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Evaluation of a practical weaning weight index for extensively-grazed beef cows

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ABSTRACT

Little objective culling is practiced in many commercial beef herds in New Zealand possibly due to the absence of a performance recording system that is able to accurately predict the calf rearing ability of cows when calving date is unknown. Data of 1,306 calves from four different herds including birth, marking and weaning weights and dates was used to construct an Extensively Grazed Weaning Index (ECWIndex) to rank cows on their calf rearing ability without the use of calving date. Three indicator traits, marking weight, weaning weight and average daily gain (ADG) between marking and weaning (all adjusted for sex of calf and age of dam but not for age of calf) were used in the index as they were the most favourably correlated with 200 day weight of the readily measurable calf traits considered. A number of easily obtainable herd variables were used to calculate index weights for the indicator traits. When the model was applied to data from two additional herds the cow ranking based on the index was very similar to that based on 200 d weight ($r = 0.95$ and 0.92 and $R^2 = 91.2\%$ and 85.4%). The use of the model will provide commercial herd managers an objective method for culling cows and selecting replacement heifers and may eventually allow the use of data from commercial herds in the calculation of breeding values of stud bulls.

Keywords: beef cows; performance recording; extensive; 200d weight.

INTRODUCTION

The main reason many NZ sheep and beef farmers have a herd of beef cows is to control pasture quality in order to improve production from their sheep (Thomas, 2007). Over the years numerous industry commentators have extolled the benefits of enhancing sheep production, lifting lambing percentages and increasing lamb carcass weights. The potential to increase the productivity and efficiency of the beef cow has largely been ignored. It is not surprising then that beef cow numbers have declined (Economic Service, 2006) and Friesian bulls have spread across the landscape.

Advice to the beef industry has concentrated on bull selection (Baker & Morris, 1981; Baker *et al.*, 1987; NZ Beef Council, 1991; Meat and Wool New Zealand, 2000;). Quantitative geneticists have devised ever more eloquent formulas to predict performance for a growing number of traits, many of which are unlikely to have immediate economic benefit to commercial producers. There have been several attempts by geneticists to define breeding objectives for the industry (Amer, 1998; Newman *et al.*, 1992) but these have not been widely supported by commercial herd managers.

More recently geneticists have developed indices summarizing estimated breeding values (EBV's) in dollar terms in order to simplify bull selection; the NZ Angus Self-Replacing Index is one example. Dystocia is rarely a problem in hill

country cow herds (Thomas, 2007) yet calving ease is the most important trait in the Angus SR index. Commercial herds routinely cull non-pregnant cows (Thomas, 2007) but consistent calf production by stud cows is not a necessity for a high index ranking as nearly 50% of the highest ranking cows six years and older have failed to rear a calf at least once (NZ Angus). The usefulness of such indices, seemingly out of touch with commercial practice, is debatable.

Despite the widespread use of EBV's and indices in bull sale catalogues, (*e.g.* Hargreaves, 2005; Wilding, 2005) there is little evidence to suggest that the national beef herd has become more efficient. Over the last twelve years the national beef calving percentage has declined from 83.8% in 1995-97 to 82.0% in 2003-05 (Economic Service, 2006). Over the same period the sheep industry has dramatically lifted the national lambing percentage by over 20% (Economic Service, 2006).

The genetic trends for growth and liveweight of the major breeds have steadily trended upwards (Angus Society of Australia, January 2003). Genetically larger beef cattle not only have higher feed demands but have in some cases been shown to be less fertile (Golden *et al.*, 2000). Some commentators have questioned whether the production efficiency of the beef industry (kg meat produced per kg of dry matter consumed) has improved or declined over time (Macfarlane,

2003).

Female selection has largely been ignored with advice to the industry largely based on attaining the “critical breeding weight” before mating yearling heifers (Hanley & Mossman, 1977; Vermunt, 1994).

With steadily falling cow numbers, increased herd maintenance costs and a declining national calving percentage it is perhaps timely to question the sole reliance on stud-based EBV's for industry progress. Increased emphasis on objective female phenotype selection is one alternative strategy. Careful study of the components of genetic change suggest the benefits of female selection are not as far behind those of male selection as traditionally thought.

1. **The contribution of an individual cow to the total variance of her calf's weaning weight is approximately four times of that of his sire** (Meyer, 1992). Female selection includes the permanent environmental effects which, although not transmissible to the next generation, can be responsible for as much as 30 kg in weaning weight (Johnsson & Morant, 1984; Johnsson & Obst, 1984).
2. **Female selection is not affected as much by genetic x environmental interactions as bull selection may be.** The environment of most hill country beef breeding properties is considerably different than that of most bull-breeding properties. G x E interactions have been shown to invalidate some predictions of fertility (Bourdon, 1998), carcass characteristic (Charteris *et al.*, 1997) and growth (Bourdon, 1998).
3. **The selection intensity possible in heifers is roughly similar to that achieved in bulls when considered from an industry perspective.** The pool of potential Angus sires, for example, consists largely of the 8,000 bull calves registered each year from which 2500 are purchased by the beef industry (Charteris, 1996). A one in three selection intensity is also possible for female selection in most commercial herds.
4. **The generation interval, as measured by the average age of parents is not that dissimilar in bulls and cows;** cows may have longer productive lives but they generally have their first progeny at age two compared to three for bulls. The short lifespan of bulls due to their high wastage

rates may be seen as an advantage by geneticists but it is not viewed as favourably by bull-buying herd managers.

For commercial beef producers it may well be that some effort could profitably be directed towards female selection. A 2005 Canterbury beef survey found very few commercial herds practiced any objective culling and most chose replacement heifers on the basis of an often subjective assessment of size and type (Thomas, 2007).

Objective female culling is based on the repeatability of a cow's calf rearing ability; published estimates of the repeatability of weaning weight range between 0.3 – 0.6 (Koots *et al.*, 1994) with records of adjacent years more highly correlated than those more distant.

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). In most cases comparison is made after adjustment of the weaning weight of the calf for age of calf, sex of calf (SOC) and age of dam (AOD) with correction for the age of the calf being the most important (Nicoll & Rae, 1977). All of the published methods require knowledge of calving date to allow age of calf correction. Since very few commercial herd managers have knowledge of the calving date of individual cows in their extensively grazed herds, it is no wonder that little performance recording has been practiced in commercial herds.

Meyer found a highly positive genetic correlation ($r > 0.90$) between pre-weaning ADG and 200 day weight in a farmlet trial that had relatively constant feeding levels from calving to weaning and suggested pre-weaning ADG could be used as an alternative to 200 day weight in performance recording programs (Meyer & Graser 1994). Whether pre-weaning ADG would be an equally reliable indicator of 200d weight in situations in which ADG declines markedly in the later portion of lactation due to summer drought and reduced feed supply is unknown.

Since most NZ beef calves are yarded between 2-4 months of age in order to castrate male calves and ear mark/ear tag, it may be possible to develop a performance recording system for extensively grazed commercial cows using some combination of readily available measures, *e.g.* marking weight, weaning weight and/or ADG between marking and weaning. Such a method would not allow comparison between herds or years but it would be useful as an objective within-herd culling method of improving phenotype performance.

MATERIALS AND METHODS

Calving records were obtained from four Angus herds.

- Whatawhata herd: A total of 202 cow/calf records from the 1995, 1996 and 1997 calving seasons were obtained from an Angus cow herd involved in a weight selection trial at Whatawhata Hill Country Research Station. Most years pasture growth was reliably maintained throughout the summer period. Calves were weaned relatively early and at reasonably light weights.
- Blackhills herd: Data from 352 Angus cows during 2001 and 2002 were also available. Cows were calved on the flats and rotated daily until marking when they were moved to a high country tussock runoff where pasture was abundant but of poor quality.
- Toshi herd: Data from 404 Angus cows calving in the spring of 2004 on Toshi Farm, in the Hanmer Basin of North Canterbury were also available. Although the cows at Toshi were calved in very good condition, by mid-summer feed quality and quantity had both declined markedly due to summer drought.
- Te Mania herd: Data were obtained from 348 Angus cows farmed by the Te Mania Angus stud from coastal Kaikoura in North Canterbury. Cows at Te Mania were lightly stocked and well fed right up to the time of weaning.

Altogether valid data from 1,306 cow calf pairs spread over four properties and six different years were available.

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. There was considerable variation between the herds in the means of birth wt, ADG, marking age, weaning weight, and calving date (Table 1).

Table 1: Range of calving parameters in the seven herd-years.

Trait	Minimum	Maximum
Birth weight (kg)	27.2	38.3
Median calving date	24-Aug	29-Sep
Mean marking age(days)	64.7	188.1
ADG birth/markings (kg/day)	0.77	1.07
ADG marking/weaning	0.27	0.96
Mean weaning weight (kg)	136.4	242.3
200 d weight (kg)	171.4	261.4

MEASURES OF COW PERFORMANCE

The traditional measure of cow performance, the 200 day weight of a cow's calf (200d wt), was calculated by adjusting calf weaning weight multiplicatively for SOC and additively for AOD according to well established methods (Nicoll & Rae, 1977).

Marking weight (mkwt)

At some time between birth and weaning calves were yarded and weighed. No adjustments were made to the recorded weight.

Adjusted marking weight (adjmkwt)

Marking weights were adjusted multiplicatively for SOC and additively for AOD as described above. No adjustment was made for the age of the calf.

Weaning weight (wnwt)

Calves were weighed at weaning; no adjustments were made.

Adjusted weaning weight (adjwnwt)

Calf weaning weights were adjusted multiplicatively for SOC and additively for AOD. No adjustment was made for the age of the calf.

ADG of calves

The ADG between birth and marking, marking and weaning and birth to weaning of each calf was calculated and adjusted additively for AOD and multiplicatively for SOC of calf.

Cows were ranked within each herd-year by the traditional measure (200 d wt) and by each of the alternative measures. Comparison of the traditional and alternative measures of cow performance was made using actual measures, cow ranking within the herd-year and percentile ranking of cows within each herd-year.

Finally an Extensively Grazed Cow Wean Index (ECWIndex) was constructed using deviations from the herd-year means (Bourdon, 1997) of the three alternative measures of cow performance (indicator traits) most highly correlated with the 200d weights.

Index weights for each of the indicator traits were calculated using the standard formula (Miller, 2006):

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

where

b is a vector representing the index weights of the indicator traits,

P is a matrix of the variances and covariance's among the information sources

c is a matrix of the covariance's of the indicator traits and the trait being predicted

The index values thus derived were specific for each herd-year.

In order to derive a generic model able to calculate ECWIndex values for any herd, a model for determining index weights was developed by regressing a number of variables from each herd on the index weights of that herd. A progressive series of regressions was used starting with the herd variable which explained the largest proportion of variance of each index weight and progressively adding additional variables.

Some of the herd variables found to be most useful in calculating index weights might not be readily available in some commercial herds. In order to estimate the necessary variables in those herds a calculator was constructed using information very readily available including frame size of cows, calving spread or approximate % calving in the first 21 days, the date of the start and finish of mating, the marking and weaning dates and the mean unadjusted marking and weaning weights of calves; the calculator is Figure 1.

Finally data from two new herd-years not involved in the model development (Whatawhata 2000 and 2001) were used to test the accuracy of the calculator and the model by comparing the traditional 200d weight and the ECWIndex.

RESULTS

Cow rankings

It made little difference if the comparison of 200d weight and the alternative measures of cow productivity was done on the basis of actual measures, cow ranking within the herd-year or percentile ranking. Accordingly, only the correlations between deviations of actual measures were used.

Indicator traits

The correlations between the potential indicator traits and 200d weights are given in Table 2. None of the alternative traits alone consistently and accurately estimated 200d wt. The indicator traits most highly correlated with 200d weight were:

- 1) SOC- and AOD-adjusted weaning weight,
- 2) SOC- and AOD-adjusted ADG between marking and weaning, and
- 3) SOC- and AOD-adjusted marking weight.

The relationship of these three traits was strong enough to suggest that an index based on those three traits might more accurately predict 200d wt than any one of the traits alone.

Herd variables

For most years the calculator was able to accurately predict herd variables as shown in Table

3. Due to an unsuccessful embryo transfer program in 2003 the Te Mania 2004 calving was very protracted and the calculator was not as successful in that very unusual year.

Generic index to estimate 200d wt

The model was used to generate ECWIndex values for the calves from the seven original herd-years by using the calculator to predict herd variables which were in turn used to determine index weights for the indicator traits. The indices generated were very highly correlated with the actual 200d deviations and explained a very high proportion of the variance (Table 4).

Use of the calculator and index on data from other herd-years

The calculator and model were used to generate ECWIndex values for calves from two other herds not involved in the model development, Whatawhata 2000 and 2001. The relationship between the ECWIndex 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 (Figure 2).

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 predict herd variables quite accurately. These predicted herd variables were then used to calculate index weights that when applied to readily-obtainable indicator traits successfully produced an index that ranked cows in a way that was very similar to the ranking based on the traditional 200d weight. This ECWI method, therefore, provides a reliable method of accurately ranking cows on their calf rearing ability when calving date is unknown.

The accuracy of the ECWIndex model was assessed by its ability to estimate 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 authors were regrettably from one of the original herds but from different years. Nevertheless the calculator and model were able to produce indices that were very highly correlated with the 200d deviations.

Estimation of cows' calf rearing ability and identification of dam parentage of calves post marking will for the first time enable objective culling of extensively grazed cows. Objective

Figure 1: Herd Variable Calculator.

Enter data this section							
herd manager	<input type="text"/>						
start of mating	<input type="text"/>					end of mating	<input type="text"/>
frame size of cows	<input type="text" value="small"/>	<input type="text" value="medium"/>	<input type="text" value="large"/>				
approximate % calved in first 21 days	<input type="text" value="80%"/>	<input type="text" value="70%"/>	<input type="text" value="60%"/>	<input type="text" value="50%"/>	<input type="text" value="40%"/>		
calf marking date	<input type="text"/>				mean marking wt	<input type="text"/>	
calf weaning date	<input type="text"/>				mean weaning wt	<input type="text"/>	
Calculated Variables appear here							
date anticipated start of calving	<input type="text"/>						
interval to median CD	<input type="text"/>				mean weight	birth	<input type="text"/>
mean marking age	<input type="text"/>				mean age	weaning	<input type="text"/>
mean average daily gains							
birth marking	to	<input type="text"/>			marking weaning	to	<input type="text"/>
		post mk ADG/ pre ADG %					<input type="text"/>
index weights							
adjusted marking weight	<input type="text"/>						
adjusted weaning weight	<input type="text"/>						
adjusted ADG marking to weaning	<input type="text"/>						

Table 2: Correlations of 200d weight and indicator traits from all 7 herd-years.

Herd-Year	Birth wt. ¹	Mark wt. ²	Adj. Mark wt. ³	ADG B/Mk ⁴	Wean wt. ⁵	Adj. Wn wt. ⁶	ADG Mk/Wn ⁷
CM 95	0.26	0.50	0.74	0.82	0.63	0.92	0.82
CM 96	0.48	0.59	0.72	0.75	0.74	0.90	0.81
CM 97	0.33	0.72	0.85	0.86	0.80	0.95	0.85
BH 01	0.27	0.54	0.57	0.69	0.80	0.88	0.50
BH 02	0.31	0.48	0.55	0.75	0.74	0.87	0.73
TM 04	0.24	0.41	0.46	0.76	0.64	0.80	0.85
TS 04	0.30	0.83	0.86	0.94	0.94	0.96	0.60

¹unadjusted birth weight, kg²unadjusted marking weight, kg³marking weight adjusted for AOD and SOC⁴average daily gain between birth and marking adjusted for AOD and SOC⁵unadjusted weaning weight⁶weaning weight adjusted for AOD and SOC⁷average daily gain between marking and weaning adjusted for AOD and SOC

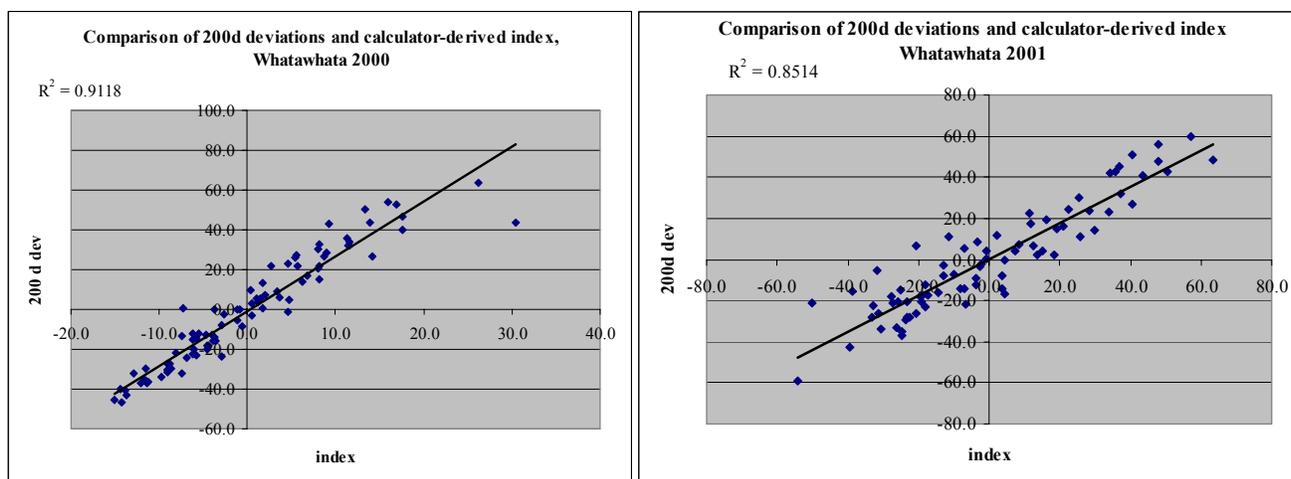
Table 3: Comparison of actual and calculator-estimated herd variables.

Herd Year	Birth weight		Mean CD		B/Mk ADG		Mk/Wn ADG as % of B/Mk ADG	
	Est.	Actual	Est.	Actual	Est.	Actual	Est.	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%

Table 4: Relationship of 200d deviations and generic, herd variable-derived index for cows in the 7 original herds.

Herd	Wh95	Wh 96	Wh 97	BH 01	Bh02	Toshi	TeMania
r	0.92	0.97	0.95	0.89	0.93	0.97	0.91
R ²	85.1%	94.7%	90.3%	84.7%	86.2%	94.9%	82.6%

Figure 2: Comparison of 200d deviations and the calculator derived index for two herd/years not involved in the index derivation.



assessment of extensively grazed cows coupled with genetic marker determined sire parentage of calves in multiple sire mated-herds will now allow more accurate assessment of breeding values of stud produced bulls used in commercial herds.

The relationship between SOC- and AOD-adjusted calf weaning wt and 200d wt was strong enough ($r=90$) to suggest that calculation of an index was possibly unnecessary. However reliance on weaning weight alone makes identification of dam parentage difficult. The easiest and most convenient times to record calf parentage are at birth and immediately after marking. Once calves are weaned farmers are reluctant to re-unite them to assess parentage. Marking is also a less stressful time. At weaning, cows are being pregnancy tested, culls sold, calves loaded for transport to calf sales, and retained calves are processed.

It is often argued that after involuntary culling, commercial beef producers have little scope for production-based, voluntary culling. It is true that herds with high empty rates and high attrition due to lameness, bad udders, poor behaviour, cancer

eye and loss of condition and that only retain enough heifers to replace 20% of the herd have few opportunities for production culling. Calf production from heifers has been shown to be profitable (Keeling *et al.*, 1991), more efficient than that from mature cows (Klosterman *et al.*, 1979) and the best means of predicting future calf production (Frey *et al.*, 1972). Retaining more than the usual number of heifer calves and basing final selection on an objective assessment of calf rearing ability is now a practical selection policy.

Anecdotally there is considerable dissatisfaction among many commercial herd managers with a continuation of the policy of buying bulls with “hot house” genetics that perform well on studs but not so well on tussock and snow. A recently begun Beef Cow Efficiency Project has attracted over 30 commercial herd managers in the South Island who have begun performance recording female selection programs based on the ECWIndex described in this report. From that we conclude that there is considerable interest in evaluating individual cow performance. The reason it has not

been done in the past has not been the lack of interest but the lack of a suitable method.

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REFERENCES

- Amer, P.; Emmans, G.C. 1998: Predicting changes in food energy requirements due to genetic changes in growth and body composition of growing ruminants. *Animal Science* **66**: 143-153.
- Angus Society of Australia. January 2003. Angus group breedplan sire summary, January 2003. Angus Society of Australia.
- Baker, R.L. 1973: Beef cattle improvement through performance recording and selection. *Proceedings of the New Zealand Society of Animal Production* **33**: 194-203.
- Baker, R.L.; Morris, C.A. 1981: Breeding plans for beef production. *Proceedings of the Ruakura Farmers' Conference* **31**: 1-11.
- Baker, R.L.; Morris, C.A.; Packard, P.M. 1987: Selection of bulls and heifers. *Proceedings of the Ruakura Farmers' Conference* **36**: 1-6.
- Bourdon, R.M. 1997: Understanding animal breeding. first ed. Prentice Hall, Upper Saddle River, New Jersey.
- Bourdon, R.M. 1998: Shortcomings of current genetic evaluation systems. *Journal of Animal Science* **76**: 2308-2323.
- Charteris, P.L., Garrick, D.J.; Morris, S.T. 1997: Sire by finishing environment interactions for beef cattle carcass and meat quality traits. *Proceedings of the New Zealand Society of Animal Production* **57**: 192-195.
- Charteris, P.L. 1996: Characteristics of beef cattle breeding industry structure. *Proceedings of the New Zealand Society of Animal Production* **56**: 386-389.
- Economic Service, Meat and Wool NZ, 2006. Sheep and beef farm survey.
- Frey, J.; Frahm, R.R.; Whiteman, J.V.; Tanner, J.E.; Stephens, D.F. 1972: Evaluation of cow type classification score and its relationship to cow productivity. *Journal of Animal Science* **34**: 1-8.
- Golden, B.L.; Gould, L.S.; Hough, R.L.; Schutte, B.R. 2000: Performance update: Heifer pregnancy epd--an economically relevant trait for improving heifer fertility. Red Angus Magazine.
- Hanley, G.; Mossman, D. 1977: Commercial beef production on hill country. *New Zealand Veterinary Journal* **25**: 3-7.
- Hargreaves, G. 2005: Kakahu Angus Bull Sale Catalogue.
- Johnsson, I.; S. Morant. 1984: Evidence of a negative relationship between heifer growth and first calf weaning weight in commercial herds. *Journal of Australian Experimental Agriculture and Animal Husbandry* **24**: 10-14.
- Johnsson, I.D.; Obst, J.M. 1984: The effects of level of nutrition before and after 8 months of age on subsequent milk and calf production of beef heifers over three lactations. *Animal Production* **38**: 57-68.
- Keeling, P.C.B.; Morris, S.T.; Gray, D.I.; W.J. Parker. 1991: A modelling study of once-bred heifer beef production. *Proceedings of the New Zealand Society of Animal Production* **51**: 389-393.
- Klosterman, E.W.; Keuren, R.W.Van.; Parker, C.F.; Byers, F.M. 1979: Breeding and management systems to optimize beef breeding herd productivity. Beef Cows and Calves 1979: a summary of research. Ohio Research and Development Centre 1979: 17-20.
- Koots, K.R., Gibson, J.P.; Smith C.; Wilton, J.W. 1994: Analysis of published genetic parameter estimates for beef production traits. 1. Heritability. *Animal Breeding Abstracts* **62**: 309-338.
- Macfarlane, A.M. 2003: Keeping the beef cow competitive. In: Canterbury Angus Field-day 2003, Cleardale, Methven, New Zealand. P. 7-15.
- Meat and Wool New Zealand. 2000: Bull selection.
- Meyer, K. 1992: Variance components due to direct and maternal effects for growth traits of Australian beef cattle. *Livestock Production Science* **31**: 179-204.
- Meyer, K.G.; Graser, H-U. 1994: Scope for genetic evaluation and selection of beef cattle for growth to weaning when birth dates are not recorded. *Australian Journal of Experimental Agriculture* **45**: 819-827.
- Miller, S.P. ed. 2006: Quantitative genetics. I. Toronto, Ontario.
- Morris, C.A. 1980: Some benefits and costs of genetic improvement in the New Zealand sheep and beef cattle industry. *New Zealand Journal of Experimental Agriculture* **8**: 331-340.
- Newman, S.; Morris, C.A.; Baker, R.L.; Nicoll, G.B. 1992: Genetic improvement of beef cattle in New Zealand: *Breeding objectives*. *Livestock Production Science* **32**: 111-130.
- New Zealand Angus Association webpage: nzangus.co.nz
- New Zealand Beef Council, 1991: Bull fertility--bull potential.
- Nicoll, G.B.; Rae. A.L. 1977: Adjustment factors for Hereford and Angus cattle weights. *New Zealand Journal Agricultural Research* **20**: 269-278.
- Thomas, C.W. 2007: Parameters of beef production in Canterbury, New Zealand. In: Proceedings Sheep and Beef Cattle Veterinarians, NZVA, 36th, Palmerston North NZ.
- Vermunt, J.J. 1994: Factors affecting reproductive performance of beef cattle. *Proceedings of the 24th Seminar of the Sheep and Beef Cattle Society, New Zealand Veterinary Association* **159**: 60-85.
- Wilding, T. 2005: Te Mania Bull Sale Catalogue.