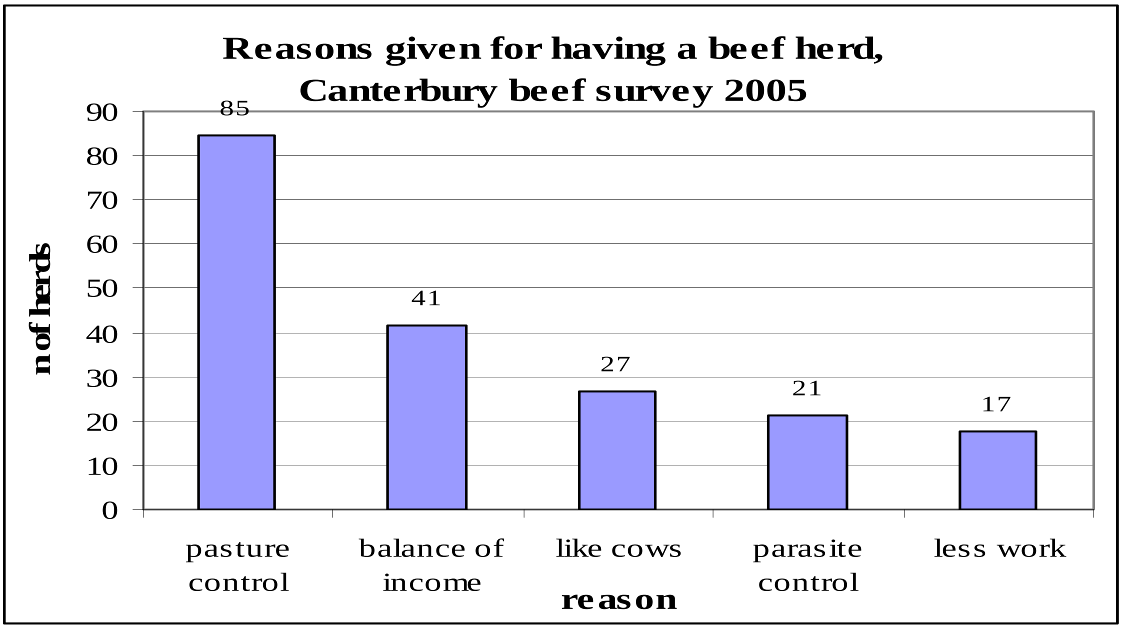
Statistical differences were analyzed using chi square procedures.

Results

Ninety two of the slightly more than 100 herds contacted agreed to take part in the survey. The number of herds supplying useful answers to each of the questions, particularly those relating to age of cow, varied considerably. In the following section the numbers above the bars in the histograms show the number of herds in each category.

Cows were predominantly seen as a necessary adjunct for a successful sheep operation: "keeping the grass right for sheep" was listed by 91% of the herds as the most important reason why they had a herd of beef cows (Figure 6).

Figure 6



Surveyed farms averaged 2,200 hectares (Figure 7) and 7,700 stock units (s.u.) (Figure 8) with beef cattle on average representing 30% of the total (Figure 9).

Figure 7

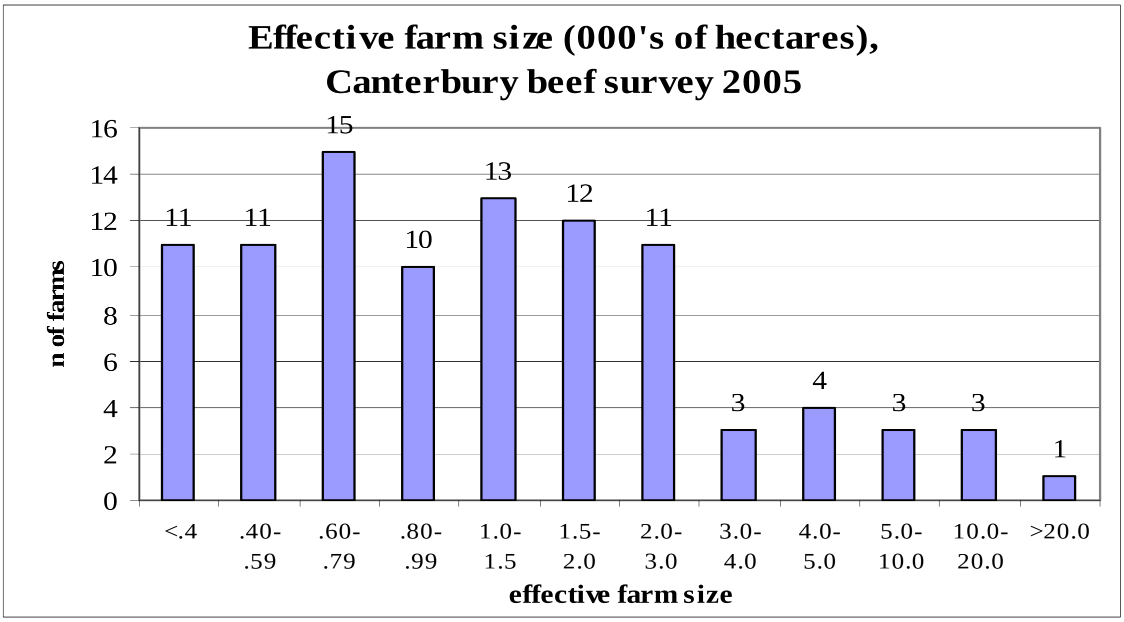


Figure 8

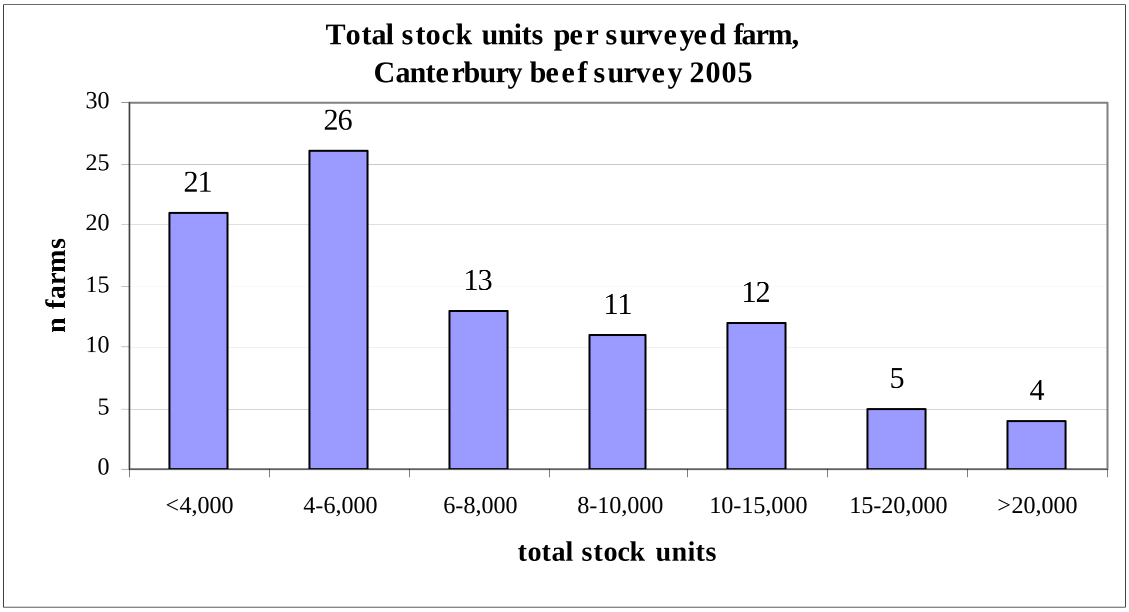
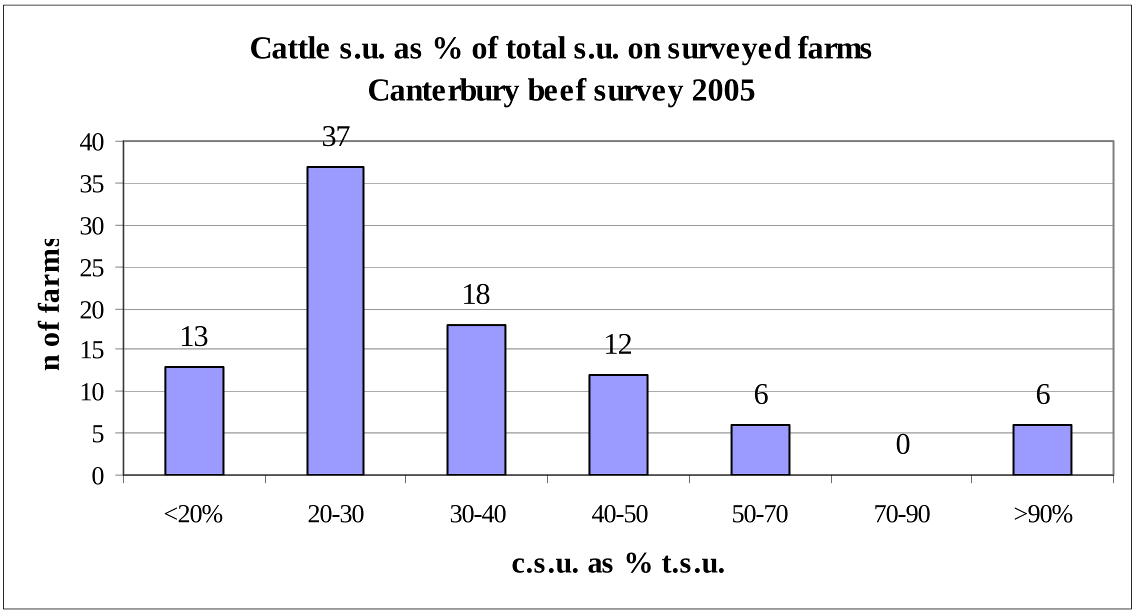
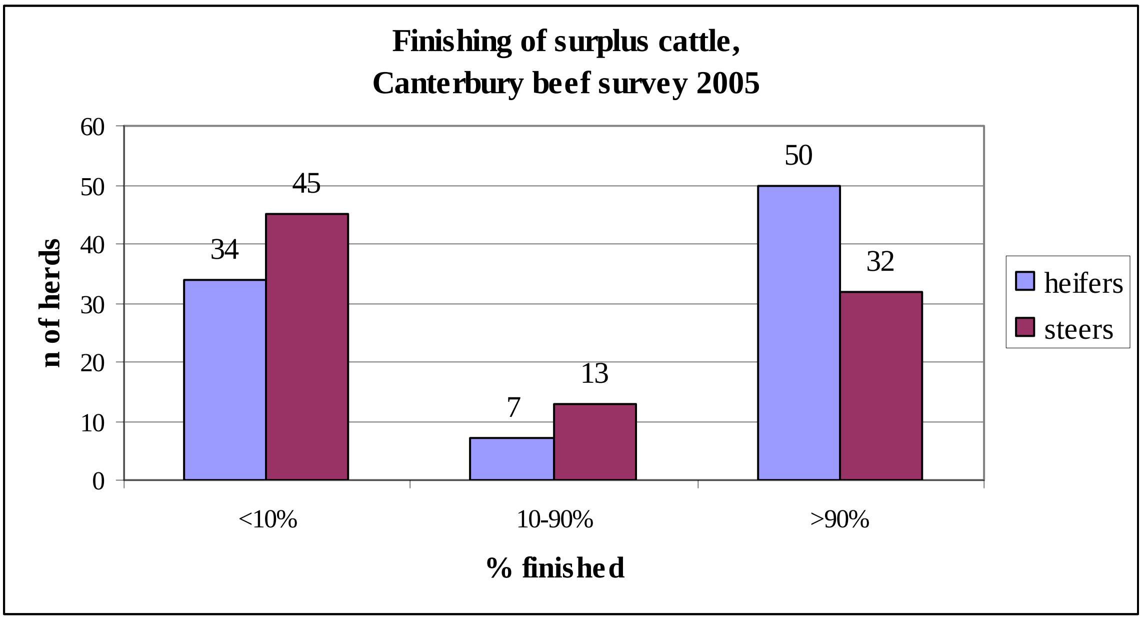


Figure 9



Beef herds averaged 238 breeding cows and were predominantly Hereford Angus cross (47%) and straight-bred Angus (39%). There was only one composite herd. Farms either tended to finish nearly all of their surplus stock (heifers and steers) or alternatively nearly none of them (Figure 10).

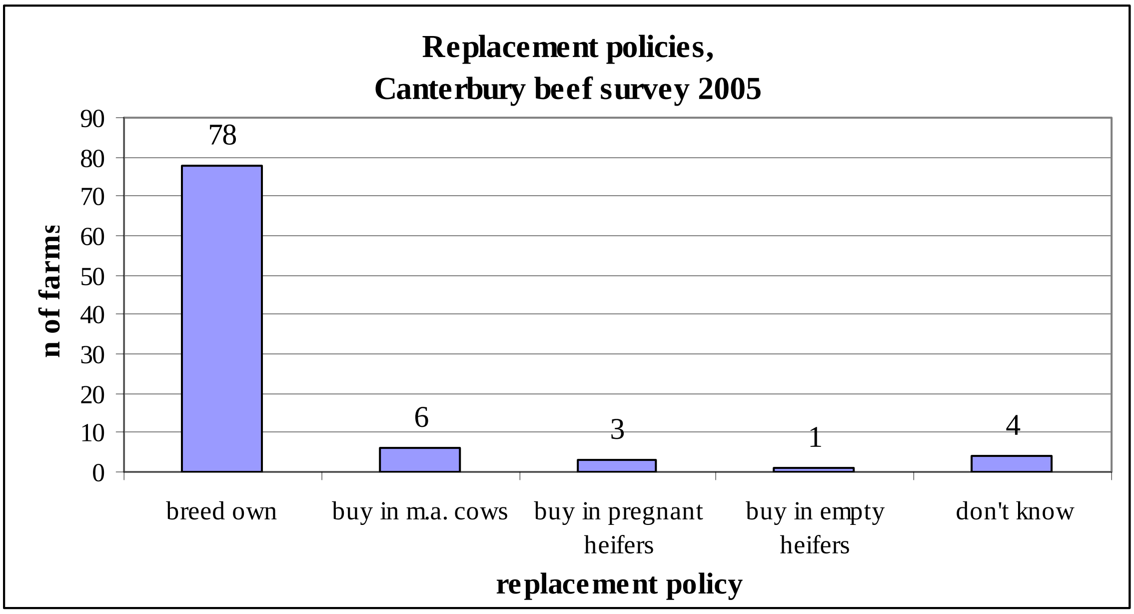
Figure 10



Choosing replacements

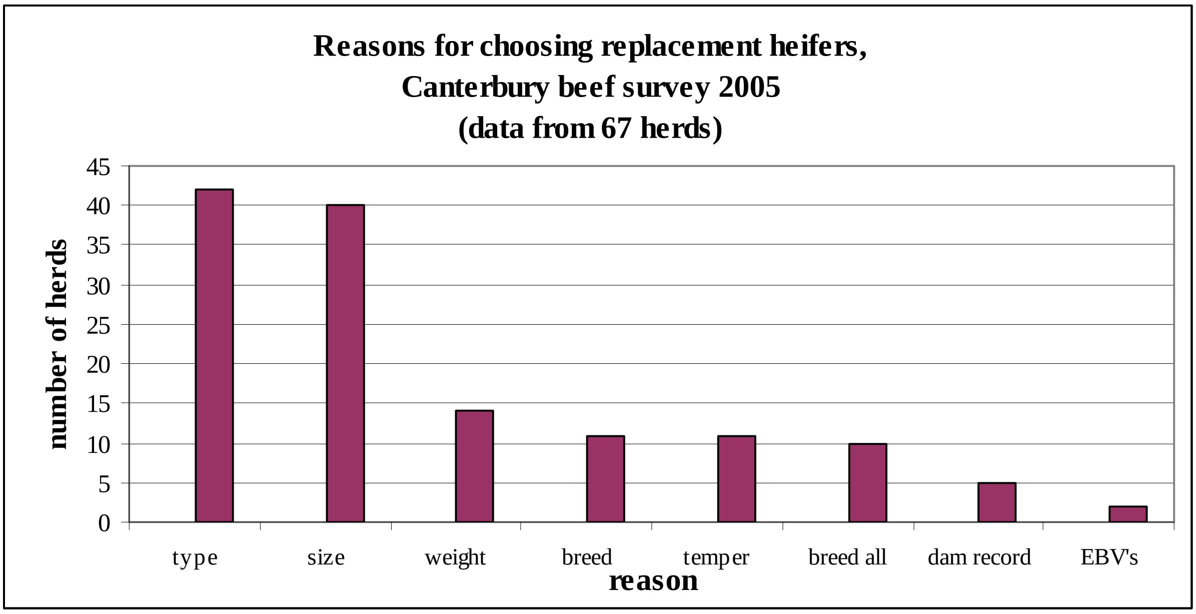
Nearly all herds (88.6%) bred their own replacements (Figure 11) and more than half (61%) first calved heifers at two years of age. A small number of herds on Banks Peninsula first calved at two and a half years and then subsequently at 4 years of age.

Figure 11



Type and size were by far the most common reasons for choosing replacement heifers (Figure 12). Only 10% of herds over-bred heifers and then selected replacements on the basis of their first calf.

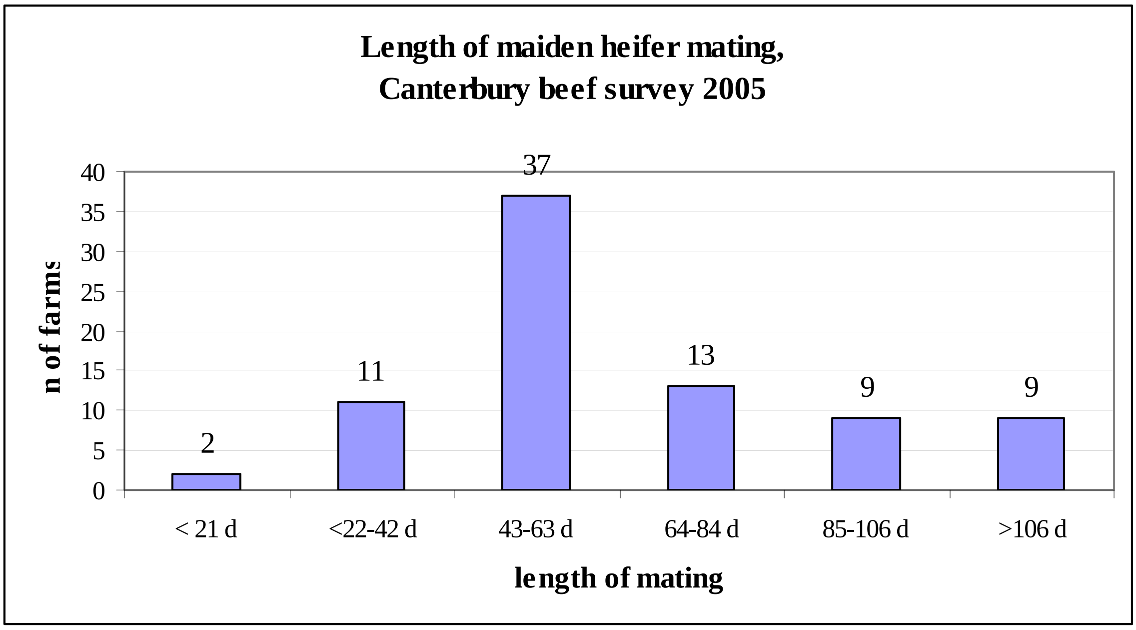
Figure 12



Mating

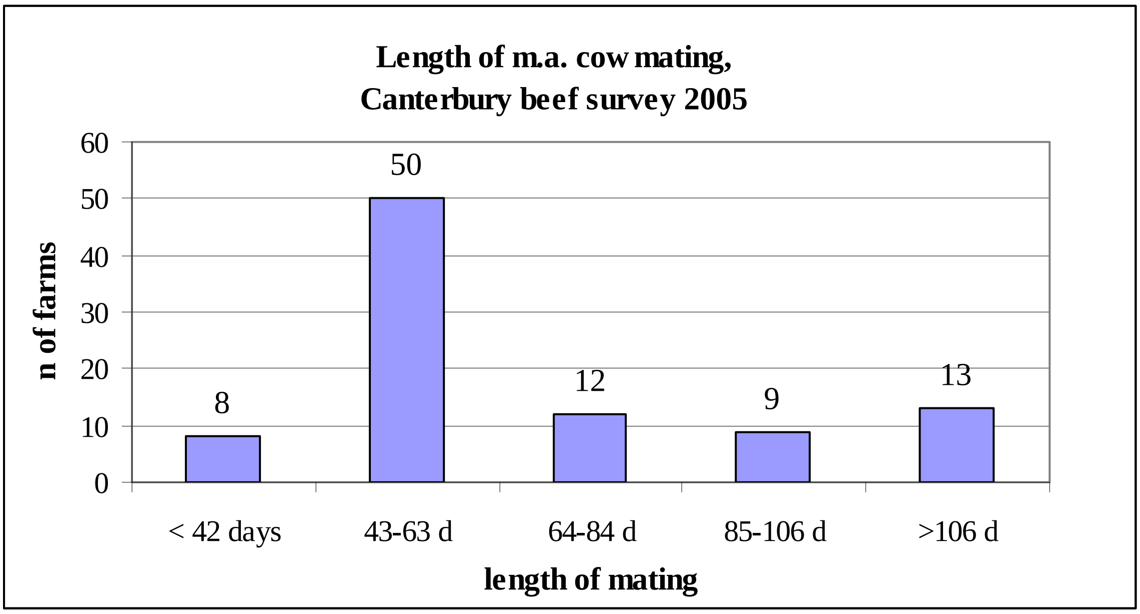
Maiden heifers were mated for an average of 76 days (Figure 13) with 43-63 days being the most common.

Figure 13



The average length of mating of mixed age cows was 78 ± 30 days. The median date of the start of mating was December first. Thirteen per cent of the herds left the bull out for more than 100 days (Figure 14). The majority of herds were mated for between 42 and 63 days.

Figure 14



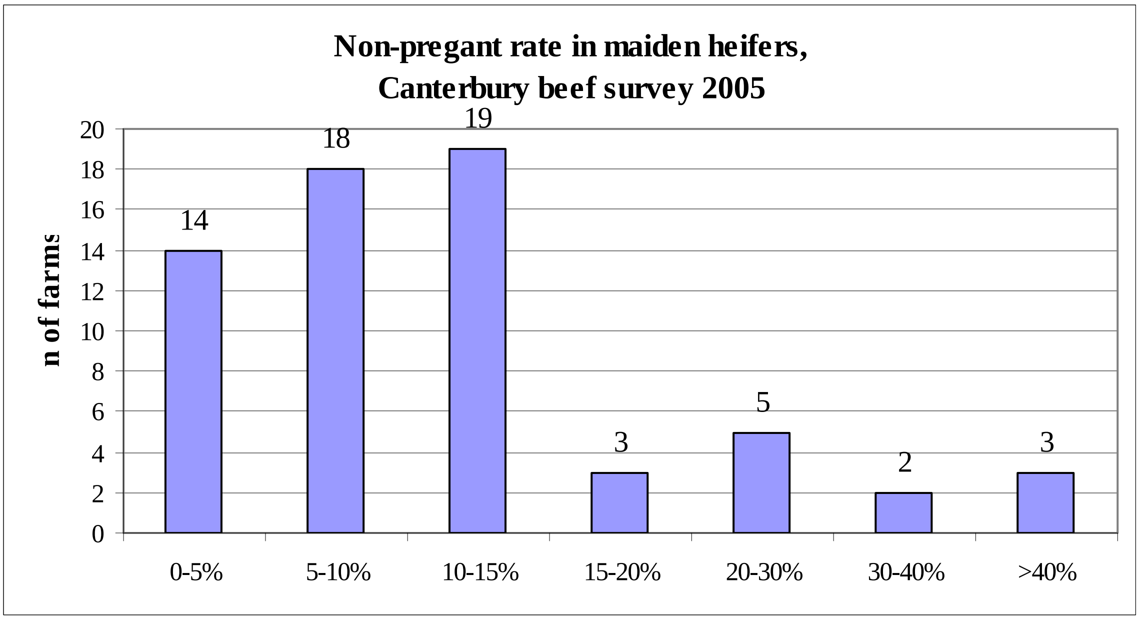
Nearly half of the herds began mating of maiden heifers and m.a. cows on the same day.

Pregnancy rates

Eight-nine percent of herds pregnancy tested with veterinarians doing 60% of the work and non-veterinarian scanners the other 40%.

Maiden heifers averaged 12.0% non-pregnant at pregnancy testing; 16% of the herds had maiden non-pregnant rates greater than 20% and nearly 40% of the herds had non-pregnant rates less than 10% (Figure 15). Maiden heifers mated to first calve at three had a slightly lower non-pregnant rate (11.5%) than those mated to first calve at two (12.2%) but the difference was not significant (P=.32). There was no significant difference in the maiden pregnancy rate of heifers mated earlier, at the same time as or later than older cows.

Figure 15



Pregnancy rates at re-breeding of first calvers averaged 92% (Figure 16) with no significant difference (P=.87) between heifers that had first calved at 2 or 3 years of age (Figure 17). However herds mating **yearling** maiden heifers as little as 7 days earlier than mixed age cows had a 4.7% lower non-pregnant rate at re-breeding than those mating their maidens at the same time as the older cattle (P<.0003) (Table 3).

Many herd managers could not provide separate data for mixed age cows and rising second calvers as the two age groups were grazed together after calving. For herds with separate data there was no significant difference (P=.07) in the empty rate between rising second calvers (7.8%) and the m.a. cows (6.9%) (Table 4). When the herds with combined data were included the overall empty rate for non-maidens was 7.6%.

Figure 16

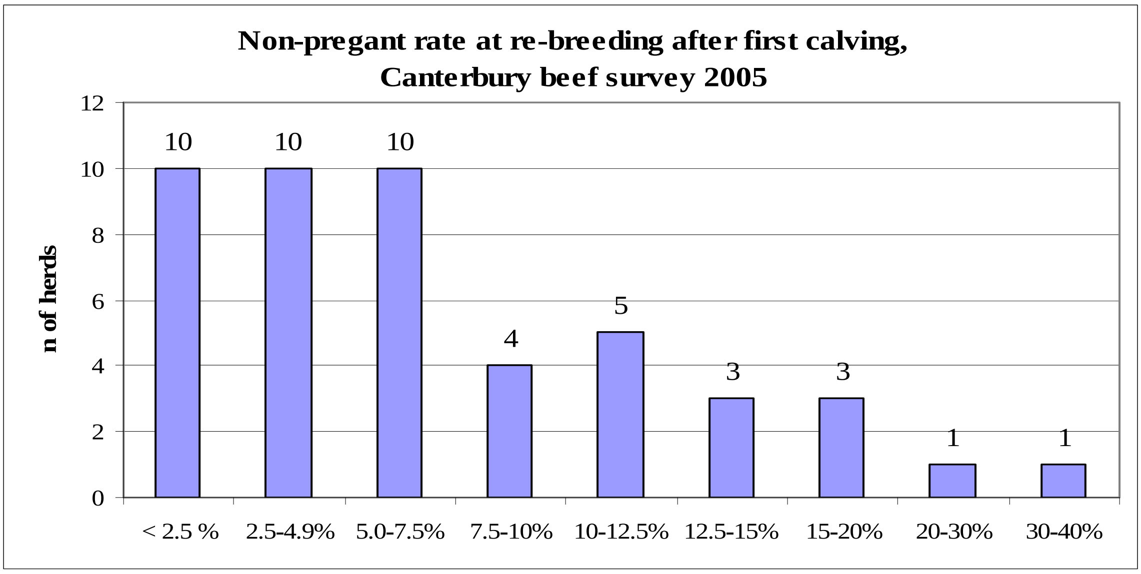


Figure 17

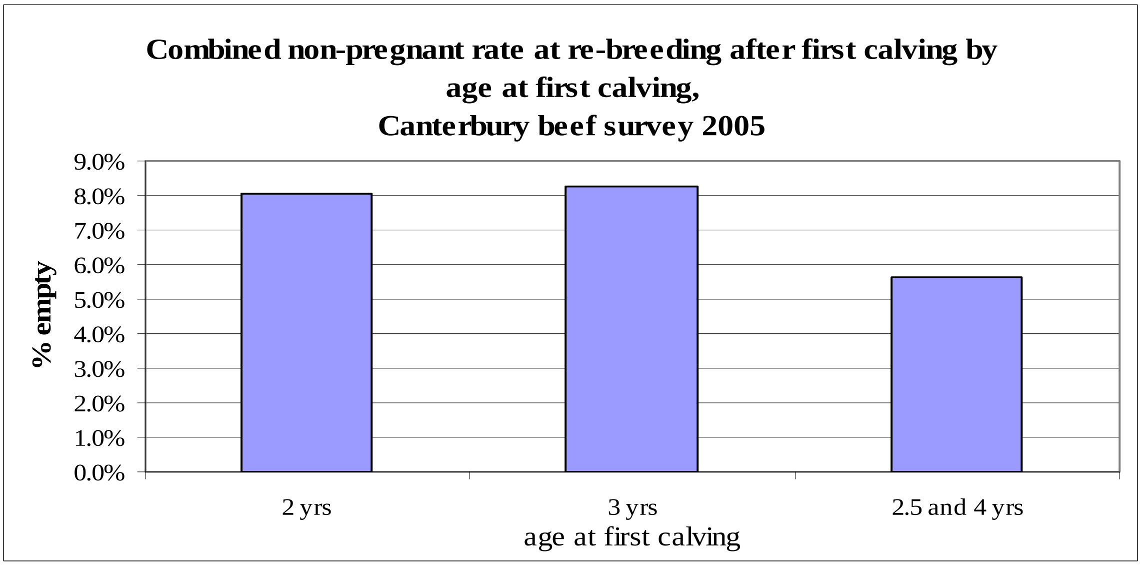


Table 3

Non-pregnant rate in rising 2nd calving heifers by maiden mating date

maiden mating date*	pregnant	non-pregnant	% non-pregnant	total
earlier	1,052	71	6.3%[a]	1,123
same	629	78	11%[a]	707

* relative to that of m.a. cows in the same herd

[a] P= 0.0003

Table 4

Non-pregnant rate by parity				
pairity	**pregnant**	**empty**	**empty %**	**total**
maiden*	4,256	578	12%[a,b]	4,834
R 2nd*	2,596	221	7.8%[a,c]	2,817
m.a.	10,632	785	6.9%[b,c]	11,417

* two and three year old combined

[a] P<.01 [b] P<.01 [c] P=.07

Herds that mated m.a. and R 2nd calvers for longer than 63 days (one third of herds) averaged 2.2% higher pregnancy rates than those mated for shorter periods (P<.001)(Table 5).

Table 5

Non-pregnant rate of mixed age cows by length of mating				
length mating	**n pregnant**	**n non-pregnant**	**% non-pregnant**	**total**
<63 days[a]	13,096	1,112	7.8%[a]	14,208
>63 days[a]	5,391	318	5.6%[a]	5,709
total	**18,487**	**1,430**	**7.2%**	**19,917**

[a] P<.001

Cows calved on downs or flats had slightly higher (but not significantly so) empty rates than those calved on the hills.

Calving

The incidence of dystocia requiring assistance in first calving heifers was 5.2% (Table 6). First calving two year olds required assistance 6.3% of the time but only 1.8% of first calving three year olds did (P<.001).

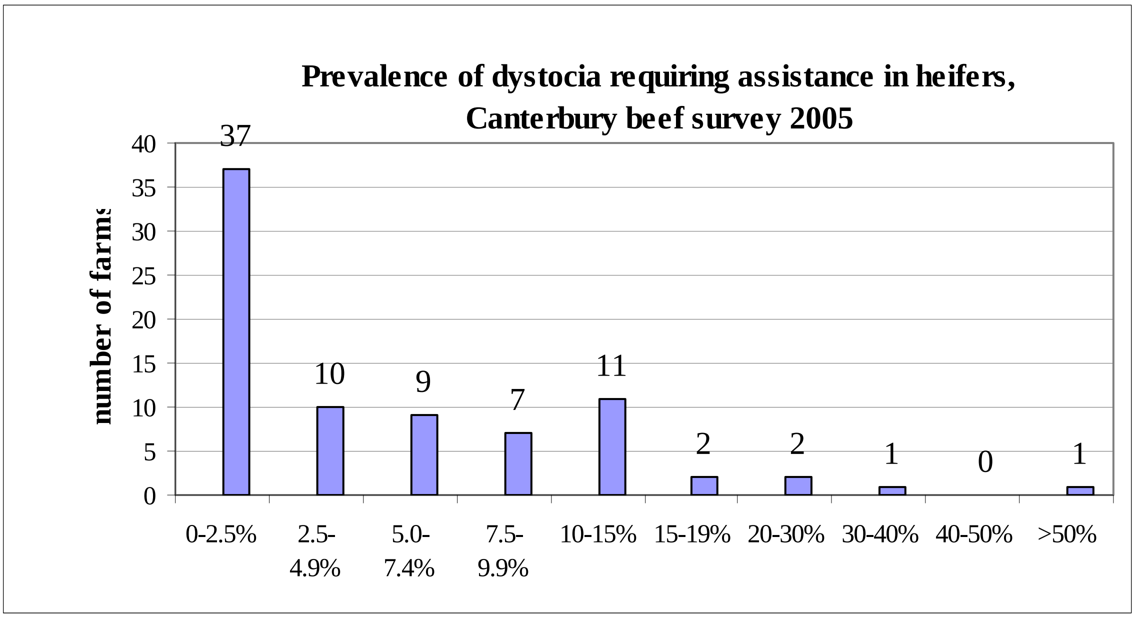
Table 6

prevalence of dystocia in maiden heifers			
age at 1st calving	**n heifers**	**n dystocia**	**% dystocia**
2	3,037	192[a]	6.3%
3	955	17[a]	1.8%
combined	**3,992**	**0**	**5.2%**

[a] P<.001

Nearly half of the properties reported a prevalence of less than 2.5% (Figure 18).

Figure 18



The death rate of heifers said to be due to dystocia was 1.2% for all first calvers, 1.4% in first-calving two year olds, and only 0.5% in first calving three year olds (P=.05). Nearly half of the herds with separate heifer data lost less than 1% of their heifers due to dystocia.

Topography at calving had a significant (P=.002) effect on heifer dystocia death rates. Those calving on hill country had the highest dystocia death rate (2.9%) followed by those calving on the flats (1.2%) and then by those calving on downs (0.3%) (Table 7).

Deaths said to be due to dystocia in m.a. cows averaged 0.3%; the incidence was nearly identical for those calved on the hills or on easier country. The question asked was "How many m.a. cows are you aware of that either experienced or died from dystocia?" The true incidence may therefore be somewhat higher.

Table 7

Heifer dystocia deaths by calving topography

topography	survived	died	death %	total
hill[a,b]	372	11	2.9%[a,b]	383
downs[a,c]	908	3	0.3%[a,c]	911
flats[b,c]	2,875	36	1.2%[b,c]	2,911
total	4,155	50	1.2%	4,205

[a] P<.001 [b] P=.01 [c] P=.02

Weaning percentage

Over all age groups and herds 88.0% of the pregnant females wintered weaned a calf. There was considerable variation in the pregnant cow weaning percentage of different herds

(Figure 19). Including the cows not pregnancy tested only 88.0% of cows wintered weaned a calf (Table 8).

Figure 19

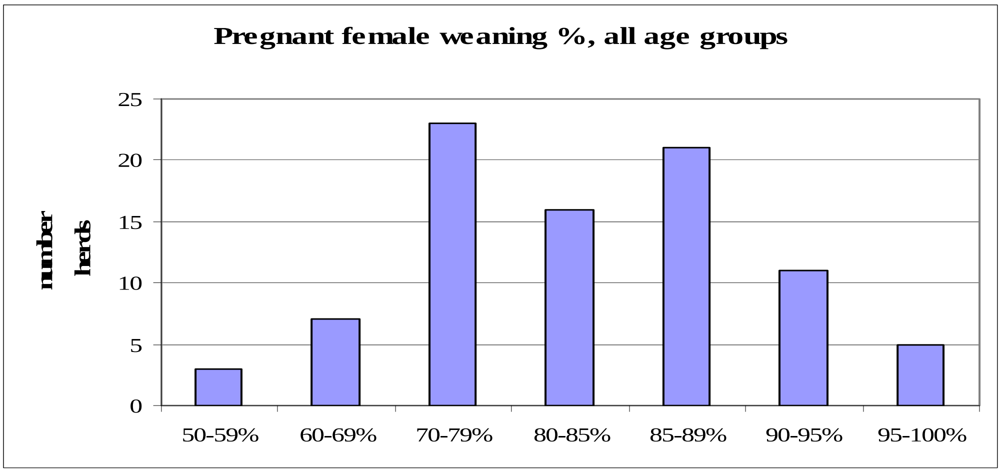


Table 8

Pregnant female weaning %

cow category	**n pregnant wintered**	**n calves weaned**	**pregnant wean %**
m.a.	8,717	7,793	89.4%
heifers	1,519	1,290	84.9%
combined^{+}	9,681	8,434	87.1%
total	19,917	17,517	87.9%
not preg tested	1,327	1,168	88.0%
combined total	**21,244**	**18,685**	**88.0%**

$^{+}$ age breakdown not available

For herds submitting data that could be separated by cow age only 89.4% of the pregnant m.a. cows weaned a calf (Table 9). Topography at calving had a highly significant effect on the pregnant cow weaning percentage; m.a. cows calved on flats weaned 91.2% while those calved on hills weaned only 88.1%.

Table 9

Weaning % of pregnant m.a. cows which survived the winter by calving topography

country	**calves weaned**	**wean %**	**wet dries**	**total**
hill[a,b]	3,916	88.1%	528	4,444
downs[a]	1,745	90.2%	190	1,935
flat[b]	2,132	91.2%	206	2,338
total	**7,793**	**89.4%**	**924**	**8,717**

[a] P=.02 [b] P=.0001

For herds with separate calving data only 84.9% of pregnant heifers wintered weaned a calf. Pregnant heifers calved on downs weaned 4.1% more calves than those calved on flats; however, the difference was not significant (P=0.1) (Table 10).

Table 10

pregnant heifer weaning % by topography at calving

topography	wet dry	weaned	wn %	total
downs	28[e]	213	88.4%	241
flats	201[e]	1,077	84.3%	1,278
total	**0**	**1,290**	**84.9%**	**1,519**

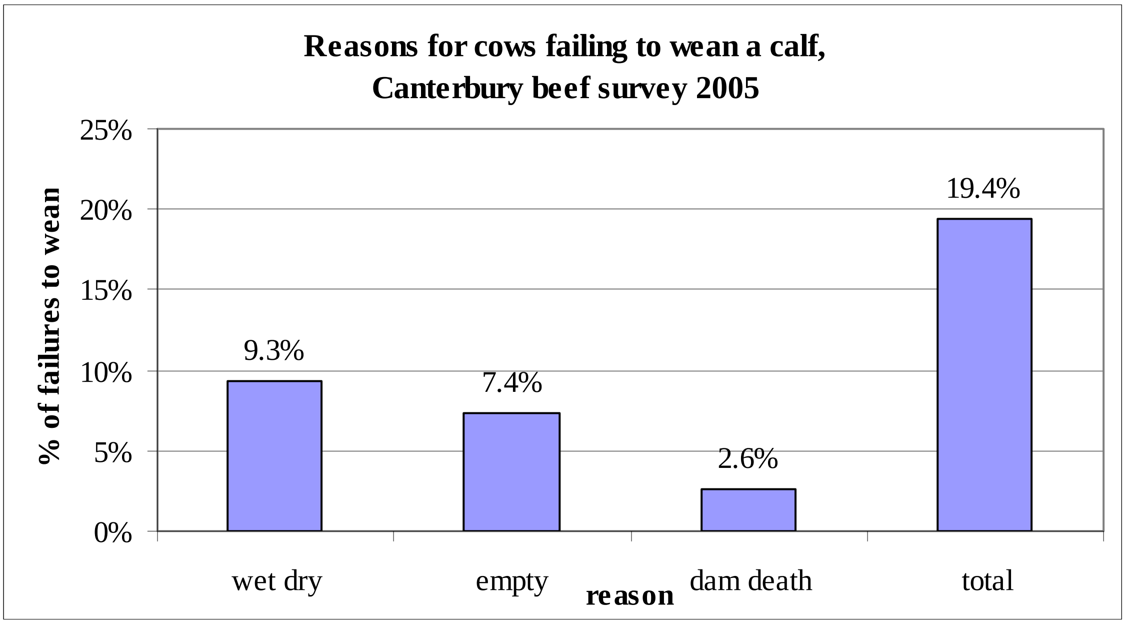
[e] P= .10

Many commentators including the Economic Service of Meat and Wool NZ calculate a "true" weaning percentage based on numbers of calves weaned per 100 cows mated after correction for pregnant females culled prior to calving.

For all properties and all age groups of cows combined, the "true" weaning percentage was 80.9%. For those herds with accurate data for each age group the true weaning percentage for first calvers was 75.9% and for m.a. cows 84.8%.

When all herds were considered, including the seven that did not pregnancy test, the failure of a pregnant cow to wean a calf (a wet dry) was the most frequent cause of reproductive inefficiency followed by pregnancy-tested-empty and then by cow death (Figure 20).

Figure 20



Calf weaning weights

Since very few of the respondents weighed all of their calves at weaning a meaningful comparison of calf weaning weights was not possible.

Cow exit

Of the total number (17,506) of mixed age pregnant beef cows at the start of the winter, 18.1% had exited the herds within 12 months. In descending order of importance the reasons for m.a. cow exit were pregnancy tested empty (6.7%), involuntary culling (4.6%), sold wet dry (2.9%) and death (2.4%) (Figure 21). Age and condition were the most common reasons for involuntary culling (Table 11). The death rate varied considerably between herds (Figure 22).

Figure 21

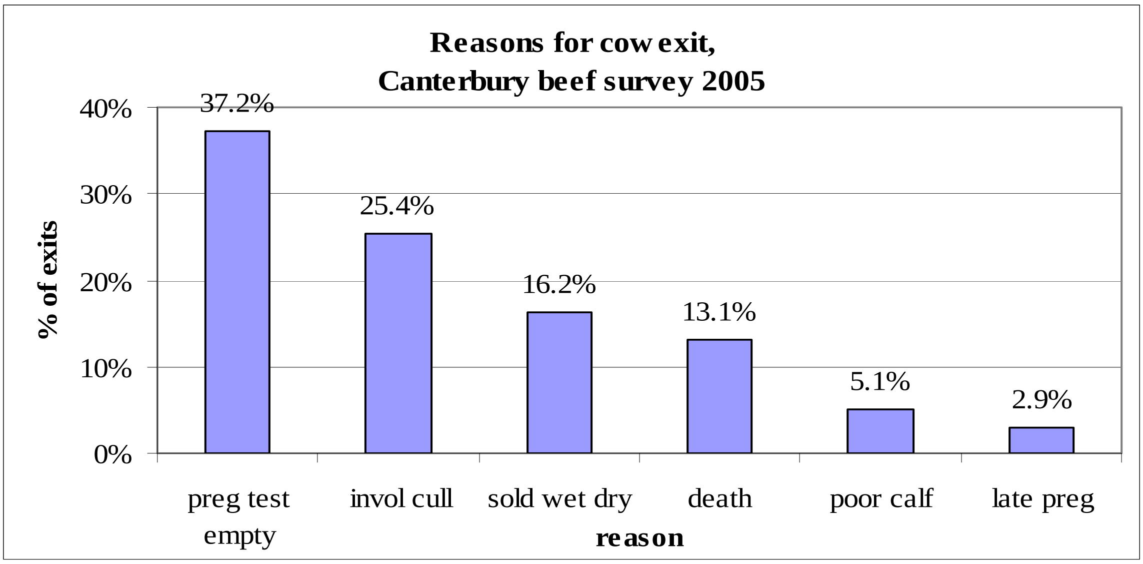
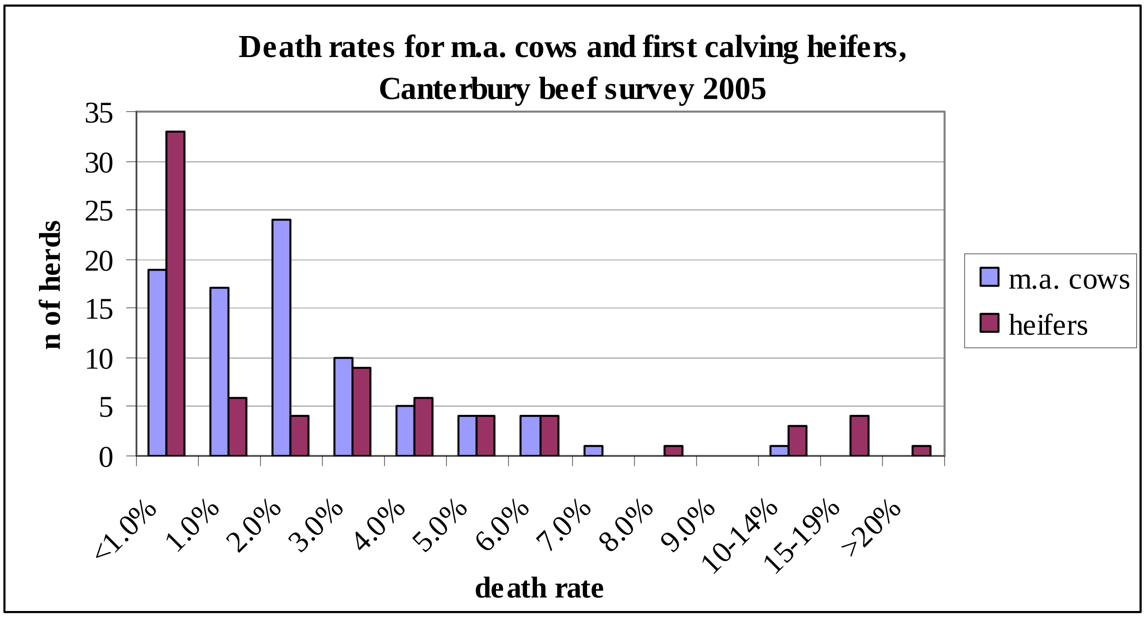


Table 11

reasons for involuntary culling of m.a. cows	
reason	**% of involuntary culls**
age	23.6%
condition	21.0%
udder	17.6%
lame	15.4%
teeth	11.2%
temper	7.7%
cancer eye	3.5%

Figure 22

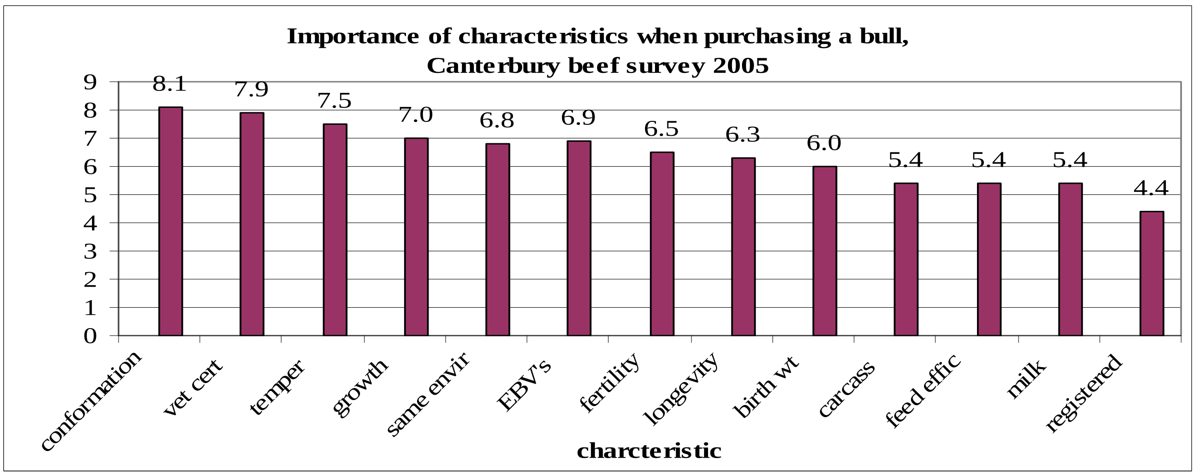


Cows culled for poor calf production constituted 5% of the cow exits, but that represented less than 1% of the total beef herd. Most of the production culling occurred in a small number of performance recording herds. Thirteen of the 26 production-culling herds culled less than three cows each out of the average herd size of over two hundred cows.

Bulls

When respondents were asked to compare the importance of different characteristics when purchasing bulls, conformation was listed as the most important of the thirteen characteristics offered with “9” being very important and “1’ being very unimportant (Figure 23). A vet certificate confirming disease free status and healthy genitalia was the second most important criteria in bull selection. Whether or not a bull was registered with a breed society was considered to be the least important of any of the characteristics offered.

Figure 23



Of the total number of bulls present at the beginning of the year 29.8% had exited by year end. Twenty three of the 91 herds with good data lost more than half of their bulls within the twelve month period. Lameness was the biggest cause of bull loss, representing over one third of all bull exits (Figure 24). Nineteen of the ninety one herds with good bull data had performed serving capacity tests on their bulls during the year.

The great majority of bulls were purchased as R 2yr bulls so the productive life of breeding bulls averaged 1.5 seasons (Figure 25).

Figure 24

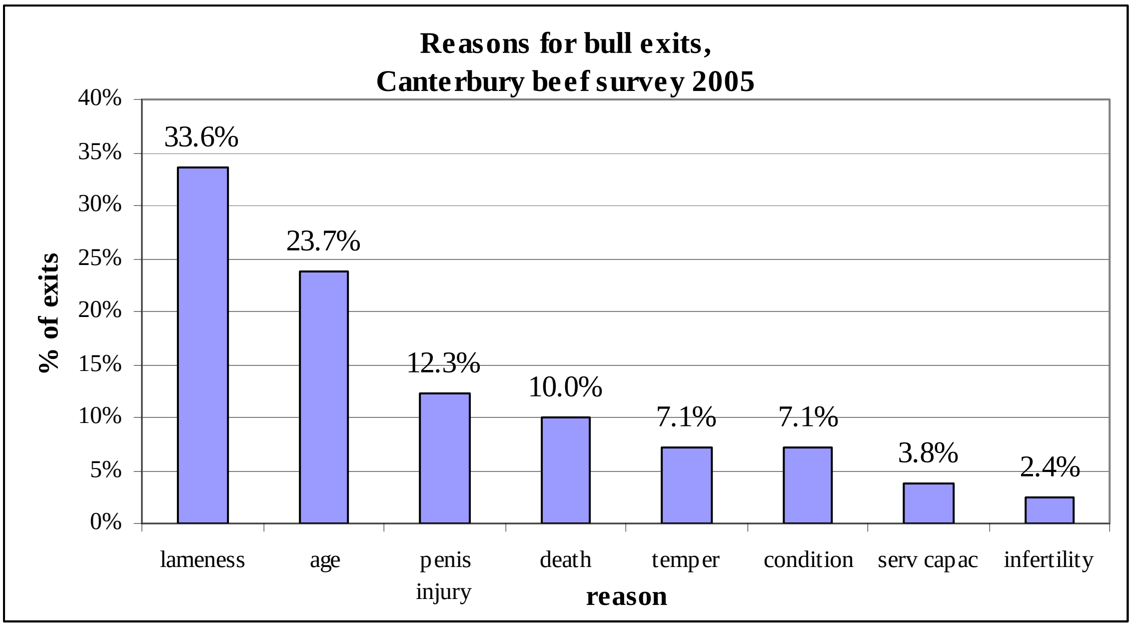
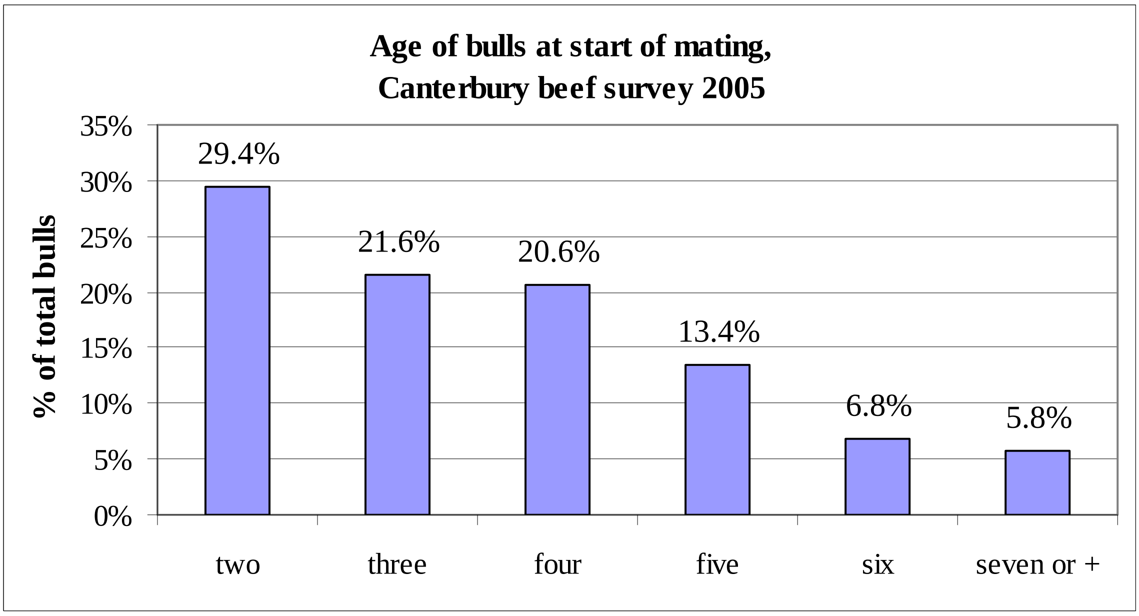


Figure 25



Animal Health

Not quite 30% of the beef herds tested their cattle for trace element levels during the year (Figure 26). Supplementation of trace elements to m.a. cows was common (Figure 27) with 55% of m.a. herds receiving selenium, 24% magnesium and 24% copper supplementation.

Figure 26

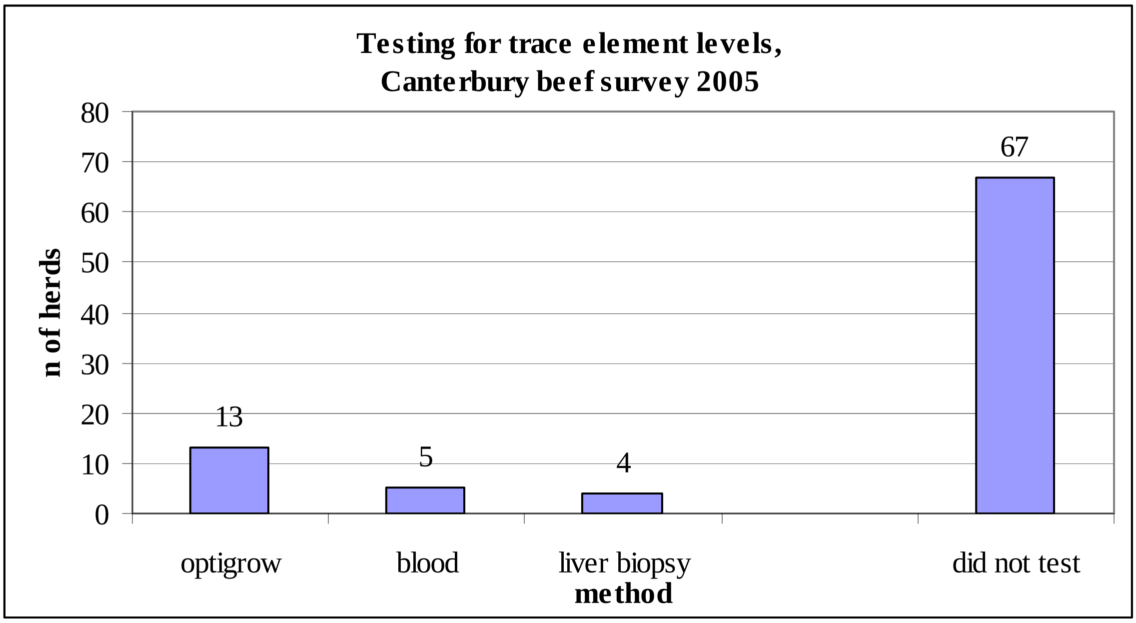
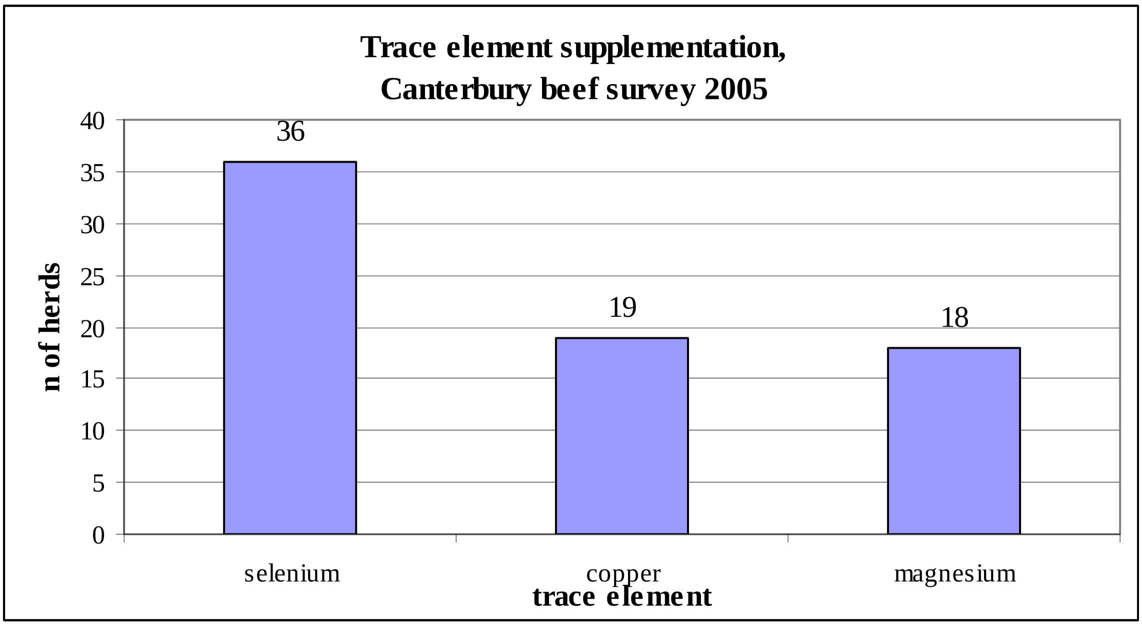


Figure 27



Vaccination of cattle was uncommon. Clostridial vaccination was the most common, followed by leptospirosis, rota virus and BVD (Figure 28). Vaccination of heifer calves was slightly more common (Figure 29).

Figure 28

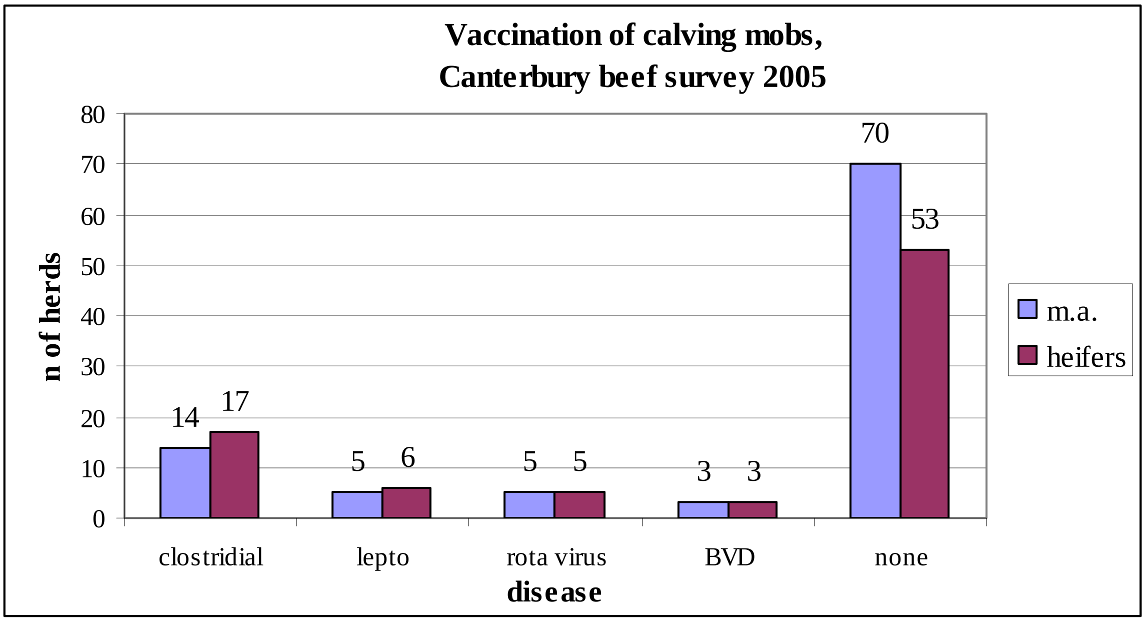
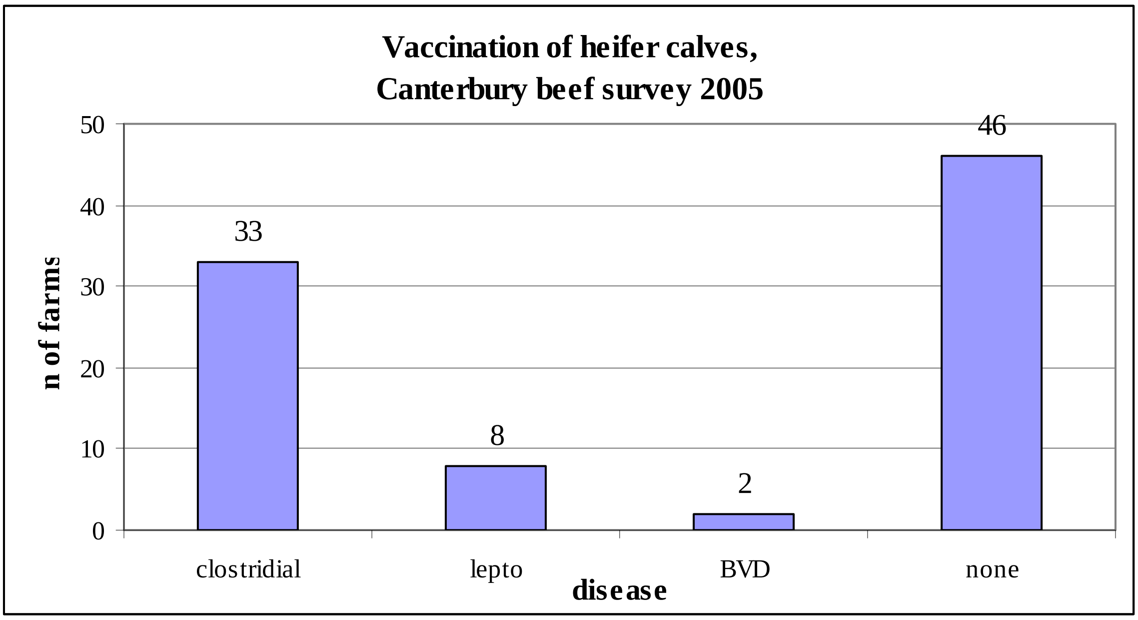


Figure 29



None of the herds had tested for anthelmintic resistance during the year.

Discussion

Compliance with requests to conduct the survey was very good; only four potential respondents refused to take part. For the most part owners and herd managers made considerable effort to supply factual and accurate information often consulting farm diaries and annual accounts.

The quantity and quality of the data available from most herds reflected the low priority most beef herds have in the pastoral farming operations surveyed. In many cases data was available for the whole herd but could not be partitioned into different age sub-groups of cows. For the most part the information supplied seemed to make sense. Only two farmers claimed to have weaned more calves than they had cows.

Very few herd managers could supply weaning weights of their entire calf crop and only one herd regularly weighed cows and compared calf production with cow live-weight.

Attempts to classify herds into predetermined types were largely unsuccessful. Of the herds practicing crossbreeding most seemed to have their own unique system with few fitting any textbook description. Despite the frequent advisory and publicity campaigns promoting composite cattle, there was only one composite herd and they have subsequently converted their property to a large dairy farm. It is likely that the presence of New Zealand's only sizeable feed lot in Mid Canterbury and its preference for Angus beef have had a marked influence on cattle breeds at least in Canterbury. Many herd managers described their current herd structure and then commented they would be "going all black."

Equally hard to classify were the four herds calving first at two and a half years and then again at four years of age: comparison with more traditional heifer programs was not attempted.

Participating herds were largely from Banks Peninsula, inland North Canterbury, the Mid Canterbury foothills or the high country. Four of the herds annually sell bulls; these were for the most part on easier down-land country but an effort was made to minimize the number of traditional "stud" herds. There was still considerable variation in property type as can be seen from Figure 10 which demonstrates that properties tended to either be strictly breeding (finished few surplus stock) or alternatively breeder/finisher (finished almost all surplus stock).

Replacement heifers

Choice of replacement heifers was nearly always based on conformation with what was thought to be "superior" type and size (Figure 12). Regrettably type has been shown to be have little relationship with future productivity (Boostrom *et al.*, 1986; Frey *et al.*, 1972; Knapp & Black, 1941; Roubicek & Ray, 1971).

The validity of size as a selection criteria is more controversial. Possibly farmers choose replacements on the basis of larger size in the expectation that they will be more likely to have achieved puberty by the start of mating and to avoid dystocia. Unfortunately Morris & Wilson, (1997) have demonstrated that extended selection for yearling weight had no effect on age or weight at puberty nor on heifer pregnancy rates. However selection for earlier sexual maturity resulted in a reduction of age of puberty by 81 days and increased pregnancy rates. It was their conclusion that size and fertility were separate traits.

Given an underlying level of genetic fertility, an improved environment (better feeding) will result in a more favourable phenotype (greater pregnancy rates). Unfortunately there is little emphasis on selection for genetic fertility in the beef industry. Much of the advice the industry receives recommends growing heifers to achieve often-specified target mating weights (New Zealand Beef Council, 1991; Vermunt, 1994).

Hanley & Mossman (1977) originally recommended that individual farms determine the critical minimum weight of their herd which they defined as the average weight of the mob which would achieve a pregnancy rate of 85% over a 45 days mating period. However they also suggested that "heifer matings at anything less than a minimum weight of 272 kg (Angus) and 295 (Hereford) at 12, 15 or 24 months under current (1977) nutrition and management (Wairoa hill country) are inviting dystocia and second or third calving culling." Although less than 5% of the cattle in the Hanley and Mossman survey were mated at 15 months of age they cite unpublished data to support their recommendation.

The idea of an absolute individual minimum mating weight for all situations is illogical. Differences in herd and individual difference of genetic fertility, different condition score at calving, different feeding levels post calving, calving date within the season, dystocia levels associated with the first mating bull type and grazing together with- or separate from- the m.a. cows are all factors that affect repeat breeding success and could dramatically alter the future success of heifers first mated at any weight.

Carter & Cox (1973) and workers in Colorado (J. Whittier, personal communication, 2007) demonstrated that satisfactory pregnancy rates over a number of years can be achieved over quite a wide range of yearling mating weights, many of which are considerably below those currently cited as "minimum" breeding weights.

Australian workers (Johnsson & Morant, 1984; Johnsson & Obst, 1984) in fact suggested that heifers grown more slowly to weaning actually produced more milk and weaned larger calves than did larger heifers more likely to catch the selector's eye at weaning or at 15 months of age.. Selection of replacements on the basis of their size other than within very broad limits is hard to justify.

The difference between cattle phenotypically large and those genetically large is important to this discussion. Heifers of any given level of genetic fertility will achieve greater pregnancy rates with environmentally-enhanced liveweight as Hanley & Mossman (1977) have suggested. Selection of replacement heifers on size, however, includes those genetically large as well as those environmentally large. Genetically larger cattle have been shown to be later maturing and less fertile as heifers (Golden *et al.*, 2000; Holmes *et al.*, 1999). Genetically larger yearlings are also likely to become genetically larger cows with higher maintenance energy requirements (Evans, 2000, 2001; Solis *et al.*, 1988) that result in increased feed demand and/or reduced cow numbers.

The Meat & Wool NZ Economic Service reports that in the 2007-08 year just over 30% of the approximately 500,000 beef R 2yr heifers were mated (pers. comm). This Canterbury survey was conducted in an area that probably has a harsher environment than that of many other beef areas. If 60% of beef herds in Canterbury first calve at two years of age then one suspects at least that many do in Hawks Bay, Gisborne, Taihape and Northland. Possibly the MWNZES statistics are underestimating the national figure.

For the herds with the capability to finish surplus heifers it is surprising that fewer took advantage of the benefits of a once-bred heifer system. American work from the 1970's (Frey et al., 1972) established that a heifer's first calf offered by far the best prediction of future productivity, far better than any measure of height or weight. Massey work in the 1990's (Keeling et al., 1991) demonstrated the efficiency of the once-bred heifer systems and suggests many of these breeding/finishing properties could profitably produce a calf from their surplus heifers prior to killing them.

<u>Mating</u>

Many commentators emphasize the importance of a short mating period and a resulting concentrated calving to produce uniform lines of calves. In this surveyed group, however, herds that mated for longer than 63 days (one-third of herds) had significantly lower non-pregnant rates than those mated for shorter periods (Table 20).

Several workers have stated that in terms of herd profitability fertility is by far the most important group of traits, 5-20 times as important as carcass characteristics and 2-10 times as important as growth traits (Trenkle & Willham, 1977; Willham, 1975). The trade-off of a concentrated calving period appears to be a lower pregnancy rate, something the industry can ill afford. No doubt even lines of calves sell for more per head than uneven lines but stock firms usually draft off the tail end calves and sell them separately anyway. One suspects that an even line of calves plus a few later-born calves is worth more than a line of even calves without the tail-enders. Since the repeatability of calving date is extremely low many of the late calving cows may calve earlier the next year (Bailey *et al.*, 1985; Mossman & Hanly, 1977)

Mating yearling heifers has at times been a contentious practice in New Zealand. Wairoa workers in the 1970's reported less than 5% of the heifers in their district first calved at two years of age (Hanley & Mossman, 1977).

Morris *et al* .(1993b) demonstrated favourable correlations between age of puberty, heifer pregnancy and lifetime pregnancy rates. Selection for age of puberty and heifer pregnancy was suggested as a useful selection strategy to improve lifetime fertility (Morris & Wilson, 1997; Morris *et al.*, 1993a). Environmental enhancement of the phenotype (heifer pregnancy) by growing heifers to heavier mating weights and extended heifer mating periods minimize the selection opportunity. Nearly 40% of the herds in this survey reported heifer pregnancy rates high enough to suspect that little selection for true genetic fertility was possible. With the low fertility of the national beef herd, perhaps more emphasis should be placed on a true test of heifer fertility.

Pregnancy rates

Pregnancy rates in heifers (88%) were quite reasonable with no reduction in success when yearling heifers were mated. Historically earlier mating of yearlings was thought to result in lower maiden heifer pregnancy rates presumably because of the close proximity of the time of puberty in heifers to the start of heifer mating, i.e. pre-pubertal heifers are unable to become pregnant. The in-calf rates of earlier-mated maiden heifers in this survey, however, were not significantly different than those of heifers mated later.

Yearling heifers mated earlier than the mixed age cows had significantly better (+4.4%) re-breeding success than those mated at the same time. The extra time between calving and re-breeding provided by earlier mating of maiden heifers appeared to be successful at overcoming the post parturient anoestrus previously common in young heifers (Fielden & McFarlane, 1959). Only 42% of the herds mated heifers earlier than older cows

Not all mobs of heifers may have had the same treatment. It is quite likely that heifers not due to calve until three years of age were less preferentially treated than those expected to calve at two, both as young cattle, at calving and during their first lactation. If this was the case, the more favourable environment experienced by the two year olds may have masked any differences between the two different ages at first calving.

Calving

Overall the dystocia rate was quite low. Deaths due to dystocia were slightly higher in two year olds (1.4%) than in three year olds (0.5%) but the extra 1% loss of heifers would appear to be more than compensated for by the substantial increase in calf production. Calving heifers unsupervised on hill country did result in significantly higher death rates but the significantly lower death rate in heifers calved on downs compared to flat paddocks is interesting. Possibly a combination of exercise and supervision is one of the answers to heifer dystocia.

Selection of different bulls for heifer mating may also partially account for the lower than expected dystocia rate in maiden heifers. Two thirds of the herd managers used different types of bulls for maidens than for mixed age cows. Heifer bulls were often smaller animals, of a different breed and often with lower EBV's for birth weight.

The NZ Angus Association has recently introduced a Self-Replacing Herd index that attempts to predict differences in herd profit likely to result from the use of different bulls. The two most important traits in that index are Calving Ease Direct and Calving Ease Maternal. The low level of dystocia (3 per 1000 m.a. cows) found in this survey suggests calving ease may be receiving more emphasis than is warranted in the NZAA index.

Weaning

A weaning percentage of 87.9% from pregnant females wintered is not indicative of an efficient industry. Since few of the surveyed farmers reported any appreciable numbers of abortions, poor reproductive inefficiency is probably associated with neonatal loss. Calving m.a. cows unsupervised on relatively inaccessible hill country is the common practice. The alternative of calving on easier country and then shifting cows to saved hill pasture has been advocated for many years (Mossman & Hanly, 1977) and in this study herds following that practice achieved a 3% higher pregnant female weaning percentage.

The "true" weaning percentage favoured by many advisors and academics was not considered a useful measure by most of the surveyed farmers possibly since the cost of replacing an empty cow with a pregnant one is negligible. The pregnant cow weaning percentage is apparently a more accurate indication of the perceived cost of infertility in beef herds.

Calf weaning weights

The failure of most herds to weigh all of their calves at weaning was surprising. Some had truck weights for those sold at calf fairs but the selection of calves weighed varied greatly: all steers, only the biggest steers, the biggest and smallest steers and any combination of the above with a variety of selections of heifers.

Cow Exit

Simply comparing the numerical frequency of the possible reasons why mated cows failed to wean a calf does not reflect the economic costs of the different causes of loss. A cow diagnosed as empty is usually replaced by a pregnant cow or a heifer for a relative small premium over the works price of the non-pregnant cow; hence the economic cost of failure to become pregnant is relatively minor. A pregnant cow wintered but not weaning a calf (a wet dry), however, is far more costly; the opportunity cost of wintering a pregnant cow that will wean a calf in her place is considerable. Wet dry cows are not only the most frequent cause of failure to wean but would also appear to be the most important economically.

When asked, many respondents stated that they killed all of their wet dries but the number killed rarely equalled the difference between the number of pregnant cows wintered minus reported deaths and the number of calves weaned.

The proportion of cow exits that were said in this survey to be due to poor calf production is probably not typical of true commercial herds. There were a small number of bull-selling herds included in the survey group and they were largely the herds that did the performance culling.

Bulls

Respondents were asked to compare the importance of different characteristics when purchasing bulls; conformation was the most important (Table 30). As long as conformation relates to jaw, feet and legs, attention to conformation is probably justified. Other aspects of conformation, e.g. masculine heads, good top lines, etc., are probably of lesser, if not dubious, economic significance. Several American studies (Boostrom *et al.*, 1986; Frey *et al.*, 1972; Knapp & Black, 1941) have in fact shown a negative relationship between "superior" conformation and productivity.

A veterinary certificate confirming disease free status and healthy genitalia was the second most important criteria in bull selection but to my knowledge no veterinary practice in Canterbury provides a formal certificate of that nature.

Whether or not a bull was registered with a breed society was considered to be the least important of any of the characteristics listed. The question put to each respondent was "If the same information (EBV's and performance data) was available for a bull but his grandfather had not been in the stud book, how important would the fact that he was not registered be to your decision to purchase?" "Not very" was the answer. One can argue that the lift in sheep production that has occurred over the last 25 years has coincided with the establishment of Romney Development Groups and other large scale ram-producing organizations that have not been bound by the rules of any breed society. According to the results of this survey there is at least the opportunity for similar scheme to develop in the beef industry.

Bulls are expensive with the average sale price of a two year old registered Angus bull of over $4,000 (Thomas, 2005). Their average breeding life, according to this study, is 1.5 years with considerable wastage. With the cost in mind and taking into consideration the reservations about bull EBV's outlined in the literature review it is possibly time for some of the larger operations to consider breeding their own bulls. If a practical, accurate and inexpensive performance recording system could be developed for extensively managed commercial herds the large scale screening shown to be successful by the Romney Development Groups and LIC will become a possibility in the beef industry.

The low frequency of serving capacity testing of bulls involved in this study (nineteen of the ninety one herds) is another manifestation of the low input nature of beef herds. Herds serving capacity testing in fact had a higher empty rate in m.a. cows than did herds not testing ($P<.01$) but they may have been bull testing because of their poor calving performance.

Animal health

The failure of most herds to test for trace element deficiencies may not be as significant as it seems. If herds have tested several years in succession and had the same result each year, there is probably little point in annual testing.

Prophylactic vaccination programs were the exception in surveyed beef herds. Vaccination against leptospirosis, one of the diseases against which there is an effective vaccine, was only practiced by 7% of the herds which is surprising since the two herds with the lowest weaning rate in this study had in fact suffered leptospirosis abortion storms during the winter. With the disease present in the district it is difficult to understand the low level of vaccination, especially since the vaccine is quite inexpensive, e.g. less than $1.00 a dose.

None of the herds had tested for anthelmintic resistance despite evidence that over 90% of beef properties in a recent North Island study demonstrated at the minimum low levels of resistance to at least one anthelmintic.

Evaluation of alternative measures of cow productivity

Materials and Methods

Calving records were obtained from five Angus herds with four from Canterbury and one from the Waikato.

Participating herds

Whatawhata herd (Appendices 1, 2, and 3) Data was obtained from an Angus cow herd involved in a weight selection trial at Whatawhata Hill Country Research Station in the northwest of the North Island. A total of 202 cow/calf records were available from the 1995, 1996 and 1997 calving seasons. Whatawhata pastures were mostly improved ryegrass/clover on reasonably steep ash/clay soils. Most years pasture growth was reliably maintained throughout the summer period. Calves were younger and lighter at weaning in these years than calves from most commercial beef herds.

Blackhills herd (Appendices 4 and 5) Data from 352 Angus cow/calf pairs of the author's own herd calving during 2001 and 2002 was also available. The home farm, Blackhills, consisted of 700 hectares of stony terraced flats at just under 400 m asl 70 km west of Christchurch. Pastures were improved and regularly top dressed. Cows and calves were shifted at one or two day intervals and feeding levels were very good. After marking cows and calves were moved to a 250 hectare high country tussock runoff 20 km away which had not been grazed the previous late winter, spring and early summer; pasture there was abundant but of poor quality.

Toshi herd (Appendix 6) Data was obtained from 404 Angus cows calving in the spring of 2004 on Toshi Farm, in North Canterbury. Toshi consists of 1000 hectares of flat un-irrigated land in the Hanmer Springs basin averaging over 300 m asl. Although cows were wintered on brassica crops and calved in very good condition, by mid-summer feed quality and quantity had both declined markedly due to summer drought. At the time of marking in 2004 there was very little pasture available, but after marking silage feeding began and continued until weaning.

Te Mania herd (Appendix 7). Data was obtained from 348 Angus cows farmed by the Te Mania Angus stud from coastal Kaikoura in North Canterbury. Te Mania is one of the leading Angus studs in the South Island and is very lightly stocked at just over 6 stock units per hectare on quite easy downs and flat country. Most of Te Mania's income is derived from the sale of breeding bulls and consequentially the cattle are very well fed throughout the year.

Altogether valid data from 1,306 cow calf pairs spread over four properties and six different years was available. The variety of environments and management practices were represented in the seven herd-years and resulted in quite varied performance of the herds (Table 13). Each herd's data included birth date and weight, marking date and weight, weaning date and weight, sex of calf (SOC), age of dam (AOD) and cow/calf pair identification (Appendices 1-7). Calving distributions also varied between herds (Appendix 8). The numbers of calves in each sub-grouping of age of dam and sex of calf are listed in Table 12.

Table 12

Numbers of calves from seven herd-years by sub-groups

	sex			AOD			
herd-year	**bull**	**heifer**	**steer**	**2**	**3**	**4**	**>5**
WhWh 95	34	24	0	16	12	9	21
WhWh 96	29	38	0	7	19	9	32
WhWh 97	37	40	0	8	14	25	30
BH 01	69	63	0	1	27	39	65
BH 02	88	115	17	69	35	17	99
Toshi 04	0	188	216	0	107	241	56
TM 04	166	182	0	97	68	19	164

Calving, marking and weaning data from all seven herds (Table 13) showed considerable variation. Mean age at marking ranged from 65 days to 188 days, mean marking weight varied from 80 to 225 kgs, mean age at weaning ranged from 160 to 250 days and mean weaning weight ranged from 134 to 243 kgs.

The percentage of the herd calving in the first 21 days (excluding outliers) varied from 18% to 65% although some of that variation was due to data collection and mating problems. Toshi did not record birth weight or dam number for the first 39 calves born; excluding those calves from the data producing an unnaturally high % calving in the apparent first 21 days. Te Mania's calving on the other hand was artificially protracted (only 8% in the first 21 days and 21% in the fourth 21 day period) due to a very unsuccessful embryo transfer program in the 2003 mating. Accordingly the number of days between the anticipated start of calving and the median calving date varied considerably.

Table 13

Summary of combined calving data

unadjusted		WhWh 95	WhWh 96	WhWh 97	BH 01	BH 02	TM 04	Toshi 04
birth weight (kgs)	mean	27.2	27.7	28.6	30.9	30.7	38.0	38.3
	Sd	3.8	3.3	4.0	3.6	4.1	5.7	5.2
median calving date		12/09/95	8/09/96	10/09/97	24/08/01	10/09/02	6/09/04	29/09/04
ADG b/mk (kgs/d)	mean	0.77	0.84	0.78	1.03	1.05	1.07	1.06
	Sd	0.19	0.16	0.19	0.16	0.18	0.20	0.17
marking age	mean	64.8	64.7	66.1	188.1	111.5	72.7	138.3
	Sd	12.1	12.6	9.3	18.0	16.7	18.6	10.0
marking weight	mean	75.9	82.8	80.0	224.7	148.1	115.9	184.4
	Sd	13.6	17.6	15.6	34.9	28.2	25.7	27.7
ADG mk/wn (kgs/d)	mear	0.53	0.60	0.65	0.27	0.56	0.96	0.33
	Sd	0.11	0.11	0.11	0.37	0.18	0.16	0.19
weaning age (days)	mean	179.0	177.7	160.1	256.0	213.5	188.8	194.3
	Sd	12.1	12.6	9.3	17.4	16.8	18.7	10.0
weaning weight (kgs)	mea	136.4	151.0	141.2	242.3	205.4	227.3	202.7
	Sd	23.4	26.5	23.8	37.2	36.2	37.6	31.3
mk-wn/b-mk ADG %		68.8%	71.4%	83.3%	26.2%	53.3%	89.7%	38.8%
% calving 1st 21 days		54%	60%	65%	55%	43%	8%	73%
interval to median CD (day:		16	18	17	19	25	40	14
adj 200d wt	mean	171.4	184.2	189.2	212.2	219.9	261.4	207.2
	Sd	20.4	22.0	23.4	28.3	25.4	26.8	31.2

Another difference between herd-years was the growth pattern of calves. In some of the herd-years summer drought meant feed levels and calf growth rates after marking were considerably lower than those before marking. As a means of quantifying this difference a ratio was calculated of the post-marking ADG to the pre-marking ADG. This percentage varied from 26% in drought conditions to nearly 90% on the stud property with good summer feed.

Mean 200 day weights also varied considerably between herd years with the lowest being 171 kgs and the highest 261 kgs.

In the case of BH 01 data for most of the 2 yr heifers was lost and with only one record no adjustments were calculated and that heifer was omitted from the analysis.

Measures of cow performance

The industry standard: 200 day weight

The traditional measure of cow performance is the 200 day weight of a cow's calf (200d wt), which is the weaning weight adjusted for the age and sex of the calf and the age of the dam. The 200d wt was calculated for each cow/calf pair according to well established methods (Cundiff & Willham, 1966; Nicoll & Rae, 1977; Swiger *et al.*, 1962) which adjust weaning weights to the equivalent of a 200 day old male calf out of a five year old cow. In all but one of the herds the adjustment was made to bull calves but the Toshi 04 data did not include any entire calves at weaning. Since the adjustments are calculated within herd the different standard of equivalent was not considered important. Adjustments calculated for each sub-group of calves are given in Appendix 9.

Each calf's birth weight was multiplicatively adjusted for SOC and additively for AOD (Cundiff & Willham, 1966; Nicoll & Rae, 1977; Swiger *et al.*, 1962). The adjustments were calculating by comparing the average birth weight of heifer calves to the average of bull calves and then multiplying each heifer calf birth weight by the ratio of mean bull calf to mean heifer calf birth weight. Age of dam adjustments were made in a similar manner with the standard being five year old dams and the difference of the means of different age groups of cows being additively adjusted (Appendices 1-8).

Each calf's average daily gain (ADG) between birth and weaning was then calculated ((weaning weight less actual birth weight)/age of calf) and adjusted for sex of calf (SOC) by multiplying the heifer and steer calves' individual ADG by the ratio of the mean bull calf ADG to the mean heifer or steer calf ADG for that herd year. Then each calf's ADG had a age of dam (AOD) correction added to it in order to adjust all to 5 year old dam equivalents (Cundiff & Willham, 1966; Nicoll & Rae, 1977; Swiger *et al.*, 1962).

Finally the adjusted ADG was multiplied by 200 and added to the corrected birth weight to produce a 200-day-weight-bull-calf-out-of-a-five-year-old-cow equivalent for all calves.

Alternative measures of cow performance (Appendices 1-8)

Birth weight (bwt). Birth weight had been measured by the farmers within 24 hours of birth by a variety of methods including clock face scales held at arm's length and electronic weigh bars/platform installed on a motorbike trailer. No adjustments were made to the observed weight.

Adjusted birth weight (adj bwt). Calf birth weights were adjusted by the method described above (Cundiff & Willham, 1966; Nicoll & Rae, 1977; Swiger *et al.*, 1962).

Marking weight (mkwt). At some time between birth and weaning, calves were yarded and weighed. Traditional farming practice would normally ear mark, castrate, ear tag, and possibly anthelmintic drench and/or vaccinate at this time. Since all of the calves in this study had been tagged and weighed at birth, the timing of marking in the study herds was probably more varied than it would be in most commercial situations. No adjustments were made to the recorded weight.

Adjusted marking weight (adj mkwt). Marking weights were adjusted multiplicatively for SOC and additively for AOD as described in the 200 day weight section above. There was no adjustment for age of calf.

Weaning weight (wnwt). Calves were weighed at weaning; no adjustments were made.

Adjusted weaning weight (adj wnwt). Calf weaning weights were adjusted multiplicatively for SOC and additively for AOD. No adjustment was made for the age of the calf.

ADG: birth to marking(ADG b/mk). The ADG between birth and marking of each calf was calculated. Mean average daily gain between birth and marking was calculated for each SOC and AOD group of calves; individual ADG's were then adjusted additively for AOD and multiplicatively for SOC of calf (Cundiff & Willham, 1966; Nicoll & Rae, 1977; Swiger *et al.*, 1962) .

ADG marking to weaning (ADG mk/wn). The ADG between marking and weaning of each calf was calculated and adjusted by the method described above.

Cows were ranked within each herd-year by the traditional measure (200 d wt) and by each of the alternative measures. The accuracy of the alternative measures in predicting the 200d wt was evaluated by calculating correlation coefficients. Three comparisons were made: between actual measures, between the ranking of each cow within the herd/year for the different measures and finally between the percentile ranking of cows within each herd/year+.

\+ as defined in Excel spreadsheet: tools/data analysis/rank and percentile

<u>Calculation of selection index</u>

In an effort to predict 200 d wt more accurately than the use of any single indicator trait allowed, an index was constructed from the indicator traits that were the most highly correlated with 200d wts. In keeping with traditional practice (Bourdon, 1997) the index was based on deviations of each measure from the herd-year means for that trait.

Index weights for each of the indicator traits were calculated using the following formula

$$b = P^{-1} c$$

where

"b" represents a vector of the index weight of the indicator traits,

"P" is a matrix of the variances and covariance's among the information sources (indicator traits) and

"c" is a matrix of the covariance's of the indicator traits and the trait being predicted (200d weight).

Once the index weights were calculated for each herd-year, an Extensively Grazed Cow Weaning Index (EGCWIndex) was constructed according to accepted formula (Hazel, 1943; Hazel *et al.*, 1994)

$$I = (b_1 * x_1) + (b_2 * x_2) + (b_3 * x_3) \; . . .(b_n * x_n)$$

where

"I" represents the index value

"b" represents the index wts for each of the indicator traits

"x" represents each of the indicator traits, and

"n" represents the number of indicator traits

The index values for the cows in each herd-year were then compared with their 200d deviations by calculating correlation coefficients.

A method was needed to determine index weights for herds in which the calving date is unknown, 200d weight cannot be calculated and accordingly there is no "c" matrix. To that end a number of <u>unadjusted</u> descriptive variables of each herd-year were regressed on the internally calculated index weights developed for each of the indicator traits from all of the herds. Starting with the variable that explained the largest proportion of the variance of each index weight, additional variables were progressively adding to the equation until all of the variance was accounted for (Table 14).

The multiple regression formulas and herd descriptive variables were then used to calculate index weights and indices for all of the seven herds. These "variable-regression-herd-descriptive-variable-derived" indices were labelled "generic" indices to distinguish them from the internally-derived indices.

Correlation coefficients were then calculated between the generic indices for the cows in each herd-year and the 200d deviations of the cows.

Table 14

Evaluation of relationship between descriptive variables and the index wt for adjusted weaning weight

	corr	**R^2**	**cummulative* R^2**
% calved in 1st 21 d	0.67	45.5%	
adj b/wn ADG	0.63	40.3%	46.0%
adj b/mk ADG	0.54	29.3%	46.3%
adj mean wn wt	0.47	22.5%	46.4%
interval to median CD	0.40	16.3%	96.6%
adj mean mk wt	0.33	10.7%	100.0%
mean age marking	0.20	3.8%	
adj post/pre ADG %	0.19	3.7%	
adj mk/wn ADG	0.07	0.5%	
mean age weaning	0.05	0.2%	

* R^2 value when additional variables were included in the regression

Some of the descriptive variables used in the regressions, i.e. mean wt at marking and weaning, will be readily available in extensively grazed herds. Knowledge of some of the other variables, particularly those dependent on knowledge of calving date, is much less likely. A calculator (Appendix 10) was therefore developed to allow estimation of the latter variables using more readily-available information including

Frame size of cows

Calving spread or approximate % calving in first 21 d

Date of start and finish of mating

Marking date and mean unadjusted marking weight

Weaning date and mean unadjusted weaning weight.

Finally data from two new herd-years not used in the construction of the model were used to test the accuracy of the calculator and the model. This new data (Whatawhata 2000 and 2001) was also kindly supplied by Dr. Chris Morris of Ruakura (Appendices 11 and 12).

The index makes no attempt to remove non-genetic effects and is best considered a Most Probable Producing Ability—weaning weight (MPPA-WnWt). Since MPPA's include not only genetic effects but also permanent environmental effects and gene combination effects they are the preferred method of predicting future productivity of individual cows.

Lush (1945) defined MPPA as

$$MPPA = \text{herd average} + \frac{(n * r)}{(1 + (n-1)*r)} * (\text{cow deviation})$$

where n is the number of records and r is the repeatability of the trait. Lush (1945) described repeatability as the fraction of total variance between corrected records which is due to permanent differences between cows and defined it as the intra class correlation between repeated unselected records on the same cow after adjustments for all known environmental effects.

Repeated measurements increase the response obtained which Lush (1945) calculated as

$$\text{increased response} = \text{sq rt of } \frac{n}{(1+ ((n-1)*r)}$$

Since 200d weight of calves as a trait of the cow has a repeatability of approximately 0.5 additional records will only modestly increase the expected response (Lush, 1945) as illustrated below

r	n	increased response
0.50	2	1.15
0.50	5	1.30
0.25	2	1.25
0.25	5	1.58

One of the herds (Whatawhata) supplied records from five years; for these herd years repeatability estimates were determined for measures of cow productivity and MPPA-WnWt's were calculated.

Results

Usefulness of Alternative measures

A number of alternative measures of cow performance were assessed as possible predictors of 200d weight (Appendix 13 and Table 15).

Birth weight

Although birth weight data is not easily available in extensive herds, if a useful relationship could be established between that and 200d weight, collecting birth weights and parentage might prove less time consuming than collecting marking and/or weaning weights.

Table 15

Correlations of 200 day weight with actual measures

herd/year	birth wt	adj bwt	mark wt	adj mkwt	wean wt	adj wnwt	adj ADG mk/wn
WhWh 95	0.26	0.32	0.50	0.74	0.63	0.92	0.82
WhWh 96	0.48	0.51	0.59	0.72	0.74	0.90	0.81
WhWh 97	0.33	0.36	0.72	0.85	0.80	0.95	0.85
BH 01	0.27	0.31	0.54	0.57	0.80	0.88	0.50
BH 02	0.31	0.32	0.48	0.55	0.74	0.87	0.73
TOS 04	0.30	0.31	0.83	0.86	0.94	0.96	0.60
TM 04	0.24	0.30	0.41	0.46	0.64	0.80	0.85
weighted mean	**0.31**	**0.32**	**0.58**	**0.68**	**0.76**	**0.90**	**0.74**

Unfortunately the relationships between both gross and adjusted birth weights and the 200d deviations were poor (Table 15). Correlations between gross birth weight and 200d weight ranged from 0.24 to 0.48 with a weighted mean of 0.31. Correlations between adjusted birth weight and 200 d wt were only slightly greater with a minimum of 0.30, a maximum of 0.51 and a weighted mean of 0.32.

Marking weight

Marking weights in most herds were moderately correlated with 200d weights with r values ranging from 0.41 to 0.83 with a weighted mean of 0.58. Adjusted marking weights were only slightly more favourably correlated with 200d weights with r values ranging from 0.46 to 0.86 with a weighted mean of 0.68 (Table 15).

In Toshi 04 the relationship between marking weights and 200d was much stronger than in any of the other herd-year. In that herd-year feeding levels were very poor after marking, calves were marked relatively late in the year (mean age of calf at marking of 138 days) and post marking ADG was very low (0.33 kgs/day). It is not surprising, therefore, that marking weight would be strongly related to weaning wt; the correlation between adjusted marking and adjusted weaning weights was 0.96.

In 4 of the 7 herd-years adjusted marking weight was among the three indicator traits most highly correlated with 200 d weight.

Weaning weight

Gross, un-adjusted weaning weight was moderately correlated with 220 d wt with a minimum correlation of 0.63, a maximum correlation of 0.94 and a weighted mean correlation of 0.76 (Table 15).

The relationship between adjusted weaning weight and 200d wt was stronger. The lowest correlation between the two was 0.80, the highest 0.96 with a weighted mean of 0.90. In six of the seven herd-years adjusted weaning weight was the indicator trait most highly correlated with 200d wt.

ADG mk/wn

Calf ADG between marking and weaning was highly correlated with 200d wt with a minimum r value in any herd-year of 0.50, a maximum of 0.85 and a weighted average was 0.74 (Table 15). In one herd ADG mk/wn was the indicator trait most highly correlated with 200d wt, in three years it was the second most highly correlated, and in one year the third most.

Cow ranking

The ranking of cows within herd-years for 200d wt and the alternative measures was not significantly different (P values between 0.70 and 0.80) whether the comparison was on the basis of actual measures, ranking within the herd or percentile ranking (Appendix 13). Accordingly only the correlations between deviations of actual measures were used.

None of the alternative traits alone consistently and accurately estimated 200d wt. Three of the traits (adjusted marking wt, adjusted weaning wt and ADG mk/wn), however, had a strong enough relationship with 200d weight to suggest that an index based on the three traits might more accurately predict 200d wt than any one trait alone.

Internal Index to estimate 200d wt

The within-herd index weights for each of the three indicator traits were quite similar for six of the herds but those for Te Mania were quite different (Table 16 and Figures 30-32).

Calculation of indices for cows in each of the herds are given in Appendix 14.

Table 16

Internally calculated index weights

herd year	$b_{adj\ mk\ wt}$	$b_{adj\ wnwt}$	$b_{ADG\ mk/wn}$
WhWh 95	0.30	0.68	59.79
WhWh 96	-0.10	0.66	83.67
WhWh 97	0.15	0.77	51.03
BH 01	0.20	0.48	2140.00
BH 02	0.02	0.54	55.00
Toshi 04	0.35	0.54	45.35
TM 04	1.17	-0.78	245.73

Figure 30

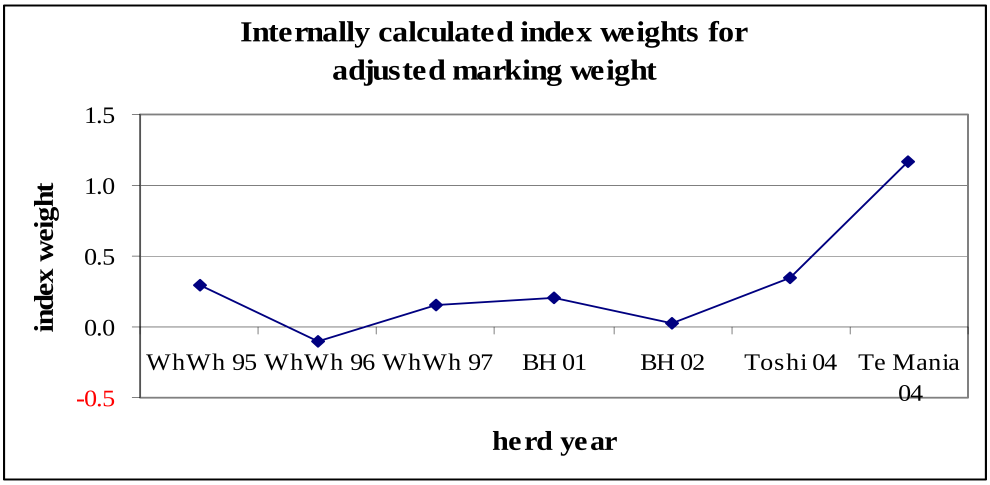


Figure 31

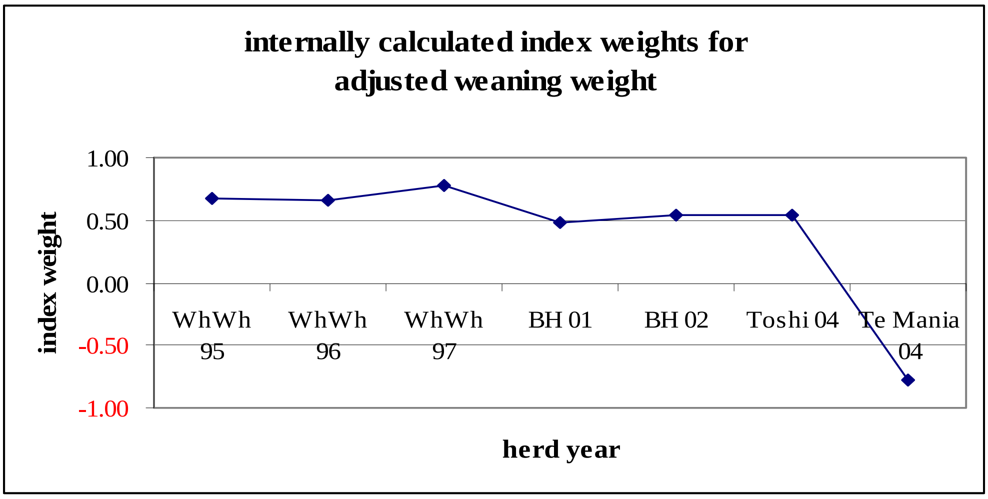
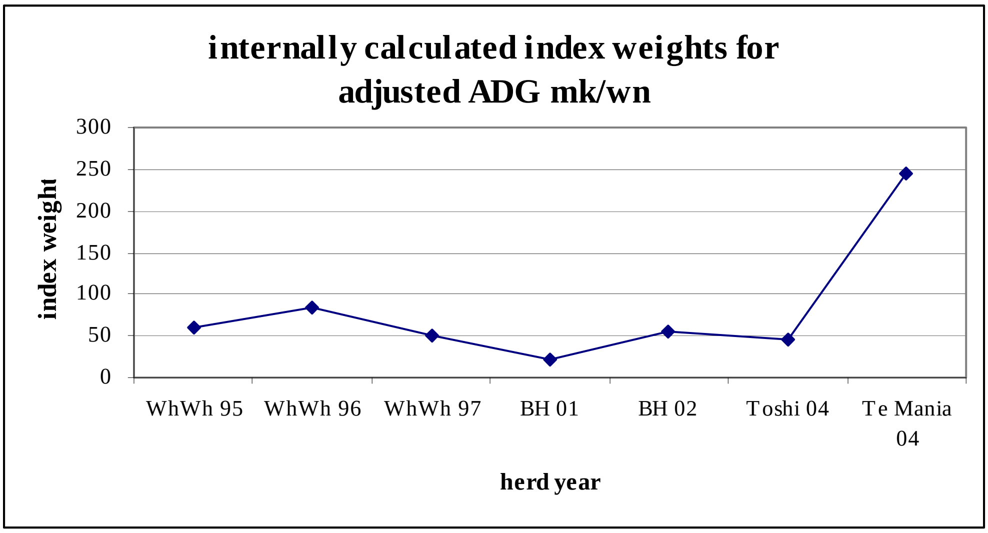


Figure 32



The internally calculated indices of individual cows accurately predicted the 200d weight deviations in each herd. Correlations between the internal index values and 200d wt deviations within each herd ranged from 0.91 to 0.97 with a mean of 0.94 (Table 17). The percentage of variance of the 200d deviation explained by the internal index ranged from 82.6% to 94.9% with a mean of 88.2%.

Table 17

Relationship of internally-calculated indices and 200d deviation		
herd year	**r**	**R^2**
Wh 95	0.92	85.1%
Wh 96	0.97	94.7%
Wh 97	0.95	90.3%
Bh 01	0.91	83.6%
BH 02	0.93	86.2%
Toshi	0.97	94.9%
Te Mania	0.91	82.6%

When index weights from each herd were used to construct indices in all the other herds the relationships between index values and 200d deviations were less favourable. The mean correlation was 89.2 but some were as low as 0.60. In 16 of the 42 evaluations these indices explained less than 80% of the variance in the 200d deviation.

Generic index to estimate 200d wt

The generic index that was designed to be used with data from herds without knowledge of calving date was then applied to the seven herd years used to develop the model. The calculator was first used to estimate the descriptive herd variables which were reasonably close to the actual figures for the seven herd years (Table 18). The variables estimated for Te Mania were furthest from the actual figures but the protracted calving pattern in that herd-year is quite unusual (Appendix 8). Perhaps it is unreasonable to expect any method of estimating variables to be accurate for such an unusual dataset.

Table 18

Comparison of actual and calculator-estimated descriptive herd variables

herd year	birth weight estd.	birth weight actual	mean CD estd.	mean CD actual	b/mk ADG estd.	b/mk ADG actual	mk/wn ADG as % of b/mk ADG estd.	mk/wn ADG as % of b/mk ADG actual
L&S 95	28.0	27.2	18-Sep	16-Sep	0.73	0.75	72.6%	70.6%
L&S 96	28.0	28.0	14-Sep	14-Sep	0.81	0.85	74.3%	71.3%
L&S 97	28.0	28.6	12-Sep	11-Sep	0.76	0.77	85.9%	84.9%
BH 01	33.0	30.9	28-Aug	29-Aug	1.01	1.03	25.7%	25.1%
BH 02	33.0	30.7	06-Sep	13-Sep	0.96	1.05	58.6%	53.6%
TO 04	38.0	38.3	05-Oct	30-Sep	1.09	1.05	29.9%	31.1%
TM 04	38.0	38.0	15-Aug	04-Sep	0.84	1.07	114.6%	90.0%
mean R^2		93.7%		80.7%		92.0%		94.6%

The regression equations (Table 19) were then used to calculate index weights for the cows in each herd-year. The calculator-derived index weights were identical to the internally derived index weights (Table 20).

Table 19

Regression Equations to determine index weights for the indicator traits

adj mkwt

Intercept	5.16
(unadjusted descriptive variables)	**Coefficients**
% calved 1st 21 d	-4.29
interval start to median CD	-0.01
ADG b/wn	0.64
ADG mk/wn	0.27
ADG b/mk	-4.41
average weaning wt	0.01

adj wnwt

Intercept	-1.54
(unadjusted descriptive variables)	**Coefficients**
% calved 1st 21 d	4.63
interval start to median CD	0.13
ADG b/wn	11.78
ADG mk/wn	-8.08
ADG b/mk	-1.02
average weaning wt	-0.04

adj ADG mk/wn

Intercept	746.91
(unadjusted descriptive variables)	**Coefficients**
interval start to median CD	-3.38
ADG mk/wn	2,553.14
% calved 1st 21 d	-122.33
ADG b/wn	-1,559.35
[ADG mk/wn] / [ADG b/wn] %	-1,406.70
mean age at marking	2.09

Table 20

Comparison of internally calculated and generic-calculator-derived index wts for the three indicator traits

	index weighs for					
	adj mk wt		**adj wn wt**		**adj ADG mk/wn**	
herd	**generic**	**internal**	**generic**	**internal**	**generic**	**internal**
WhWh95	0.30	0.30	0.68	0.68	59.79	59.79
WhWh96	-0.10	-0.10	0.66	0.66	83.67	83.67
WhWh 97	0.15	0.15	0.77	0.77	51.03	51.03
BH 01	0.20	0.20	0.48	0.48	21.40	21.40
BH 02	0.02	0.02	0.54	0.54	55.00	55.00
Toshi 04	0.45	0.45	0.54	0.54	45.35	45.35
TM 04	1.17	1.17	-0.78	-0.78	245.73	245.73

Index values for all cows in each of the 7 herd-years were calculated using the generic index weights. The resulting values were highly correlated with the 200d deviations of each calf (Table 21 and Appendix 15) with correlations between 0.89 to 0.97 with a mean of 0.93. The percentage of variance of 200d deviations explained by the index ranged from 82.6% to 94.9% with a mean of 84.9%.

Table 21

Relationship of 200d deviations and generic, descriptive-derived index values for cows in each herd

herd	**r**	**R^2**
Wh 95	0.92	85.1%
Wh 96	0.97	94.7%
Wh 97	0.95	90.3%
BH 01	0.89	84.7%
BH 02	0.93	86.2%
Toshi	0.97	94.9%
Te Mania	0.91	82.6%

Finally the calculator and model were used to estimate 200d weights of calves from two other herds not involved in the model development, Whatawhata 2000 and 2001. The relationship between the index values and the 200d deviations were very good with r values of 0.95 and 0.92 and R^2 values of 91.2% and 85.4% respectively (Figures 33 and 34).

Figure 33

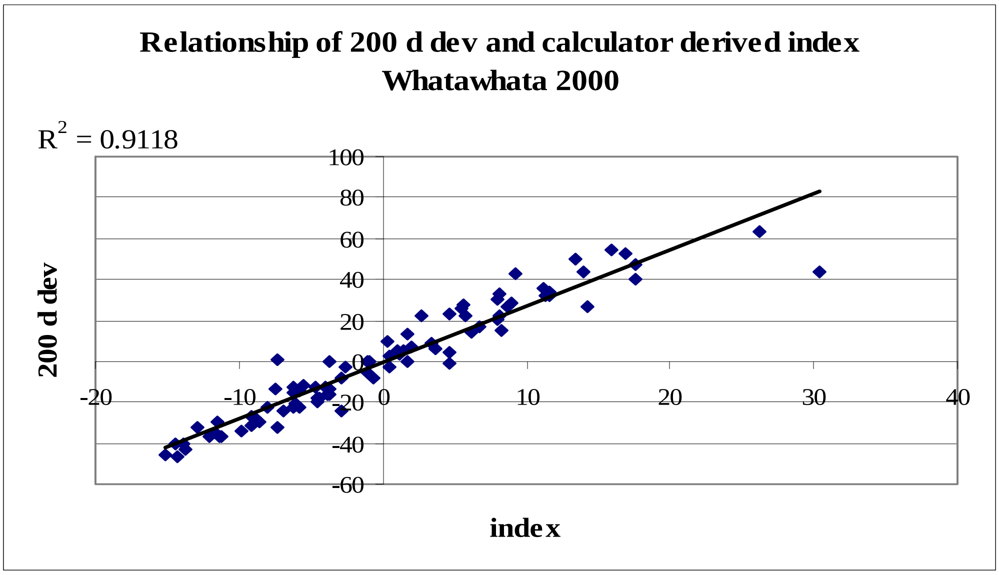
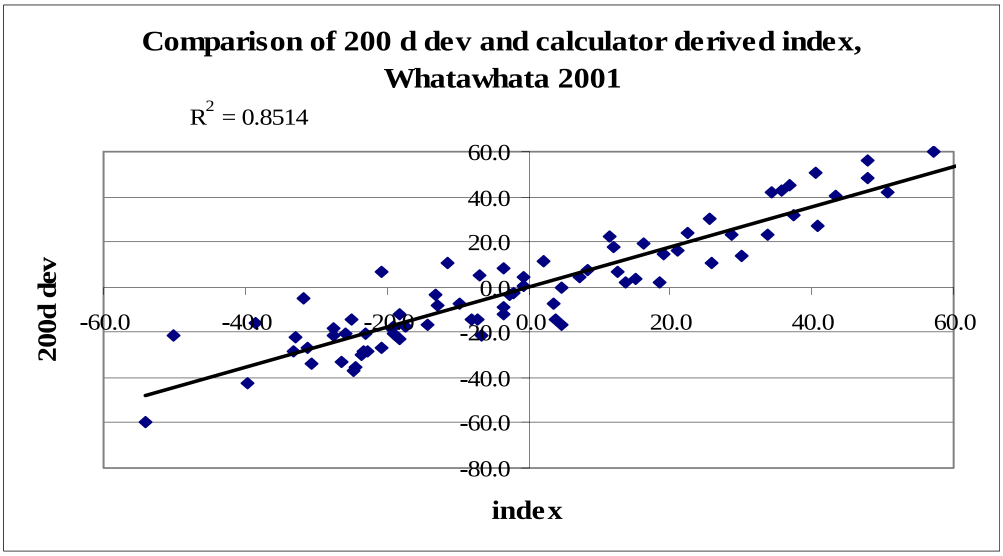


Figure 34



Repeatability of measures of cow productivity

The between year correlation of the various measures of cow productivity were calculated from the herds with repeat records (Table 22) and were found to be similar to those found in the literature (Table 2).

Table 22

Repeatability estimates

	Wh95/96	Wh 96/97	Wh 00/01	**average**
adj mk wt	0.38	0.30	0.48	**0.39**
adj wn wt	0.42	0.45	0.64	**0.50**
adj ADG mk/wn	0.46	0.49	0.56	**0.50**
200d	0.45	0.48	0.67	**0.53**
index	0.47	0.50	0.72	**0.56**

MPPA values for cows were calculated (Table 23). Because the repeatability value used was less than 1.0 the differences between individual cows were less for MPPA values (standard deviation of 17.9 kgs) than they were for the index values unadjusted for repeatability (S_d of 26.9 kgs).

Table 23

Illustration of MPPA calculation for Whatawhata 96

herd	dam #	96 index	MPPA index
WhWh96	88075	-44.4	-29.6
WhWh96	88096	-22.0	-14.7
WhWh96	86663	-16.9	-11.3
WhWh96	89804	-16.7	-11.1
WhWh96	86044	-14.5	-9.7
WhWh96	88246	-3.0	-2.0
WhWh96	87241	-2.4	-1.6
WhWh96	87090	11.7	7.8
WhWh96	90817	19.1	12.8
WhWh96	88278	26.5	17.7
WhWh96	90657	28.3	18.9
WhWh96	90650	37.4	25.0
WhWh96	90613	46.9	31.3
Sd		26.9	17.9

number of records	2.0	(n * r)
repeatability	0.5	(1 + (n-1)*r)
herd mean 200d	179.8	

Discussion

Despite the variety of conditions of the seven original herd-years (North and South Islands, flat land and high country, well-fed and not-so-well fed and early and late marking and weaning) the calculator was able to accurately predict descriptive herd variables. These predicted herd variables were then used to produce index weights that when applied to three indicator traits produced an index that ranked cows in a way that was very similar to the ranking based on the traditional 200d weight. Thus the Extensively Grazed Commercial Cow Weaning Index (EGCW Index) proved a reliable method of accurately ranking cows on their calf rearing ability when calving date was unknown.

The EGCW Index model was successful in estimating the calf rearing ability of cows from two additional herds not initially involved in the production of the model. Complete data sets of calving date, marking and weaning data are quite rare; the only two additional datasets available to the author were regrettably from one of the original herds but from different years. Nevertheless the calculator and model were able to produce indices based on the regression equations that used herd descriptive variables that were very highly correlated with the 200d deviations.

The relationship between the adjusted weaning wt and 200d wt was strong enough (r = .90) to suggest possibly that calculation of an index was unnecessary. The true test of the two predictors of is how accurate they are in identifying the most and least productive cows in each of the herds. The purpose of identifying the most productive cows might be to aid selection of replacement cows based on their first calf record. Identification of the least productive would permit objective culling. The index missed fewer of the top and bottom cows than did the adjusted weaning weight in all but one instance although the difference was only significant in one case (Table 24).

There are as well other reasons to persevere with the index.

Firstly it stands to reason that the more information included in an estimate, the more accurate the estimate will be. Marking weight can easily be recorded when the calves are yarded for calf marking and average daily gain between marking and weaning is simple to calculate so the extra information is relatively simple to collect.

Table 24

Accuracy of adj wnwt and index in identifying cow ranking in the top 50% and bottom 10% for 200d wt

	top 50% of 200d wt							
		adj wnwt			index			
	n cows	n identified	n missed	% missed	n identified	n missed	% missed	signif
WhWh95	29	25	4	13.8%	26	3	10.3%	n.s.
WhWh96	34	30	4	11.8%	31	3	8.8%	n.s.
WhWh97	39	38	1	2.6%	37	2	5.1%	n.s.
BH 01	61	49	12	19.7%	49	12	19.7%	n.s.
BH 02	110	98	12	10.9%	99	11	10.0%	n.s.
Toshi 04	202	179	23	11.4%	182	20	9.9%	n.s.
TM 04	174	131	41	23.6%	150	24	13.8%	P=0.02

	bottom 10% of 200d wt							
		adj wnwt			index			
	n cows	n identified	n missed	% missed	n identified	n missed	% missed	
WhWh95	6	3	3	50.0%	3	3	50.0%	n.s.
WhWh96	7	5	2	28.6%	5	2	28.6%	n.s.
WhWh97	8	6	2	25.0%	7	1	12.5%	n.s.
BH 01	13	10	3	23.1%	10	3	23.1%	n.s.
BH 02	22	17	5	22.7%	18	4	18.2%	n.s.
Toshi 04	40	37	3	7.5%	36	4	10.0%	n.s.
TM 04	35	24	11	31.4%	26	9	25.7%	n.s.

significance by Chi square

Secondly literature reports consistently record that of the usual adjustments made to weaning weight, age of calf is the most important (Cardellino & Frahm, 1971; Cundiff & Willham, 1966; Lehmann *et al.*, 1962; Minyard & Dinkel, 1965; Nicoll & Rae, 1977; Pell & Thayne, 1978; Vernon *et al.*, 1964). The main reason for adjusting for age of calf is the low repeatability of both calving date and calving period (Table 25).

Table 25

Repeatability estimates of calving date

	repeatability	
author	CD	21 day period
Plasse (1966)	0.03	
Harwin (1964)	0.14	
Schalles (1969)	0.02	
Lesmeister (1973)	.09-.11	
Bailey (1985)	.13-.29	.14-.26
this study	.10-.39	.03-.34

A result, such as the one in this thesis, that suggests that age of calf is relatively unimportant is in conflict with earlier reports and is difficult to accept.

Thirdly the average correlation of the index and 200d deviation is greater (r= .94) than that of the adjusted weaning wt (r=.90). It may be that with larger numbers of records from more herds and possibly from herds less diverse than these seven, the difference between the accuracy of the index and adjusted weaning weight would be greater than in this study.

Fourthly the repeatability of the index was higher than that of adjusted weaning weight in those herds with records from more than one year (Table 22). If repeatability is a measure of the inherent ability of a cow to produce a calf unaffected by temporary environmental effects then the greater repeatability of the index suggests it is a more accurate measure than the adjusted weaning weight.

Finally reliance on adjusted weaning weight alone would make identification of dam parentage more difficult. The easiest and most convenient times to record dam parentage are at birth and immediately after marking. Once calves are weaned it is highly unlikely that anyone would be willing to re-unite them to assess parentage.

The index does not include any fertility component which may appear illogical due to the economic importance of fertility to commercial herd profitability(Melton, 1995; Melton *et al.*, 1994; Trenkle & Willham, 1977). There is a good reason for the omission of fertility, however. The index is designed to identify which cows to retain for another year. As the survey clearly demonstrated, cows diagnosed not pregnant are not retained therefore the index is designed to identify which of the pregnant cows are likely to be the most productive in the coming year. For the same reason the index is constructed as an MPPA and not an Estimated Breeding Value. In terms of the cow’s contribution to the growth of her calf, the additive genetic value for growth is less than one quarter of the total contribution of the cow, i.e. 10% vs. 46.3% (Table 1). The industry has focused on EBV’s which of course portray as accurately as possible each bull’s contribution to the growth of his calves but if immediate increases in herd productivity are the goal, female selection should be based on MPPA.

The absence of a practical method of performance recording extensively grazed commercial beef cows has compromised improvements in the beef industry. Female selection has in the past been confined to subjective assessment of suitable type and culling has largely been based on age, infirmity or failure to get in-calf. Us of the index will permit objective selection of rising second calvers as herd replacements and of poor performing cows for culling. Substantial improvement in cow productivity can be anticipated.

The genetic pool providing sires has been limited to intensively managed herds in reasonably favourable environments recording calving date. Objective assessment of extensively grazed cows coupled with genetic marker determined sire parentage of calves in multiple sire mated-herds will also now enable more accurate and comprehensive assessment of herd sires and will permit considerable expansion of the pool of potential future sires.

Accurate estimation of cow productivity in extensive herds will allow the use of commercial herd data in the calculation of breeding values of stud herd sires. Through extensive herd testing LIC has adopted a similar approach and currently chooses most of the sires used for artificial insemination from herd test-proven cows in commercial herds. In much the same way the very successful Romney Development Groups have forsaken stud flocks of pampered sheep and now screen large numbers of unregistered sheep from commercial flocks to select their elite sheep. Whether the beef industry will follow the same path is debateable but at least now there is a mechanism for accurately evaluating beef bulls used in extensively grazed commercial herds.

If farmers were prepared to identify parentage at birth, they could use any number of established performance recording systems. The survey results suggest very few are prepared to do that.

It is often argued that after involuntary culling, commercial beef producers have little scope for production-based, voluntary culling. Herds with poor fertility and high rates of involuntary culling that only retain enough heifers to replace 20-25% of the herd indeed have few opportunities for production culling. Management practices have been identified in the benchmarking survey portion of this thesis, (e.g. heifer mating before that of m.a. cows, longer m.a. mating, etc.) that may go some way towards increasing the fertility of many herds.

Ultimately the limiting factor for the number of cows that can be voluntarily culled is the number of heifers that are retained for entry into the herd. Many farmers have in the past only retained enough heifers for mating to insure they have replacements for the number of cows exiting the herd due to non-pregnant status or infirmity. If more heifers were retained, possibly as part of a once-bred heifer system, there would be more opportunity for production culling.

The EGCW Index is focused only on production and no consideration is given to the cost of production, i.e. the feed costs associated with calf production. The datasets used for this thesis did not include cow liveweight or body condition score and consequently energy costs could not be calculated. The author is currently undertaking further study to evaluate the efficiency of calf production using the EGCW Index to predict relative value of calves and the NRC model (National Research Council, 2000) to predict net energy costs of the cow calf pair.

The author has recently (2006) begun a Beef Cow Efficiency Project that has attracted over 40 commercial herd managers in the South Island who are currently performance recording either first calving heifers or their whole herd using the EGCW Index described in this report. From that I conclude that there is considerable interest in evaluating individual cow performance. The reason it has not been done in the past is not the lack of interest but the lack of a suitable method. Hopefully this thesis will address that need.

Summary

Fertility in Canterbury beef herds is poor:

- Only 88% of pregnant females wintered weaned a calf.
- Only 81% of females mated weaned a calf (76% of heifers and 85% of m.a. cows).
- Wet dries were the most numerous cause of mated cows failing to wean a calf.
- Pregnancy tested empty was the biggest cause of cow exit.
- 60% of herds first calved heifers at two years of age and did so without jeopardizing future fertility.
- Mating maiden heifers earlier than mixed age cows and mating mixed age cows for longer than 63 days both resulted in higher pregnancy rates.
- Calving heifers on downs rather than flats resulted in fewer dystocia deaths. Dystocia in m.a. cows was rare (0.3%).

Performance recording/production culling/selection are rarely practiced:

- most replacement heifers are chosen on type and size.
- less than 1% of cows are culled for poor production.
- conformation is the most important criteria in bull selection.
- few herds know the average weaning weight of their calves and none identify the most/least profitable cows in their herds.

Performance recording of extensively grazed cows is possible

- Using complete data sets from 7 herd-years an Extensively Grazed Cow Weaning Index was developed that was highly correlated with 200d weight, the industry standard.
- The most useful indicator traits for the index were found to be
  Marking wt adjusted for sex of calf and age of dam
  Weaning wt adjusted for sex of calf and age of dam and
  ADG between marking and weaning adjusted for sex of calf and age of dam
- Descriptive variables of the herds were regressed on the internally-calculated index weights to develop a regression equation that can produce index weights for herds not involved in the original model.
- When applied to data from two herds not used in the initial development the model produced index values that were highly correlated (r.>90) with 200d weights of these herds.
- Adoption of the EGCW Index will enable performance recording in extensively grazed herds and will allow commercial herd data to be used in genetic evaluations of pedigree bulls.

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Appendix 1

Summary Whatawhata calving 1995

	sex of calf			AOD				
	bulls	heifers	total	2 yr	3yr	4yr	> 5 yrs	total
birth wt								
count	34	24	58	16	12	9	21	58
mean	**27.7**	**26.5**	**27.2**	23.9	27.7	27.3	29.3	27.2
Sd	3.9	3.6	3.8	3.0	3.4	2.6	3.4	3.8
c of v			14.0%					14.0%
adjustment	**1.00**	**1.05**	multiplic	5.4	1.6	2.0	0.0	additive
adjusted b wt								
mean			29.9					
Sd			3.1					
c of v			10.4%					
calving date								
mean				18/09/95	17/09/95	15/09/95	14/09/95	16/09/95
Sd, days				11.5	17.3	10.2	10.0	12.1
median								12/09/95
interval start to mean CD		16	days	**% calved in first 21 days**				54%
		start of calving	31/08/95					
mark age								
mean	66	63	64.8	63	63	65	67	65
Sd	11.2	13.3	12.1	11.5	17.3	10.2	10.0	12.1
mark wt								
mean	79.6	70.8	75.9	64.3	71.2	79.0	86.2	76.0
Sd	13.9	11.6	13.6	8.3	8.6	12.7	11.5	13.6
c of v	17.5%	16.4%	17.9%	12.9%	12.1%	16.1%	13.3%	17.9%
adj	1.00	1.12	multiplic	21.9	15.0	7.2	0.0	additive
adjusted mk wt								
mean			89.7					
Sd			9.9					
c of v			11.0%					
ADG b/mk								
mean	**0.80**	**0.72**	**0.77**	**0.66**	**0.73**	**0.79**	**0.86**	**0.77**
Sd	0.20	0.17	0.19	0.15	0.23	0.16	0.17	0.19
adjustment	**1.00**	**1.11**	multiplic	**0.20**	**0.13**	**0.07**	**0.00**	additive
adj ADG b/mk								
mean			**0.89**					
Sd			0.18					
c of v			20.2%					

Appendix 1, cont.

Summary Whatawhata calving 1995, cont.

	sex of calf			AOD				
	bulls	heifers	total	2 yr	3yr	4yr	> 5 yrs	total
gross weaning								
age								
mean	180.0	177.0	179.0	177.0	177.0	179.0	181.0	179.0
Sd	11.2	13.3	12.1	11.5	17.3	10.2	10.0	12.1
weight								
mean	142.4	128.0	136.4	115.3	130.6	144.1	152.5	136.4
Sd	24.9	18.5	23.4	13.2	15.2	20.1	21.7	23.4
c of v	17.5%	14.5%	17.2%	11.4%	11.6%	13.9%	14.2%	17.2%
adjustment	1.00	1.11	multiplic	37.2	21.9	8.4	0.0	additive
adjusted wn wt								
mean			158.3					
Sd			17.1					
c of v			10.8%					
ADG b/wn								
mean	**0.64**	**0.57**	**0.61**	**0.52**	**0.59**	**0.65**	**0.68**	**0.61**
Sd	0.13	0.09	0.12	0.07	0.11	0.09	0.12	0.12
c of v			19.7%					19.7%
adjustment	1.00	1.12	multiplic	**0.16**	**0.09**	**0.03**	**0.00**	additive
adj ADG b/wn								
mean			0.71					
Sd			0.10					
c of v			14.1%					
200 day weight								
mean			**171.4**					
Sd			20.4					
adjustment			11.9%					
ADG mk/wn								
mean	**0.55**	**0.50**	**0.53**	**0.45**	**0.52**	**0.57**	**0.58**	**0.53**
Sd	0.11	0.10	0.11	0.06	0.09	0.08	0.11	0.11
adjustment	**1.00**	**1.10**	multiplic	**0.13**	**0.06**	**0.01**	**0.00**	additive
adj ADG mk/wn								
mean			0.60					
Sd			0.09					
c of v			15.0%					

unadjusted mk/wn ADG/unadjusted b/mk ADG % 68.8%

all adjustments are to bull calves out of 5 year old cows

Appendix 2

Summary of Whatawhata calving 1996

	sex of calf			AOD				
	bulls	heifers	total	2 yr	3yr	4yr	> 5 yrs	total
birth wt								
count	29	38	67	7	19	9	32	67
mean	28.5	27.1	27.7	26.1	27.4	26.6	28.6	27.7
Sd	3.0	3.4	3.3	4.2	2.7	2.4	3.4	3.3
c of v			11.9%					
adjustment	1.00	1.05	multiplic	2.5	1.2	2.0	0.0	additive
adjusted b wt								
mean			29.4					
Sd			3.2					
c of v			10.9%					
calving date								
start								27/08/96
mean				20/09/96	16/09/95	14/09/96	11/09/96	14/09/96
Sd, days				7.0	13.4	11.6	13.2	12.6
median								8/09/96
interval start to mean CD		18		**% calved in first 21 days**			60%	
mark age								
mean	65.3	64.2	64.7	59.0	62.6	64.8	67.1	64.7
Sd	13.1	12.4	12.6	7.0	13.4	11.6	13.2	12.6
mark wt								
mean	86.8	79.7	82.8	67.1	77.6	78.7	90.4	82.8
Sd	17.8	17.1	17.6	10.0	18.2	16.6	15.6	17.6
c of v	20.5%	21.5%	21.3%	14.9%	23.5%	21.1%	17.3%	21.3%
adjustment	1.00	1.09	multiplic	23.3	12.8	11.7	0.0	additive
adjusted mk wt								
mean			94.5					
Sd			16.4					
c of v			17.4%					
ADG b/mk								
mean	0.88	0.81	0.84	0.71	0.79	0.79	0.92	0.84
Sd	0.16	0.16	0.16	0.21	0.15	0.14	0.13	0.16
c of v			19.0%					
adjustment	1.00	1.09	multiplic	0.21	0.13	0.13	0.00	additive
adj ADG b/mk								
mean			0.96					
Sd			0.15					
c of v			15.6%					

Appendix 2, cont.

Summary of Whatawhata calving 1996, contin.

	sex of calf			AOD				
	bulls	heifers	total	2 yr	3yr	4yr	> 5 yrs	total
gross weaning								
age								
mean	178.3	177.2	177.7					
Sd	13.1	12.4	12.6					
weight								
mean	156.3	146.9	151.0	124.6	141.8	142.3	164.6	151.0
Sd	23.1	28.4	26.5	20.7	25.7	24.5	21.2	26.5
c of v	14.8%	19.3%	17.5%	16.6%	18.1%	17.2%	12.9%	17.5%
adjustment	1.00	1.06	multiplic	40.0	22.8	22.3	0.0	additive
adjusted wn wt								
mean			169.6					
Sd			23.3					
c of v			13.7%					
ADG b/wn								
mean	0.71	0.67	0.69	0.57	0.65	0.65	0.75	0.69
Sd	0.10	0.13	0.12	0.11	0.10	0.11	0.10	0.12
c of v			17.4%					17.4%
adjustment	1.00	1.06	multiplic	0.18	0.10	0.10	0.00	additive
adj ADG b/wn								
mean			0.77					
Sd			0.10					
c of v			13.0%					
200 d weight								
mean			184.2					
Sd			22.0					
c of v			11.9%					
V			484					
ADG mk/wn								
mean	0.62	0.59	0.60	0.51	0.57	0.56	0.66	0.60
Sd	0.10	0.12	0.11	0.10	0.09	0.09	0.10	0.11
c of v			18.3%					
adjustment	1.00	1.05	multiplic	0.15	0.09	0.10	0.00	additive
adj ADG mk/wn								
mean			0.68					
Sd			0.10					
c of v			14.7%					

unadjusted mk/wn ADG/unadjusted b/mk ADG % 71.4%

all adjustments are to bull calves out of 5 year old cows

Appendix 3

Summary of Whatawhata 1997 calving

	sex of calf			AOD				
	bulls	heifers	total	2 yr	3yr	4yr	> 5 yrs	total
birth wt								
count	37	40	77	8	14	25	30	77
mean	29.5	27.9	28.6	24.8	28.3	28.7	29.8	28.6
Sd	3.6	4.3	4.0	4.9	4.3	3.4	3.7	4.0
c of v			14.0%					14.0%
adjustment	1.00	1.06	multiplic	5.0	1.5	1.1	0.0	additive
adjusted b wt								
mean			30.6					
Sd			3.8					
c of v			12.4%					
calving date								
start								25/08/97
mean				14/09/97	13/09/97	11/09/97	10/09/97	11/09/97
Sd				9.5	7.2	9.5	10.1	9.3
median								10/09/97
interval to mean calving date		17		**% calved in first 21 days**			64.9%	
mark age								
mean	65.5	66.6	66.1	63.6	64.4	66.6	67.1	66.1
Sd	9.3	9.4	9.3	9.5	7.2	9.5	10.1	9.3
c of v		14.1%	14.1%	14.9%	11.2%	14.3%	15.1%	14.1%
mark wt								
mean	82.1	78.0	80.0	60.4	73.1	84.0	85.0	80.0
Sd	16.5	14.7	15.6	6.6	14.1	14.3	14.2	15.6
c of v	20.1%	18.8%	19.5%	10.9%	19.3%	17.0%	16.7%	19.5%
adjustment	1.00	1.05	multiplic	24.6	11.9	1.0	0.0	additive
adjusted mark wt								
mean			87.00					
Sd			13.60					
c of v			15.6%					
ADG b/mk								
mean	0.80	0.75	0.78	0.57	0.70	0.84	0.82	0.78
Sd	0.21	0.17	0.19	0.15	0.21	0.19	0.15	0.19
adjustment	1.00	1.07	multiplic	0.25	0.12	-0.02	0.00	additive
adj ADG b/mk								
mean			0.84					
Sd			0.18					
c of v			21.4%					

Appendix 3, cont.

Summary of Whatawhata 1997 calving, cont.

	sex of calf			AOD				
	bulls	heifers	total	2 yr	3yr	4yr	> 5 yrs	total
weaning								
age								
mean	159.5	160.6	160.1	157.6	158.4	160.6	161.1	160.1
Sd	9.3	9.4	9.3	9.5	7.2	9.5	10.1	9.3
c of v	5.8%	5.9%	5.8%	6.0%	4.5%	5.9%	6.3%	5.8%
weight								
mean	144.4	138.3	141.2	109.4	132.4	145.6	150.1	141.2
Sd	23.9	23.7	23.8	11.0	23.8	21.5	20.2	23.8
c of v	16.6%	17.1%	16.9%	10.1%	18.0%	14.8%	13.5%	16.9%
adjustment	1.00	1.04	multiplic	40.7	17.7	4.5	0.0	additive
adjusted wn wt								
mean			153.0					
Sd			20.4					
c of v			13.3%					
ADG b/wn								
mean	0.72	0.69	0.70	0.54	0.66	0.73	0.75	0.70
Sd	0.13	0.13	0.13	0.08	0.15	0.11	0.10	0.13
c of v			18.6%					18.6%
adjustment	1.00	1.04	multiplic	0.21	0.09	0.02	0.00	additive
adj ADG b/wn								
mean			0.76					
Sd			0.11					
c of v			14.5%					
200 d weight								
mean			189.2					
Sd			23.4					
c of v			12.4%					
V			547.6					
ADG mk/wn								
mean	0.66	0.64	0.65	0.52	0.63	0.65	0.69	0.65
Sd	0.11	0.11	0.11	0.07	0.13	0.09	0.10	0.11
c of v	16.7%	17.2%	16.9%	13.5%	20.6%	13.8%	14.5%	16.9%
adjustment	1.00	1.03	multiplic	0.17	0.06	0.04	0.00	additive
adj ADG mk/wn								
mean			0.70					
Sd			0.10					
c of v			14.3%					

unadjusted mk/wn ADG/unadjusted b/mk ADG % 83.3%

all adjustments are to bull calves out of 5 year old cows

Appendix 4

Summary of Blackhills Calving data 2001

	sex of calf			AOD				
	bulls	**heifers**	**total**	**2 yr**	**3yr**	**4yr**	**> 5 yrs**	**total**
birth wt								
count	69	63	132	1	27	39	65	132
mean	32.0	29.6	30.9	30.0	30.4	30.0	31.6	30.9
Sd	3.5	3.2	3.6		3.6	4.2	3.0	3.6
c of v			11.7%					11.7%
adjustment	1.00	1.08	multiplic	1.6	1.2	1.6	0.0	additive
adj b wt								
mean			32.7					
Sd			3.4					
c of v			10.4%					
calving date								
start								10/08/01
mean				10/09/01	31/08/01	2/09/01	25/08/01	29/08/01
Sd, days					19.5	19.4	11.6	16.3
interval to mean CD	19	days		**% calved in first 21 days**			55.4%	
mark age								
mean	187.1	189.1	188.1	182.0	184.6	183.1	192.6	188.1
Sd	19.4	16.5	18.0		19.5	20.7	14.6	18.0
c of v	10.4%	8.7%	9.6%		10.6%	11.3%	7.6%	9.6%
mark wt								
mean	235.3	213.0	224.7	182.0	214.1	222.4	231.1	224.7
Sd	35.0	30.9	34.9		35.4	32.7	35.0	34.9
c of v	14.9%	14.5%	15.5%		16.5%	14.7%	15.1%	15.5%
adjustment	1.00	1.10	multiplic	49.1	17.0	8.7	0.0	additive
adj mark wt								
mean			241.3					
Sd			33.4					
c of v			13.8%					
ADG b/mk								
mean	1.09	0.97	1.03	0.84	1.00	1.06	1.04	1.03
Sd	0.16	0.14	0.16		0.16	0.16	0.16	0.16
c of v	14.7%	14.4%	15.5%		16.0%	15.1%	15.4%	15.5%
adjustment	1.00	1.12	multiplic	0.20	0.04	-0.02	0.00	additive
adj ADG b/mk								
mean			1.09					
Sd			0.15					
c of v			13.8%					

Appendix 4, cont.

Summary of Blackhills Calving data 2001, cont.

	sex of calf			AOD				
	bulls	**heifers**	**total**	**2 yr**	**3yr**	**4yr**	**> 5 yrs**	**total**
gross weaning								
age								
mean	254.9	257.3	256.0	240.0	250.4	253.4	260.2	256.0
Sd	18.4	16.3	17.4		21.1	19.2	13.4	17.4
c of v	7.2%	6.3%	6.8%		8.4%	7.6%	5.1%	6.8%
weight								
mean	257.0	226.2	242.3	207.0	233.6	237.9	249.1	242.3
Sd	36.2	31.3	37.2		40.7	33.7	37.1	37.2
c of v	14.1%	13.8%	15.4%		17.4%	14.2%	14.9%	15.4%
adjustment	1.00	1.14	multiplic	42.1	15.5	11.2	0.0	additive
adjusted weaning wt								
mean			264.2					
Sd			34.9					
c of v			13.2%					
ADG b/wn								
mean	0.89	0.77	0.83	0.74	0.82	0.82	0.84	0.83
Sd	0.14	0.12	0.14		0.16	0.13	0.14	0.14
c of v	0.16	0.16	0.17		19.5%	15.9%	16.7%	16.9%
adjustment	1.00	1.16	multiplic	0.10	0.02	0.02	0.00	additive
adj ADG b/wn								
mean			0.90					
Sd			0.14					
c of v			15.6%					
200d wt								
mean			212.20					
Sd			28.30					
c of v			13.3%					
V			800.9					
ADG mk/wn								
mean	0.33	0.20	0.27	0.43	0.31	0.22	0.28	0.27
Sd	0.45	0.25	0.37		0.40	0.19	0.44	0.37
c of v	136.4%	125.0%	137.0%		129.0%	86.4%	157.1%	137.0%
adjustment	1.00	1.65	multiplic	-0.15	-0.03	0.06	0.00	additive
adj ADG mk/wn								
mean			0.33					
Sd			0.43					
c of v			130.3%					
unadj mk/wn ADG/unadj b/mk ADG %			26.2%					

all adjustments are to bull calves out of 5 year old cows

Appendix 5

Summary of Blackhills calving data 2002

	sex of calf				AOD				
	bulls	steers	heifers	total	2 yr	3yr	4yr	> 5 yrs	total
birth wt									
count	88	17	115	220	69	35	17	99	220
mean	31.4	29.4	30.3	30.7	28.7	29.3	31.8	32.4	30.7
Sd	4.0	4.4	4.0	4.1	3.0	3.9	4.9	3.8	4.1
c of v				13.4%					13.4%
adjustment	1.00	1.07	1.04	multiplic	3.7	3.1	0.6	0.0	additive
adjusted birth wt									
mean				33.2					
Sd				3.7					
c of v				11.1%					
calving date									
start									19/08/02
mean				13/09/02	12/09/02	16/09/02	11/09/02	12/09/02	13/09/02
Sd, days				16.8	16.7	9.5	22.7	17.8	16.8
interval start to mean CD		25	days		**% calves in first 21 days**				42.7%
mark age									
mean				111.5					
Sd				16.7					
c of v				15.0%					
mark wt									
mean	156.3	131.2	144.3	148.1	132.6	143.9	157.2	158.8	148.1
Sd	25.6	39.0	26.5	28.2	27.9	18.6	30.2	25.7	28.2
c of v	16.4%	29.7%	18.4%	19.0%	21.0%	12.9%	19.2%	16.2%	19.0%
adjustment	1.00	1.19	1.08	multiplic	26.2	14.9	1.6	0.0	additive
adjusted mk wt									
mean				166.8					
Sd				26.2					
c of v				15.7%					
ADG b/mk									
mean	1.11	1.02	1.01	1.05	0.93	1.05	1.10	1.13	1.05
Sd	0.18	0.26	0.15	0.18	0.17	0.13	0.10	0.17	0.18
c of v				17.1%					17.1%
adjustment	1.00	1.09	1.10	multiplic	0.20	0.08	0.03	0.00	additive

Appendix 5, cont.

Summary of Blackhills calving data 2002, cont.

	sex of calf				AOD				
	bulls	steers	heifers	total	2 yr	3yr	4yr	> 5 yrs	total
adj ADG b/mk									
mean				1.19					
Sd				0.16					
c of v				13.4%					
gross weaning									
age									
mean	214.7	200.6	214.6	213.5					
Sd	13.2	21.7	17.8	16.8					
weight									
mean	215.8	186.1	200.4	205.4	182.3	191.5	224.2	223.3	205.4
Sd	37.1	45.0	32.0	36.2	32.7	24.0	24.5	32.1	36.2
c of v	17.2%	24.2%	16.0%	17.6%	17.9%	12.5%	10.9%	14.4%	17.6%
adjustment	1.00	1.16	1.08	multiplic	41.0	31.8	-0.9	0.0	additive
adj wn wt									
mean				234.0					
Sd				30.9					
c of v				13.2%					
V				954.8					
ADG b/wn									
mean	0.86	0.78	0.79	0.82	0.72	0.77	0.89	0.89	0.82
Sd	0.16	0.20	0.12	0.15	0.13	0.11	0.06	0.13	0.15
c of v				18.3%					18.3%
adjustment	1.00	1.10	1.09	multiplic	0.17	0.12	0.00	0.00	additive
adj ADG b/wn					**200d wt**				
mean				0.93		mean			219.9
Sd				0.12		Sd			25.4
c of v				12.9%		c of v			11.6%
ADG mk/wn									
mean	0.58	0.54	0.55	0.56	0.48	0.47	0.66	0.63	0.56
Sd	0.22	0.19	0.15	0.18	0.16	0.18	0.09	0.18	0.18
c of v				32.1%					32.1%
adjustment	1.00	1.07	1.05	multiplic	0.15	0.16	-0.03	0.00	additive
adj ADG mk/wn									
mean				0.65					
Sd				0.17					
c of v				26.2%					

unadj mk/wn ADG/unadj b/mk ADG % 53.3%

all adjustments are to bull calves out of 5 year old cows

Appendix 6

Summary of Toshi Calving 2004

	sex of calf			age of dam			
	steers	heifers	total	3yr	4yr	> 5 yrs	total
birth wt							
count	216	188	404	107	241	56	404
mean	39.3	37.3	38.3	38.1	38.8	37.0	38.4
Sd	5.3	5.0	5.2	5.4	5.1	5.5	5.2
c of v	13.5%	13.4%	13.6%	14.2%	13.1%	14.9%	13.5%
adjustment	1.00	1.05	multiplic	-1.1	-1.8	0.0	additive
adjusted birth wt							
mean			37.9				
Sd			5.2				
c of v			13.7%				
calving date							
start							16/09/04
mean	1/10/04	30/09/04	30/09/04	5/10/04	30/09/04	23/09/04	30/09/04
Sd, days	9.9	10.2	10.0	10.0	9.0	9.9	10.0
interval start to mean CD		14	days	**% calved in first 21 days**			72.5%
mark age							
mean	138.0	138.7	138.3	133.9	138.6	145.7	138.3
Sd	9.9	10.2	10.0	10.0	9.0	9.9	10.0
c of v	7.2%	7.4%	7.2%	7.5%	6.5%	6.8%	7.2%
mark wt							
mean	188.8	179.5	184.4	177.6	187.1	186.3	184.4
Sd	28.4	26.1	27.7	28.5	27.4	26.0	27.7
c of v	15.0%	14.5%	15.0%	16.0%	14.6%	14.0%	15.0%
adjustment	1.00	1.05	multiplic	8.7	-0.8	0.0	additive
adjusted mk wt							
mean			190.4				
Sd			27.6				
c of v			14.5%				
ADG b/mk							
mean	1.08	1.02	1.06	1.04	1.07	1.02	1.06
Sd	0.17	0.17	0.17	0.19	0.16	0.15	0.17
c of v	15.7%	16.7%	16.0%	18.3%	15.0%	14.7%	16.0%
adjustment	1.00	1.06	multiplic	-0.02	-0.05	0.00	additive
adj ADG b/mk							
mean			1.05				
Sd			0.17				
c of v			16.2%				

Appendix 6, cont.

Summary of Toshi Calving 2004, contin.

	sex of calf			age of dam			
	steers	heifers	total	3yr	4yr	> 5 yrs	total
gross weaning							
age							
mean	194.0	194.7	194.3	189.9	194.6	201.7	194.3
Sd	10.2	9.9	10.0	10.0	9.0	9.9	10.0
c of v	5.3%	5.1%	5.1%	5.3%	4.6%	4.9%	5.1%
weight							
mean	207.0	197.8	202.7	195.8	205.7	203.2	202.7
Sd	31.6	30.3	31.3	33.6	30.4	29.3	31.3
c of v	15.3%	15.3%	15.4%	17.2%	14.8%	14.4%	15.4%
adjustment	1.00	1.05	multiplic	7.4	-2.5	0.0	additve
adjusted wn wt							
mean			207.8				
Sd			31.4				
c of v			15.1%				
ADG b/wn							
mean	0.86	0.82	0.85	0.83	0.86	0.83	0.85
Sd	0.15	0.15	0.15	0.17	0.14	0.14	0.15
c of v	17.4%	18.3%	17.6%	20.5%	16.3%	16.9%	17.6%
adjustment	1.00	1.05	multiplic	0.00	-0.03	0	additive
adj ADG b/wn							
mean			0.85				
Sd			0.15				
c of v			17.6%				
200d wt							
mean			207.2				
Sd			31.2				
c of v			15.1%				
ADG mk/wn							
mean	0.33	0.33	0.33	0.32	0.33	0.30	0.33
Sd	0.20	0.18	0.19	0.20	0.19	0.20	0.19
c of v	60.6%	54.5%	57.6%	62.5%	57.6%	66.7%	57.6%
adjustment	1.00	1.00	multiplic	-0.02	-0.03	0.00	additive
adj ADG mk/wn							
mean			0.30				
Sd			0.19				
c of v			63.3%				
unadj mk/wn ADG/ unadj b/mk ADG %			38.8%				

all adjustments are to steer calves out of 5 year old cows

Appendix 7

Summary of Te Mania calving 2004

	sex of calf			AOD					
	bulls	heifers	total	2 yr	3yr	4yr	5-12 yrs	> 12 yrs	total
birth wt									
count	166	182	348	97	68	19	143	21	348
mean	39.2	36.8	38.0	33.1	38.1	40.3	40.3	42.0	38.0
Sd	5.6	5.6	5.7	3.7	5.3	5.8	4.8	6.3	5.7
c of v	14.3%	15.2%	15.0%	11.2%	13.9%	14.4%	11.9%	15.0%	15.0%
adjustment	1.00	1.07	multiplic	7.20	2.20	0.00	0.00	**-1.70**	additive
adjusted birth wt									
mean			41.6						
Sd			4.8						
c of v			11.5%						
calving date									
start									
mean	7/09/04	2/09/04	4/09/04	10/09/04	2/09/04	2/09/04	2/09/04	#####	4/09/04
Sd, days	18.3	18.8	18.7	18.1	18.1	20.9	18.3	20.3	18.7
interval start to mean CD		40	days	**% calved in first 21 days**				8.0%	
mark age									
mean	70.5	74.7	72.7	67.3	75.4	74.7	74.6	73.4	72.7
Sd	18.2	18.7	18.6	18.1	18.1	20.8	18.1	20.2	18.6
c of v	25.8%	25.0%	25.6%	26.9%	24.0%	27.8%	24.3%	27.5%	25.6%
mark wt									
mean	116.8	115.0	115.9	99.4	113.0	122.5	127.2	118.5	115.9
Sd	25.8	25.3	25.7	22.4	21.8	27.0	23.8	21.6	26.7
c of v	22.1%	22.0%	22.2%	22.5%	19.3%	22.0%	18.7%	18.2%	23.0%
adjustment	1.00	1.02	multiplic	27.8	14.2	4.7	0.0	8.7	additive
adjusted mk wt									
mean			128.4						
Sd			23.2						
c of v			18.1%						
V			538.2						
ADG b/mk									
mean	1.10	1.05	1.07	0.98	0.99	1.12	1.17	1.06	1.07
Sd	0.20	0.20	0.20	0.18	0.18	0.22	0.17	0.17	0.20
c of v	18.2%	19.0%	18.7%	18.4%	18.2%	19.6%	14.5%	16.0%	18.7%
adjustment	1.00	1.05	multiplic	0.19	0.18	0.05	0.00	0.11	additive
adj ADG b/mk									
mean			1.20						
Sd			0.18						
c of v			15.0%						

Appendix 7, cont.

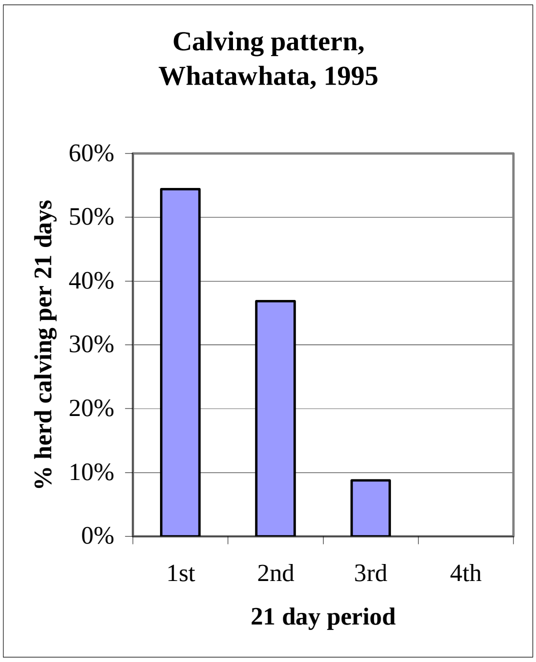
Summary of Te Mania calving 2004, contin.

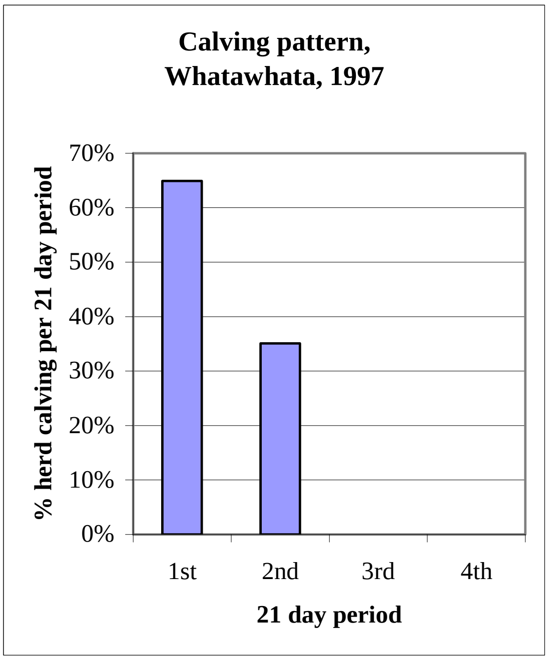
	sex of calf			AOD					
	bulls	heifers	total	2 yr	3yr	4yr	5-12 yrs	> 12 yrs	total
gross weaning									
age									
mean	190.8	187.0	188.8	183.0	191.3	192.3	191.0	189.0	188.8
Sd	18.3	18.8	18.7	17.5	17.5	21.4	18.8	19.6	18.7
c of v	9.6%	10.1%	9.9%	9.6%	9.1%	11.1%	9.8%	10.4%	9.9%
weight									
mean	235.2	220.1	227.3	195.0	228.0	242.2	246.2	230.9	227.3
Sd	38.5	35.3	37.6	31.7	26.8	43.1	31.0	31.0	37.6
c of v	16.4%	16.0%	16.5%	16.3%	11.8%	17.8%	12.6%	13.4%	16.5%
adjustment	1.00	1.07	multiplic	51.2	18.2	4.0	0.0	15.3	additive
adjusted wn wt									
mean			254.3						
Sd			31.3						
c of v			12.3%						
V			979.7						
ADG b/wn									
mean	1.02	0.98	1.00	0.88	1.00	1.05	1.08	1.01	1.00
Sd	0.15	0.15	0.15	0.13	0.12	0.18	0.12	0.16	0.15
c of v	14.7%	15.3%	15.0%	14.8%	12.0%	17.1%	11.1%	15.8%	15.0%
adjustment	1.00	1.04	multiplic	0.20	0.08	0.03	0.00	0.07	additive
adj ADG b/wn				**200d wt**					
mean			1.10		mean			261.4	
Sd			0.13		Sd			26.8	
c of v			11.8%		c of v			10.3%	
ADG mk/wn									
mean	0.98	0.93	0.96	0.82	1.00	1.02	1.02	0.97	0.96
Sd	0.17	0.15	0.16	0.13	0.12	0.22	0.13	0.19	0.16
c of v	17.3%	16.1%	16.7%	15.9%	12.0%	21.6%	12.7%	19.6%	16.7%
adjustment	1.00	1.05	multiplic	0.20	0.02	0.00	0.00	0.05	additive
adj ADG mk/wn									
mean			1.05						
Sd			0.14						
c of v			13.3%						

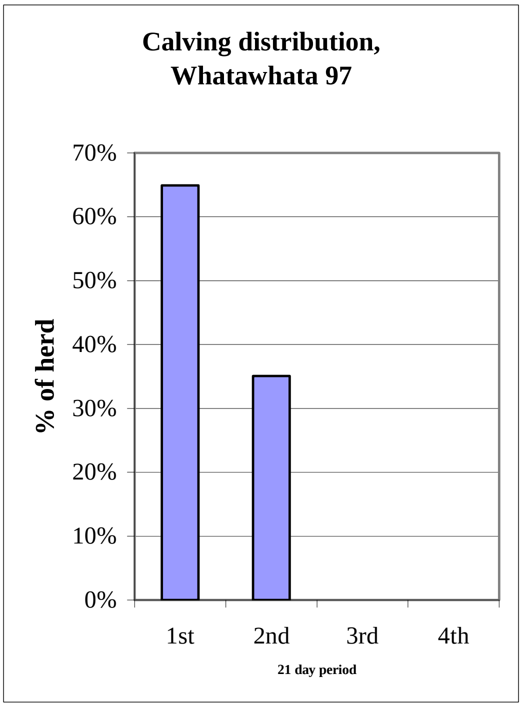
unadj mk/wn ADG/ unadj b/mk ADG % 89.7%

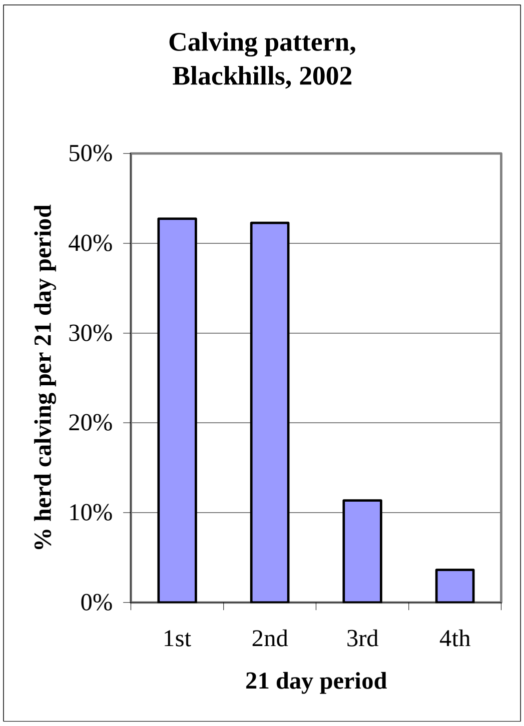
all adjustments are to bull calves out of 5 year old cows

Appendix 8
Calving Distributions



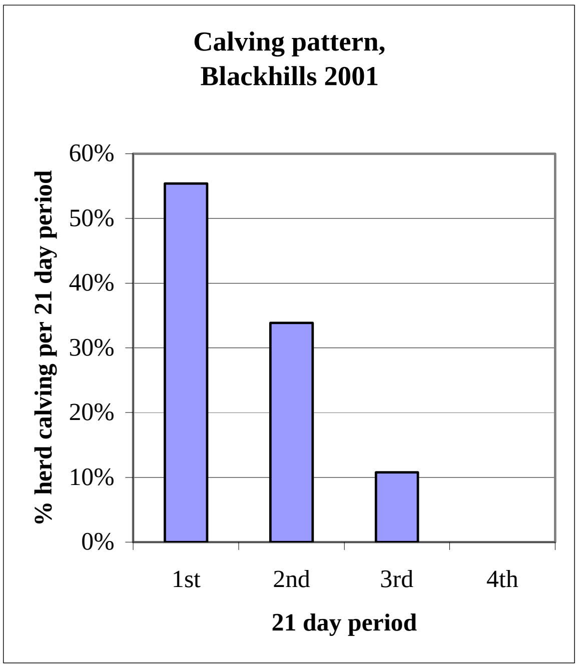


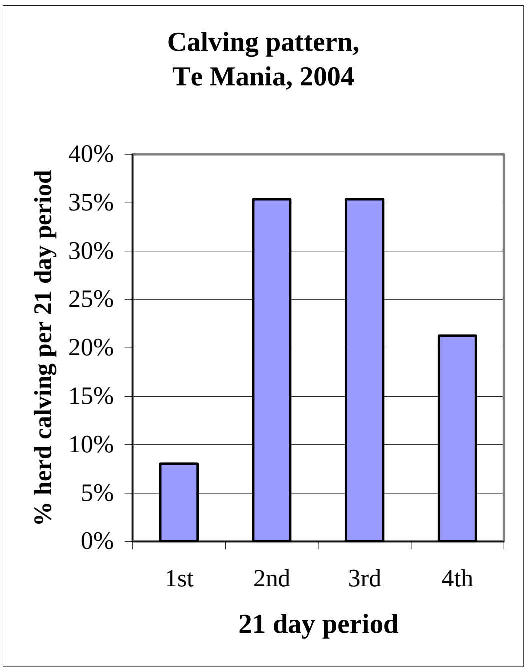


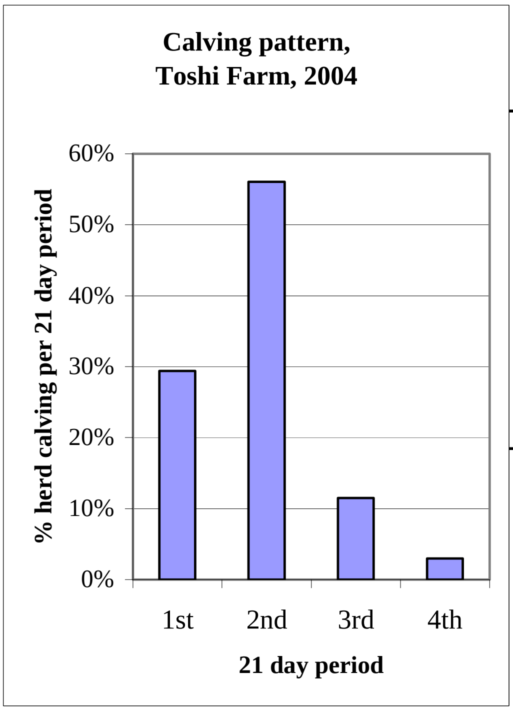


Appendix 8, cont.

Calving Distributions, cont.







	% calving in each 21 day period			
	1st	**2nd**	**3rd**	**4th**
WhWh95	54.4%	36.8%	8.8%	0.0%
WhWh96	59.7%	35.8%	4.5%	0.0%
WhWh97	64.9%	35.1%	0.0%	0.0%
BH 01	55.4%	33.8%	10.8%	0.0%
BH 02	42.7%	42.3%	11.4%	3.6%
TOS 04	29.4%	56.1%	11.5%	3.0%
TM 04	8.0%	35.3%	35.3%	21.3%

Appendix 9

Calf weight adjustments

BIRTH WT	multiplicative adjustments			additive adjustments			
herd-year	**bull***	**heifer**	**steer**	**2**	**3**	**4**	**>5***
WhWh 95	1.00	1.05	none	5.4	1.6	2.0	0.0
WhWh 96	1.00	1.05	none	2.5	1.2	2.0	0.0
WhWh 97	1.00	1.06	none	5.0	1.5	1.1	0.0
BH 01	1.00	1.08	none	insuff	1.2	1.6	0.0
BH 02	1.00	1.04	1.07	3.7	3.1	0.6	0.0
Toshi 04#	none	1.05	1.00	none	-1.1	-1.8	0.0
TM 04	1.00	1.07	none	7.2	2.2	0	0.0

MARKING WT							
herd-year	**bull***	**heifer**	**steer**	**2**	**3**	**4**	**>5***
WhWh 95	1.00	1.12	none	21.9	15.0	7.2	0.0
WhWh 96	1.00	1.09	none	23.3	12.8	11.7	0.0
WhWh 97	1.00	1.05	none	24.6	11.9	1.0	0.0
BH 01	1.00	1.10	none	insuff	17.0	8.7	0.0
BH 02	1.00	**1.08**	1.19	26.2	14.9	1.6	0.0
Toshi 04#	none	1.05	1.00	none	8.7	-0.8	0.0
TM 04	1.00	1.02	none	27.8	14.2	4.7	0.0

WEANING WT							
herd-year	**bull***	**heifer**	**steer**	**2**	**3**	**4**	**>5***
WhWh 95	1.00	1.11	none	37.2	21.9	8.4	0.0
WhWh 96	1.00	1.06	none	40.0	22.8	22.3	0.0
WhWh 97	1.00	**1.04**	none	40.7	17.7	4.5	0.0
BH 01	1.00	1.14	none	insuff	15.5	11.2	0.0
BH 02	1.00	1.08	1.16	41.0	31.8	-0.9	0.0
Toshi 04#	none	1.05	1.00	none	7.4	-2.5	0.0
TM 04	1.00	1.07	none	51.2	18.2	4.0	0.0

ADG b/mk							
herd-year	**bull***	**heifer**	**steer**	**2**	**3**	**4**	**>5***
WhWh 95	1.00	1.11	none	0.20	0.13	0.07	0.0
WhWh 96	1.00	1.09	none	0.21	0.13	0.13	0.0
WhWh 97	1.00	1.07	none	0.25	0.12	-0.02	0.0
BH 01	1.00	1.12	none	insuff	0.04	-0.02	0.0
BH 02	1.00	1.10	1.09	0.20	0.08	0.03	0.0
Toshi 04#	none	1.06	1.00	none	-0.02	-0.05	0.0
TM 04	1.00	1.05	none	0.19	0.18	0.05	0.0

Appendix 9, cont.

Calf weight adjustments, contin.

ADG mk/wn

herd-year	bull*	heifer	steer	2	3	4	>5*
WhWh 95	1.00	1.10	none	0.13	0.06	0.01	0.0
WhWh 96	1.00	1.05	none	0.15	0.09	0.10	0.0
WhWh 97	1.00	**1.03**	none	0.17	0.06	0.04	0.0
BH 01	1.00	1.65	none	insuff	-0.03	0.06	0.0
BH 02	1.00	1.05	1.07	0.15	0.16	-0.03	0.0
Toshi 04#	none	1.00	1.00	none	-0.02	-0.03	0.0
TM 04	1.00	1.05	none	0.20	0.02	0.00	0.0

ADG b/wn

herd-year	bull*	heifer	steer	2	3	4	>5*
WhWh 95	1.00	1.12	none	0.16	0.09	0.03	0.0
WhWh 96	1.00	1.06	none	0.18	0.10	0.10	0.0
WhWh 97	1.00	1.04	none	0.21	0.09	0.02	0.0
BH 01	1.00	1.16	none	insuff	0.02	0.02	0.0
BH 02	1.00	1.09	1.10	0.17	0.12	0.00	0.0
Toshi 04#	none	1.05	1.00	none	0.00	-0.03	0.0
TM 04	1.00	1.04	none	0.20	0.08	0.03	0.0

* standard to which other calves are adjusted

\# steer calf was the standard in the absence of bull calves in this herd

insuff insufficient numbers to allow meaningful adjustment

Appendix 10

Calculator for deriving index weights

Performance Recording Data Entry Sheet

herd manager ______ **tel:** ______

farm name ______ **fax:** ______

date start of mating ______ **date end of mating** ______

(enter 1 in appropriate green box)

frame size of cows

small	0
medium	0
large	0

estimate of calving spread

tight	0
	0
moderate	0
	0
wide	0

Do you know the % of calves born in the first 21 days of calving?	0
If yes what is the percentage	

calf marking

marking date	
mean marking weight	

calf weaning

weaning date	
mean weaning wt	

(yellow)	cells are to be filled with data
(green)	cells are to be filled in with "0" or "1"
(grey)	cells are the result of calculation

Appendix 10, contin.

Calculator for deriving index weights

Performance Recording auto-calculation Sheet

anticipated start of calving				**7/10/00**
gestation length			281	
start of mating			0/01/00	
% calved in first 21 days				**83.0%**
if known				
if not known, estimated as			83.0%	
calving spread			**(interval)**	
tight	12			
	15			
moderate	18		0	
	21			
wide	24			

% calved 1st 21 d = intercept +(regression * interval)

0.83 + (-.014*interval)

interval to median CD = (-41.27 * (%calved1st 21 days)) + 42.37

median calving date		**7/10/00**	

anticipated start of calving date + interval to median CD =

mean birth weight		**0**	
frame size	ave b wt		**ave b wt**
small	28		
medium	33		0
large	38		

mean marking age **-281**

marking date - median calving date

mean ADG birth to marking **0.00**

mean gain birth to marking(mean marking wt less mean birth wt) divided by mean age at marking

mean ADG marking to weaning **#DIV/0!**

(mean weaning wt - mean marking wt) / days between marking and weaning

mean ADG birth to weaning **0.00**

(mean wn wt - mean birth wt)/ mean age at weaning

post mk ADG/ pre ADG % **#DIV/0!**

Appendix 10, contin.

Commercial beef cow
Index weight calculation

adj mkwt

Intercept	5.16
(unadjusted descriptive variables)	**Coefficients**
% calved 1st 21 d	-4.29
interval start to median CD	-0.01
ADG b/wn	0.64
ADG mk/wn	0.27
ADG b/mk	-4.41
average weaning wt	0.01

	index wts calculated
adj marking wt	
adj weaning wt	
adj mark/wn ADG	

adj wnwt

Intercept	-1.54
(unadjusted descriptive variables)	**Coefficients**
% calved 1st 21 d	4.63
interval start to median CD	0.13
ADG b/wn	11.78
ADG mk/wn	-8.08
ADG b/mk	-1.02
average weaning wt	-0.04

adj ADG mk/wn

Intercept	746.91
(unadjusted descriptive variables)	**Coefficients**
interval start to median CD	-3.38
ADG mk/wn	2,553.14
% calved 1st 21 d	-122.33
ADG b/wn	-1,559.35
[ADG mk/wn] / [ADG b/wn] %	-1,406.70
mean age at marking	2.09

Appendix 11

Summary of Whatawhata calving 2000

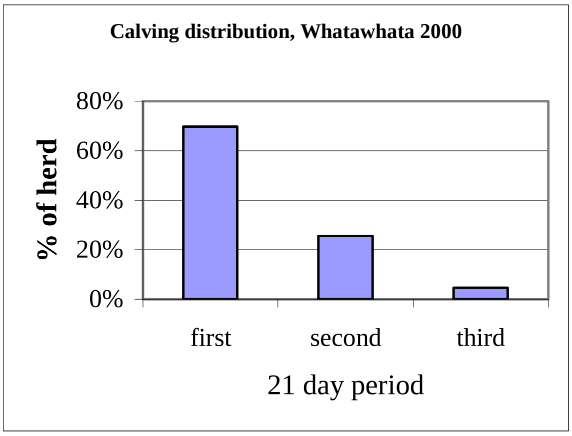
	sex of calf			AOD				
	bulls	heifers	total	2 yr	3yr	4yr	5-12 yrs	total
birth wt								
count	43	43	86	18	18	20	30	86
mean	30.9	29.7	30.3	26.7	30.4	30.3	32.4	30.3
Sd	4.3	4.0	4.2	3.3	4.4	4.3	3.0	4.2
c of v	13.9%	13.5%	13.9%	12.4%	14.5%	14.2%	9.3%	13.9%
adjustment	1.00	1.04	multiplic	5.7	2.0	2.1	0.0	additive
adjusted birth wt								
mean			33.0					
Sd			3.7					
c of v			11.2%					
calving date								
mean	15/09/00	13/09/00	14/09/00	16/09/00	20/09/00	12/09/00	10/09/00	14/09/00
Sd, days	12.7	12.6	12.6	11.6	15.5	7.9	13.0	12.6
median			11/09/00					
mark age								
mean	55.8	57.5	56.7	54.4	51.0	58.6	60.2	56.7
Sd	12.7	12.6	12.6	11.6	15.6	7.9	16.6	12.6
c of v	22.8%	21.9%	22.2%	21.3%	30.6%	13.5%	27.6%	22.2%
mark wt								
mean	83.0	78.2	80.6	72.0	73.0	84.2	87.9	80.6
Sd	17.7	15.3	16.6	14.3	16.3	13.1	16.6	16.6
c of v	21.3%	19.6%	20.6%	19.9%	22.3%	15.6%	18.9%	20.6%
adjustment	1.00	1.06	multiplic	15.9	14.9	3.7	0.0	additive
adjusted mk wt								
mean			90.2					
Sd			15.2					
c of v			16.9%					
V			231.0					
ADG b/mk								
mean	0.94	0.84	0.89	0.83	0.83	0.91	0.93	0.89
Sd	0.18	0.14	0.17	0.15	0.16	0.12	0.20	0.17
c of v	19.1%	16.7%	19.1%	18.1%	19.3%	13.2%	21.5%	19.1%
adjustment	1.00	1.12	multiplic	0.10	0.10	0.02	0.00	additive
adj ADG b/mk								
mean			0.98					
Sd			0.16					
c of v			16.3%					

Appendix 11, cont.

Summary of Whatawhata calving 2000, contin.

	sex of calf			AOD				
	bulls	heifers	total	2 yr	3yr	4yr	5-12 yrs	total
gross weaning								
age								
mean	184.8	186.5	185.7	183.4	180.0	187.6	189.2	185.7
Sd	12.7	12.6	12.6	11.6	15.5	7.9	13.0	12.6
c of v	6.9%	6.8%	6.8%	6.3%	8.6%	4.2%	6.9%	6.8%
weight								
mean	180.9	167.8	174.3	157.4	164.9	176.8	188.5	174.3
Sd	31.7	27.6	30.3	24.7	24.4	25.4	33.4	30.3
c of v	17.5%	16.4%	17.4%	15.7%	14.8%	14.4%	17.7%	17.4%
adjustment	1.00	1.08	multiplic	31.1	23.6	11.7	0.0	additive
adjusted wn wt								
mean			195.2					
Sd			27.9					
c of v			14.3%					
V			778.4					
ADG b/wn								
mean	0.81	0.74	0.77	0.71	0.75	0.78	0.83	0.77
Sd	0.14	0.12	0.13	0.11	0.11	0.11	0.16	0.13
c of v	17.3%	16.2%	16.9%	15.5%	14.7%	14.1%	19.3%	16.9%
adjustment	1.00	1.09	multiplic	0.12	0.08	0.05	0.00	additive
adj ADG b/wn					**200d wt**			
mean			0.86		mean			205.3
Sd			0.13		Sd			27.6
c of v			15.1%		c of v			13.4%
ADG mk/wn								
mean	0.76	0.69	0.73	0.66	0.71	0.72	0.78	0.73
Sd	0.14	0.13	0.13	0.10	0.11	0.12	0.16	0.13
c of v	18.4%	18.8%	17.8%	15.2%	15.5%	16.7%	20.5%	17.8%
adjustment	1.00	1.10	multiplic	0.12	0.07	0.06	0.00	additive
adj ADG mk/wn								
mean			0.82					
Sd			0.13					
c of v			15.9%					
post mk ADG/ pre ADG %			82.0%					

all adjustments are to bull calves out of 5 year old cows



Appendix 12

Summary of Whatawhata calving 2001

	sex of calf			AOD				
	bulls	heifers	total	2 yr	3yr	4yr	5-12 yrs	total
birth wt								
count	44	35	79	20	13	17	29	79
mean	27.0	27.2	27.1	25.1	24.9	28.9	28.4	27.1
Sd	3.7	4.9	4.2	3.8	3.5	4.4	3.8	4.2
c of v	13.7%	18.0%	15.5%	15.1%	14.1%	15.2%	13.4%	15.5%
adjustment	1.00	0.99	multiplic	3.3	3.5	-0.5	0.0	additive
adjusted birth wt								
mean			28.3					
Sd			3.8					
c of v			13.4%					
calving date								
mean	2/09/01	31/08/01	1/01/00	6/09/01	7/09/01	28/08/01	28/08/01	1/09/01
Sd, days	12.3	15.4	13.7	11.4	16.3	12.9	13.0	13.7
mark age								
mean	70.5	72.5	71.4	66.3	65.7	75.1	75.2	71.4
Sd	12.2	15.4	13.7	11.4	16.3	12.9	13.0	13.7
c of v	17.3%	21.2%	19.2%	17.2%	24.8%	17.2%	17.3%	19.2%
mark wt								
mean	88.6	88.7	88.6	76.7	77.2	99.4	95.7	88.6
Sd	19.0	19.7	19.2	12.9	17.8	18.6	17.1	19.2
c of v	21.4%	22.2%	21.7%	16.8%	23.1%	18.7%	17.9%	21.7%
adjustment	1.00	1.00	multiplic	19.0	18.5	-3.7	0.0	additive
adjusted mk wt								
mean			95.7					
Sd			16.3					
c of v			17.0%					
V			265.7					
ADG b/mk								
mean	0.87	0.84	0.86	0.78	0.79	0.94	0.89	0.86
Sd	0.17	0.13	0.15	0.10	0.13	0.19	0.13	0.15
c of v	19.5%	15.5%	17.4%	12.8%	16.5%	20.2%	14.6%	17.4%
adjustment	1.00	1.04	multiplic	0.11	0.10	-0.05	0.00	additive
adj ADG b/mk								
mean			0.90					
Sd			0.14					
c of v			15.6%					

Appendix 12, cont.

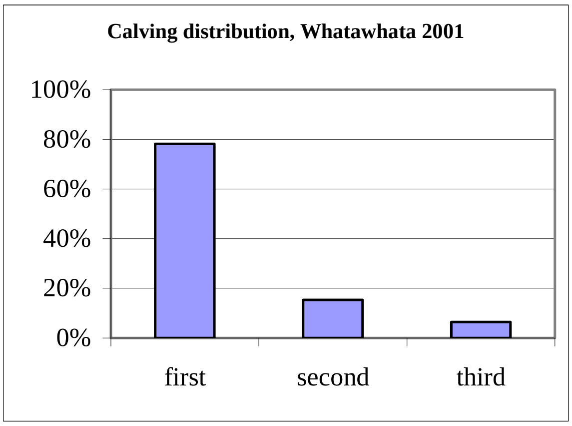
Summary of Whatawhata calving 2001, contin.

	sex of calf			AOD				
	bulls	heifers	total	2 yr	3yr	4yr	5-12 yrs	total
gross weaning								
age								
mean	197.5	199.5	198.4	193.3	192.7	202.1	202.2	198.4
Sd	12.3	15.4	13.7	11.4	16.3	12.9	13.0	13.7
c of v	6.2%	7.7%	6.9%	5.9%	8.5%	6.4%	6.4%	6.9%
weight								
mean	183.7	179.9	182.0	165.4	165.7	198.8	190.3	182.0
Sd	31.7	30.6	31.1	25.2	27.5	33.8	26.9	31.1
c of v	17.3%	17.0%	17.1%	15.2%	16.6%	17.0%	14.1%	17.1%
adjustment	1.00	1.02	multiplic	24.9	24.6	-8.5	0.0	additive
adjusted wn wt								
mean			189.8					
Sd			33.4					
c of v			17.6%					
V			1115.6					
ADG b/wn								
mean	0.77	0.76	0.77	0.72	0.67	0.84	0.80	0.77
Sd	0.19	0.11	0.16	0.10	0.25	0.16	0.11	0.16
c of v	24.7%	14.5%	20.8%	13.9%	37.3%	19.0%	13.8%	20.8%
adjustment	1.00	1.01	multiplic	0.08	0.13	-0.04	0.00	additive
adj ADG b/wn				**200d wt**				
mean		0.80			mean			189.3
Sd		0.15			Sd			31.5
c of v		18.8%			c of v			16.6%
ADG mk/wn								
mean	0.72	0.72	0.72	0.70	0.70	0.78	0.75	0.75
Sd	0.26	0.12	0.21	0.12	0.11	0.13	0.14	0.14
c of v	36.1%	16.7%	29.2%	17.1%	15.7%	16.7%	18.7%	18.7%
adjustment	1.00	1.00	multiplic	0.05	0.05	-0.03	0.00	additive

adj ADG mk/wn			
mean			0.75
Sd			0.13
c of v			17.3%

post mk ADG/ pre ADG % 83.7%

all adjustments are to bull calves out of 5 year old cows



Appendix 13

Correlations of calf measurements with 200 day weight,

Whatawhata calving 1995

actual weights, ADG's		cow rankings		cow percentiles	
birth wt	0.26	birth wt	0.25	birth wt	0.25
adj b wt	0.32	adj b wt	0.34	adj b wt	0.33
adj ADG b/mk	0.82	adj ADG b/mk	0.83	adj ADG b/mk	0.83
mark wt	0.50	mark wt	0.47	mark wt	0.46
adj mk wt	0.74	adj mk wt	0.78	adj mk wt	0.76
adj ADG mk/wn	0.82	adj ADG mk/wn	0.84	adj ADG mk/wn	0.83
gross wn wt	0.63	gross wn wt	0.57	gross wn wt	0.57
adj wn wt	0.92	adj wn wt	0.92	adj wn wt	0.92

other correlations of gross measures

	b wt	b/mk	mk wt	mk/wn	wn wt	adj wn wt
b wt		0.20	0.48	0.09	0.47	
b/mk			0.46	0.39	0.43	
mk wt				0.32	0.93	
adj mk wt						0.85

mean post marking adj ADG as a percentage of mean pre-marking adj ADG **68.8%**

Whatawhata 1996 calving:

Correlations of calf charcteristics with 200 day weight,

actual weights, ADG's		cow rankings		cow percentiles	
birth wt	0.46	birth wt	0.43	birth wt	0.42
adj b wt	0.51	adj b wt	0.47	adj b wt	0.47
adj ADG b/mk	0.84	adj ADG b/mk	0.85	adj ADG b/mk	0.85
mark wt	0.62	mark wt	0.60	mark wt	0.60
adj mk wt	0.72	adj mk wt	0.72	adj mk wt	0.72
adj ADG mk/wn	0.91	adj ADG mk/wn	0.91	adj ADG mk/wn	0.91
gross wn wt	0.77	gross wn wt	0.76	gross wn wt	0.75
adj wn wt	0.90	adj wn wt	0.91	adj wn wt	0.91

other correlations of gross measures

	b wt	b/mk	mk wt	mk/wn	wn wt	adj wn wt
b wt		0.15	0.23	0.47	0.42	
b/mk			0.00	0.58	0.67	
mk wt				0.36	0.92	
adj mk wt						0.91

mean post marking adj ADG as a percentage of mean pre-marking adj ADG **70.8%**

Appendix 13, cont.

Whatawhata 1997 calving

Correlations of calf charcteristics with 200 day weight,

actual weights, ADG's		cow rankings		cow percentiles	
birth wt	0.33	birth wt	0.37	birth wt	0.38
adj b wt	0.36	adj b wt	0.40	adj b wt	0.39
adj ADG b/mk	0.86	adj ADG b/mk	0.87	adj ADG b/mk	0.87
mark wt	0.72	mark wt	0.74	mark wt	0.74
adj mk wt	0.85	adj mk wt	0.89	adj mk wt	0.89
adj ADG mk/wn	0.85	adj ADG mk/wn	0.84	adj ADG mk/wn	0.83
gross wn wt	0.80	gross wn wt	0.80	gross wn wt	0.80
adj wn wt	0.95	adj wn wt	0.95	adj wn wt	0.95

other correlations of gross measures

	b wt	b/mk	mk wt	mk/wn	wn wt	adj wn wt
b wt		0.10	0.37	0.25	0.42	
b/mk			0.71	0.95	0.89	
mk wt				0.51	0.95	
adj mk wt						0.93

mean post marking adj ADG as a percentage of mean pre-marking adj ADG **83.3%**

Blackhills 2001 calving

Correlations of calf chacteristics with 200 day weight,

actual weights, ADG's		cow rankings		cow percentiles	
birth wt	0.28	birth wt	0.28	birth wt	0.25
adj b wt	0.31	adj b wt	0.29	adj b wt	0.27
adj ADG b/mk	0.69	adj ADG b/mk	0.64	adj ADG b/mk	0.64
mark wt	0.52	mark wt	0.45	mark wt	0.44
adj mk wt	0.57	adj mk wt	0.50	adj mk wt	0.49
adj ADG mk/wn	0.50	adj ADG mk/wn	0.52	adj ADG mk/wn	0.52
gross wn wt	0.80	gross wn wt	0.80	gross wn wt	0.80
adj wn wt	0.88	adj wn wt	0.85	adj wn wt	0.85

other correlations of gross measures

	b wt	b/mk	mk wt	mk/wn	wn wt	adj wn wt
b wt		0.24	0.35	-0.01	0.32	
b/mk			0.72	-0.23	0.54	
mk wt				-0.26	0.74	
adj mk wt						0.74

mean post marking adj ADG as a percentage of mean pre-marking adj ADG **30.3%**

Appendix 13, cont.

Blackhills 2002 calving:

Correlations of calf characteristics with 200 day weight,

actual weights, ADG's		cow rankings		cow percentiles	
birth wt	0.31	birth wt	0.34	birth wt	0.33
adj b wt	0.32	adj b wt	0.36	adj b wt	0.34
adj ADG b/mk	0.75	adj ADG b/mk	0.74	adj ADG b/mk	0.75
mark wt	0.48	mark wt	0.48	mark wt	0.49
adj mk wt	0.55	adj mk wt	0.56	adj mk wt	0.56
adj ADG mk/wn	0.73	adj ADG mk/wn	0.70	adj ADG mk/wn	0.73
gross wn wt	0.74	gross wn wt	0.70	gross wn wt	0.74
adj wn wt	0.87	adj wn wt	0.87	adj wn wt	0.85

other correlations of gross measures

	b wt	b/mk	mk wt	mk/wn	wn wt	adj wn wt
b wt		0.19	0.47	0.08	0.49	
b/mk			0.56	0.15	0.54	
mk wt				-0.02	0.84	
adj mk wt						0.82

mean post marking adj ADG as a percentage of mean pre-marking adj ADG **54.6%**

Toshi 2004 calving:

Correlations of calf charcteristics with 200 day weight,

actual weights, ADG's		cow rankings		cow percentiles	
birth wt	0.30	birth wt	0.30	birth wt	0.31
adj b wt	0.31	adj b wt	0.32	adj b wt	0.31
adj ADG b/mk	0.94	adj ADG b/mk	0.90	adj ADG b/mk	0.90
mark wt	0.83	mark wt	0.76	mark wt	0.76
adj mk wt	0.86	adj mk wt	0.79	adj mk wt	0.79
adj ADG mk/wn	0.60	adj ADG mk/wn	0.59	adj ADG mk/wn	0.59
gross wn wt	0.94	gross wn wt	0.91	gross wn wt	0.91
adj wn wt	0.96	adj wn wt	0.94	adj wn wt	0.94

other correlations of gross measures

	b wt	b/mk	mk wt	mk/wn	wn wt	adj wn wt
b wt		0.19	0.34	-0.02	0.29	
b/mk			0.89	0.33	0.90	
mk wt				0.16	0.94	
adj mk wt						0.94

mean post marking adj ADG as a percentage of mean pre-marking adj ADG **28.6%**

Appendix 13, cont.

Te Mania 2004 Calving

Correlations of calf charcteristics with 200 day weight,

actual weights, ADG's

	200 day all cows	200 day 2yr heifer only
birth wt	0.24	0.29
adj b wt	0.30	0.26
adj ADG b/mk	0.76	0.76
mark wt	0.41	0.63
adj mk wt	0.46	0.62
adj ADG mk/wn	0.85	0.86
gross wn wt	0.64	0.88
adj wn wt	0.80	0.86

cow rankings

	200 day
birth wt	0.28
adj b wt	0.33
adj ADG b/mk	0.76
mark wt	0.40
adj mk wt	0.46
adj ADG mk/wn	0.82
gross wn wt	0.59
adj wn wt	0.76

cow percentiles

	200 day
birth wt	0.28
adj b wt	0.33
adj ADG b/mk	0.76
mark wt	0.40
adj mk wt	0.46
adj ADG mk/wn	0.82
gross wn wt	0.59
adj wn wt	0.76

other correlations of gross measures

	b wt	b/mk	mk wt	mk/wn	wn wt	adj wn wt
b wt		0.04	0.32	0.11	0.44	
b/mk			0.46	0.36	0.47	
mk wt				0.16	0.87	
adj mk wt						0.85

mean post marking adj ADG as a percentage of mean pre-marking adj ADG **87.5%**

Appendix 14

Internal index calculation

index weights calculated by the following formula = $b = P^{-1} c$

where b is the index wt,

P is a matrix of of variances/covariances among the information sources

and c is a matrix of covariances between the information sources and the trait being predicted

$$P = \begin{bmatrix} V_{mkwt} & Cov_{mk,wn} & Cov_{mk,ADG} \\ Cov_{mk,wn} & V_{wnwt} & Co_{vwn,ADG} \\ Cov_{mk,ADG} & Co_{vwn,ADG} & V_{ADG} \end{bmatrix} \qquad C = \begin{bmatrix} Cov_{mk,200d} \\ Cov_{wn,200d} \\ Cov_{ADG,200d} \end{bmatrix}$$

Whatwhata 95 internal index calculation

	Variances	Sd
adj mk wt	98.01	9.90
adj wn wt	292.4	17.10
ADG mk/wn	0.0081	0.09

	P covariances
mk, wn	141.57
mk, ADG	0.40
wn, ADG	1.29

$$P = \begin{bmatrix} 98.01 & 141.57 & 0.40 \\ 141.57 & 292.4 & 1.29 \\ 0.40 & 1.29 & 0.0081 \end{bmatrix}$$

c =	Cov with 200d
adj mk wt	148.86
adj wn wt	317.07
ADG mk/wn	1.476

$$b = P^{-1} c = \begin{bmatrix} 0.30 \\ 0.68 \\ 59.79 \end{bmatrix}$$

$b_{adj\ mk\ wt} =$ 0.30

$b_{adj\ wn\ wt} =$ 0.68

$b_{ADG\ mk/wn} =$ 59.79

Appendix 14, cont.

Whatwhata 96 internal index calculation

$b = P^{-1} c$

	Variances	Sd
adj mk wt	268.96	16.4
adj wn wt	542.89	23.3
adj ADG mk/wn	0.01	0.1

P covariances	
mk, wn	340.68
mk, ADG	0.72
wn, ADG	1.76

P =

268.96	340.68	0.72
340.68	542.89	1.76
0.72	1.76	0.01

c =	Cov with 200d
adj mk wt	257.08
adj wn wt	469.65
adj ADG mk/wn	1.92

b = P-1 c =

P-1 c		b	
-0.0992		$b_{adj\ mk\ wt}$ =	-0.10
0.656059		$b_{adj\ wn\ wt}$ =	0.66
83.67343		$b_{ADG\ mk/wn}$ =	83.67

Whatwhata 97internal index calculation

$b = P^{-1} c$

	Variances	Sd
adj mk wt	184.96	13.60
adj wn wt	416.16	20.40
adj ADG mk/wn	0.01	0.10

P covariances	
mk, wn	255.13
mk, ADG	0.78
wn, ADG	1.68

P =

184.96	255.13	0.78
255.13	416.16	1.68
0.78	1.68	0.01

c =	Cov with 200d
adj mk wt	265.63
adj wn wt	446.93
adj ADG mk/wn	1.93

b = P-1 c =

P-1 c		b	
0.15382		$b_{adj\ mk\ wt}$ =	0.15
0.77361		$b_{adj\ wn\ wt}$ =	0.77
51.0349		$b_{ADG\ mk/wn}$ =	51.03

Black Hills 01 internal index calculation

$b = P^{-1} c$

	V	Sd
adj mk wt	1115.56	33.4
adj wn wt	1218.01	34.9
adj ADG mk/wn	0.1849	0.43

P covariances	
mk, wn	862.58
mk, ADG	-4.02
wn, ADG	5.86

P =

1115.56	862.58	-4.02
862.58	1218.01	5.86
-4.02	5.86	0.18

C =	Cov with 200d
adj mk wt	557.58
adj wn wt	888.64
adj ADG mk/wn	5.96

b =

0.204271		$b_{adj\ mk\ wt}$ =	0.204
0.481963		$b_{adj\ wn\ wt}$ =	0.482
21.40001		$b_{ADG\ mk/wn}$ =	21.400

Appendix 14, cont.

Blackhills 02 internal index calculation

$b = P^{-1} c$

	Variances	Sd
adj mk wt	686.44	26.20
adj wn wt	954.81	30.90
adj ADG mk/wn	0.0289	0.17

P covariances	
mk, wn	664.18
mk, ADG	-0.15
wn, ADG	2.80

P =

686.44	664.18	-0.15
664.18	954.81	2.80
-0.15	2.80	0.03

c =

Cov with 200d	
adj mk wt	366.77
adj wn wt	686.71
adj ADG mk/wn	3.11

b =

0.02
0.54
55.00

$b_{adj\ mk\ wt}$ =	0.02
$b_{adj\ wn\ wt}$ =	0.54
$b_{ADG\ mk/wn}$ =	55.00

Toshi 04 internal index calculation

$b = P^{-1} c$

	Variances	Sd
adj mk wt	763.6	27.63
adj wn wt	985.02	31.39
adj ADG mk/wn	0.0367	0.19

P covariances	
mk, wn	812.24
mk, ADG	0.88
wn, ADG	2.97

P =

763.60	812.24	0.88
812.24	985.02	2.97
0.88	2.97	0.04

c =

Cov with 200d	
adj mk wt	738.73
adj wn wt	942.91
adj ADG mk/wn	3.56

b =

0.345029
0.535993
45.35356

$b_{adj\ mk\ wt}$ =	0.35
$b_{adj\ wn\ wt}$ =	0.54
$b_{ADG\ mk/wn}$ =	45.35

Te Mania 04 internal index calculation

$b = P^{-1} c$

	Variances	Sd
adj mk wt	538.24	23.20
adj wn wt	979.69	31.30
adj ADG mk/wn	0.0196	0.14

P covariances	
mk, wn	617.46
mk, ADG	0.57
wn, ADG	2.91

P =

538.24	617.46	0.57
617.46	979.69	2.91
0.57	2.91	0.02

c =

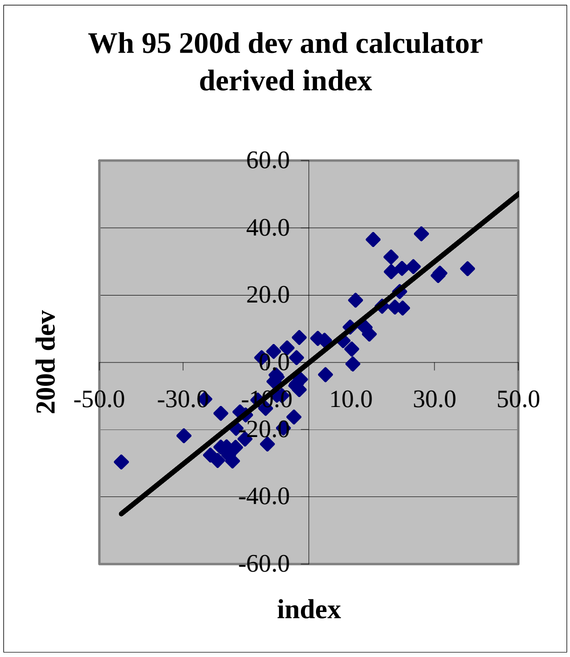
Cov with 200d	
adj mk wt	283.47
adj wn wt	666.92
adj ADG mk/wn	3.2

b =

1.165539
-0.78376
245.7332

$b_{adj\ mk\ wt}$ =	1.17
$b_{adj\ wn\ wt}$ =	-0.78
$b_{ADG\ mk/wn}$ =	245.73

Appendix 15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200d dev
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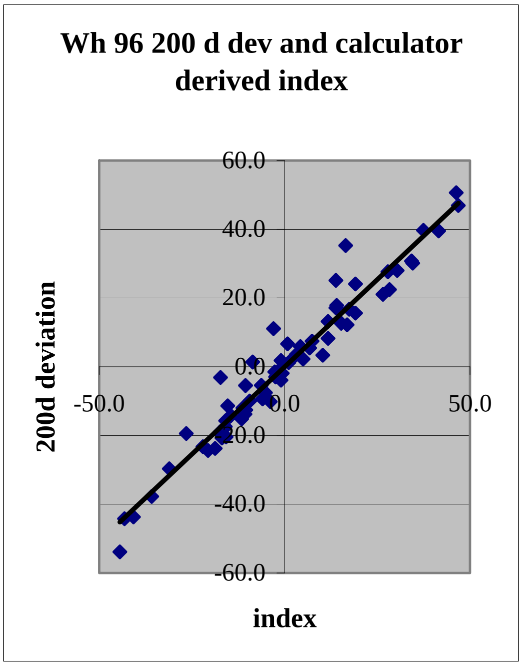
30.0
50.0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200d deviation
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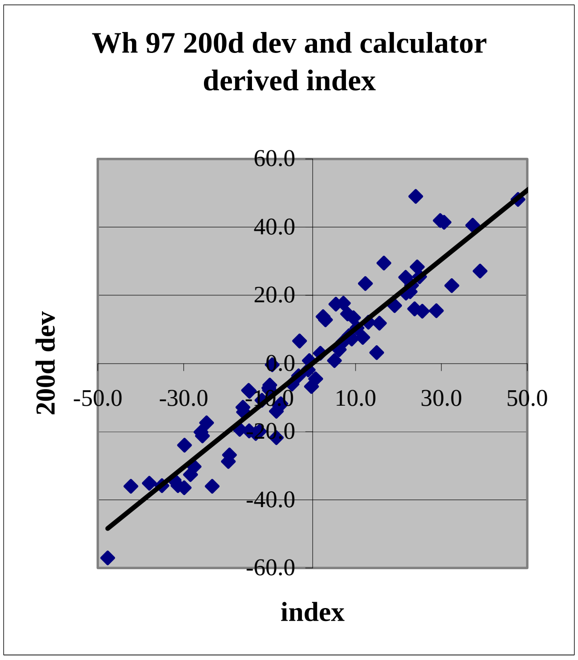
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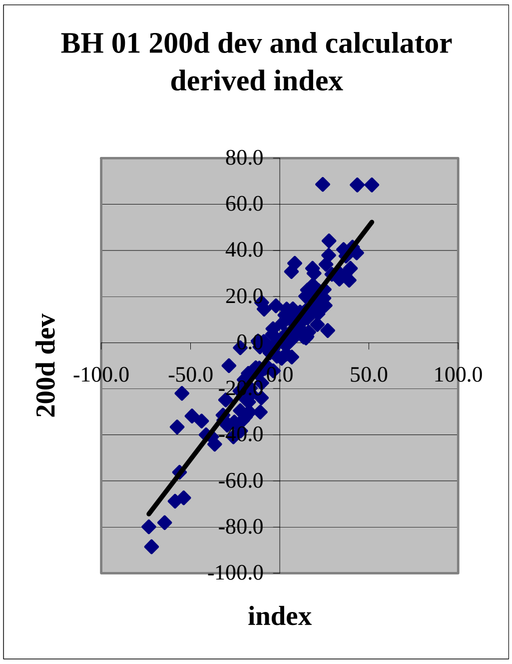
10.0
30.0
50.0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index
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-80.0
-100.0
-100.0
-50.0
0.0
50.0
100.0

Appendix 15, cont.