A GENETIC ANALYSIS OF THE BARTLOW COMBINE

NGUNI CATTLE STUD

by

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CHAPTER 1

INTRODUCTION

The name "Nguni" is derived from the Nguni tribe of people who occupied most of the south-eastern parts of Africa in the early nineteenth century. The cattle were initially referred to as "Zulu" or "Swazi" depending on the tribe of Nguni people in whose possession they were found but subsequently recognized as one breed (Bonsma *et al*, 1950).

Curson & Thornton (1936) and Bisschop (1937) suggest that the Nguni breed of cattle may have had their origin in an inter-mixture of the extinct Hamitic Longhorn and the Lateral-Horned Zebu in north-eastern Africa which migrated to southern Africa (Joshi *et al*, 1957). The Nguni is classified as a *Bos indicus* (Epstein, 1971), Sanga type, due to the cervico-thoracic hump (Mason & Maule, 1960). However, Meyer (1984) reported indigenous Sanga cattle to have a sub-metacentric Y-chromosome which is characteristic of *Bos taurus* in contrast to the acrocentric Y-chromosome found in *Bos indicus*, Zebu types.

In the past, indigenous cattle in southern Africa were mainly used as foundation stock for upgrading with *Bos taurus* bulls, (Faulkner, 1947; Walker, 1952; Vorster, 1962) such as the South Devon, Friesland and Red Poll and later also the indigenous Afrikaner (Schutte, 1935; Bonsma *et al*, 1950), which were thought to be superior. The Cattle Improvement Act (Act 48 of 1934), did not regard the Nguni favourably as inspectors condemned all bulls showing signs of Nguni characteristics. This Act was not applicable in the traditional Zulu areas where Proclamation R198 of 1934 promoted the improvement of the indigenous breeds and attempts were actually made to preserve the Nguni as a pure breed and to improve its conformation and milk production.

It was only during the 1940's that the potential of indigenous breeds were realized. The failure of the upgrading programmes of such breeds with the Afrikaner and *Bos taurus* in subtropical and tropical regions due to the decline in the reproduction and production, focused the attention on the development of the various indigenous breeds. In 1947, the Department of Agriculture appointed a Committee (Bonsma *et al*, 1950) to investigate the nature, numbers and desirability and means of preserving indigenous livestock. They recommended that steps be taken to arrest the deterioration of indigenous cattle and that a purebred herd of not less than 500 Nguni breeding stock be established to investigate the growth, production and reproduction potential of the breed and to serve as the nucleus of Nguni stud cattle.

The Bartlow Combine Breeding Station was established in approximately 1954 to accommodate the Nguni herd which originated in 1931. The herd has subsequently played a significant role in the development of the breed and has formed the foundation of a number of Nguni studs. In 1983, the Nguni became a recognized breed under the Livestock Improvement Act (Act 25 of 1977) and the herd at Bartlow Combine was registered with the South African Stud Book in 1985. The Nguni Cattle Breeders' Society currently consists of about 125 registered studs with approximately 15 000 registered cattle. The characteristics of Nguni cattle have been described by Armstrong & Meyer (1986).

The ability of the Nguni to produce and reproduce under harsh environmental conditions (Barnard & Venter, 1983; Scholtz, 1988), their natural immunity against endemic diseases (Spicket & Scholtz, 1985) and its suitability as a dam line in terminal crossbreeding (Hofmeyr, 1974; Scholtz, 1988) have generated interest in the breed amongst many cattle farmers.

The introduction of the National Beef Cattle Performance and Progeny Testing Scheme in 1959 made a significant contribution

to the livestock industry since it provides facilities for the construction of a reliable database and the analysis of performance data of various important economic traits. Prior to this, data on a number of traits such as weight at different ages, milk production, body measurements, etc. were collected since 1931 and kept in numerous registers, but due to the absence of a suitable system of storage and analysis, a considerable amount of the information has unfortunately been mislaid making it useless for research purposes.

The development of mixed model procedures during the 1970's and the theory of Best Linear Unbiased Prediction (BLUP) has created new dimensions in animal breeding. Not only can predicted breeding values be effectively used in breeding programmes, but the methodology can be effectively used for research.

This dissertation is in essence compiled from four articles submitted to the South African Journal of Animal Science (Kars *et al*, 1994, 1994a, 1994b, 1994c) but also includes relevant information on the history of the stud as well as a chapter on general conclusions and recommendations. No attempt has been made to present individual predicted breeding values in the dissertation, which was ironically, from a practical point of view, one of the major motivations for this, and probably many other similar studies.

CHAPTER 2

THE NGUNI STUD AT BARTLOW COMBINE

2.1 History of the stud

The history of the stud at Bartlow Combine has been compiled from a host of official reports and correspondence on record at the Department of Agriculture and the Department of Agriculture and Forestry, KwaZulu. Reference is only made to specific reports which are considered suitable.

Mr R.W. Thornton, former Director of Agriculture of the Department of Native Affairs, visited Nigeria in 1927 (Curson & Thornton, 1936) and was impressed with the White Fulani cattle that occurred in the northern parts of this country. He subsequently recommended the establishment of a herd of white Nguni cattle on the farm Thokazi near Nongoma. The aim of the herd was to preserve the breed and to improve its conformation and milk production.

In the Zulu tradition, these cattle are called "iNyoni-ka-yi-Pumule" meaning "birds that have no rest" since they were so numerous that they gave no rest to the tick-birds that followed them. These cattle have a characteristic colour pattern of a white hair coat while the muzzle, inner surfaces of the ear and horn tips are black. The name was given by the Zulu King Cetswayo, and these cattle were claimed, also by his predecessors Shaka and Dingaan, as a recognized tax system. They were not assigned to any particular kraal, but were kept and cared for throughout the whole of Zululand.

In January 1931, one cow, four heifers and a bull calf were purchased from Inkosi Mtubatuba at Somkhele, district Hlabisa, and in March 1931 a mature bull, three cows and three heifers

were purchased in the Nongoma district. The establishment of a specifically white Nguni herd was not considered essential. The progeny varied in colour and it was realized that there were other factors of importance than colour. Efforts were made to improve conformation and to conduct research on milk production by hand-rearing calves.

By December 1935 the breeding herd had increased to 34 after another bull was purchased, a cow and a heifer culled, eight bull calves castrated and eight had died. The herd was partly moved to the farm Vuma near Eshowe in January 1938 to develop a milking dual-purpose type of Nguni cattle. A two-quarter-to-the-calf system was applied and calves were allowed to suckle in the morning and afternoon before the cows were milked. The daily production of the other two quarters showed such enormous fluctuations that the results were considered unreliable.

A number of Nguni cattle were purchased from the Eshowe area by the Division of Veterinary Services, Onderstepoort, in 1935. Preference was given to the black Nkone pattern which has a black solid colouring with a white top and underline and were selected for beef characteristics. A number of these cattle were transferred to Vuma in January 1951, but as the cows were not accustomed to being milked, they were excluded from the milk research project.

Various reports from 1949 to 1951 indicate that the Nguni cattle at Vuma and Thokazi were an inferior example to what could be seen in the traditional Zulu areas as the better standard of animal was hardly ever made available for sale. Attempts were continuously made to purchase additional Nguni breeding stock to build up a representative type.

The farm Vuma was not considered fully representative of the natural habitat of Nguni cattle and it was recommended that Crown land which was available in the Ubombo district, be used to establish a Nguni cattle project (Bonsma *et al*, 1950). The

original farms of Bartlow Combine were acquired in 1947 and were initially used as a bull station. Besides a number of Nguni cattle transferred to Bartlow Combine from Thokazi and Vuma, additional breeding material was also purchased in the districts Ingwavuma, Ubómbo, Nongoma and Hlabisa. The remainder of the Nguni cattle at Vuma were transferred to Bartlow Combine in November 1957.

At Bartlow Combine, recording of milk production continued until 1964. Body measurements were taken from 1957 until 1961 (Beeslaar, 1963) and liveweights were recorded at quarterly intervals up to two years of age and then annually. As from 1960, data were collected under the supervision and rules of the National Beef Cattle Performance and Progeny Testing Scheme.

2.2 Environment

Bartlow Combine is situated in the districts of Ubombo and Hlabisa, northern Zululand, 30 km south of Mkuze at latitude 32°03' E and longitude 27°54' S. Bartlow Combine currently consists of seven adjacent farms covering an area of 7 496 hectares which is managed as one breeding station for Nguni cattle and indigenous goats.

The area is undulating, hilly to steep with isolated hills and forms part of the uMkhuze river catchment. The altitude varies from 210 to 678 m above sea-level. The mean annual rainfall is 582 mm with dry months from May to August. The mean annual evaporation from a USA type A pan is 2 070 mm and the mean monthly relative humidity ranges between 30.5% and 92%. The mean maximum (minimum) monthly summer and winter temperatures are 31.2°C (20.2°C) and 24.1°C (6.1°C) (Department of Agricultural Development, 1991).

The vegetation is classified as Veld Types 6 and 10 (Acocks,

1975). The veld varies from a sourish mixed open bushveld to sweet veld. *Acacia* spp, *Themeda triandra* and *Panicum* spp predominate.

The area is heavily tick-infested with commonly found species like *Boophilus* spp, *Amblyomma hebraeum*, *Hyalomma rufipes* and *Rhipicephalus* spp. requiring precautionary and control measures against *Babesia bovis, B. bigemina, Anaplasma marginale, Rickettsia ruminantium* and tick damage.

2.3 Management and selection

The stud originated from Nguni cattle purchased and bred since 1931. It was closed from 1957 for a period of 24 years until 1981 when 20 Pedi heifers from Lebowa and in 1983, 18 female cattle and one bull from the districts of Ingwavuma and Ubombo were introduced.

The breeding herd consisted of 14 bulls and 394 cows and heifers in 1960. A calving percentage of 92% was recorded for this particular season. Assortative mating was practised until 1975. Selection was mainly for type, conformation and weight at weaning and two years of age. Milk production of the dam and performance of progeny were important factors in the selection of breeding bulls (Hamburger, 1960-1968). Other selection criteria were against temperament, hypoplasia, albinism and hollow backs. After 1970, more emphasis was placed on fertility (Hamburger & Swanepoel, 1978; Ramsay & Swanepoel, 1981; Lepen, 1986) as well as growth performance as recorded with the National Performance and Progeny Testing Scheme under Phase A and from 1974, Phase B (Armstrong, 1975; Ramsay, 1981). Breeding bulls were also selected on growth performance as recorded for either Phase C or D (Lepen, 1988).

In 1976, seven breeding lines were formed, based on the relationship of animals with the original sires used in 1958

(Hamburger & Swanepoel, 1978). The progeny of original sire NT 158 had increased considerably in numbers and were used to form two separate breeding lines; the progeny of NT 109 and NT 151 were consolidated, while the progeny from NT 84, NT 85, NT 243 and NT 351 were grouped in separate breeding lines. Line breeding was applied in the 1976 breeding season, but subsequently breeding bulls of a particular breeding line were mated to females of other lines (Pretorius, 1980). Single sire mating was practised and sires were replaced as required.

An autumn and spring breeding season of 90 and 65 days respectively, was used until 1974 after which one season of 90 days per year was retained. Since 1976, it was decreased to 65 days for cows and 45 days for heifers. The latter commenced one month in advance of the cows. More than the required number of replacement heifers were included for mating (Hamburger & Swanepoel, 1978) and final selection was on reproduction rate and progeny performance (Lepen, 1988). The mean female breeding herd was approximately 400 animals.

Records of animals used in this study have been collected according to the procedures prescribed by the National Beef Cattle Performance and Progeny Testing Scheme (Bosman & Hunlun, 1984; Department of Agriculture and Water Supply, 1988). Phase A has been recorded from 1960 with preweaning weight from 1972, phase B since 1974 and for some bulls Phases C and D from 1971. Weight indices as calculated by the Scheme was subsequently taken into consideration for selection.

The herd was registered with the South African Stud Book in 1985 and after the establishment of the Nguni Cattle Breeders' Society in 1986, it was required that breeding animals comply with the minimum breed standards.

2.4 Data

The data consisted of records collected according to the procedures prescribed by the National Beef Cattle Performance and Progeny Testing Scheme (Bosman & Hunlun, 1984; Department of Agriculture and Water Supply, 1988) from calves at birth (1960-1991), 205 days (1960-1991), 365 days (1974-1990) and 540 days (1975-1990) of age. Except for birth weight, the actual weight of individual calves was corrected for each trait according to the following example:

$$\text{205-day weight} = BW + 205 \left(\frac{\text{actual } WW - BW}{\text{age in days at weaning}} \right)$$

where BW = birth weight and WW = weaning weight.

Full pedigree records were available. Inbreeding coefficients were calculated for all animals using the algorithm described by Quaas (1976).

The data were edited to exclude the following records for the purpose of model specification (Chapter 3.2) only:

(i) Animals without positive sire identification;
(ii) Sires with less than ten progeny;
(iii) Animals born during the period 16 January to 14 August;
(iv) Progeny of dams with unknown dates of birth; and
(v) Progeny of dams younger than 957 days and older than 6 072 days.

The data set was used in four related but separate studies which are presented in Chapters 3 to 6.

CHAPTER 3

FACTORS INFLUENCING GROWTH TRAITS

3.1 Introduction

Environmental factors can have a considerable influence on the phenotypic expression and hence the genetic evaluation of animals. Environmental factors have been reviewed by Dickerson (1962) and the quantification of these effects in cattle have been extensively investigated. However, no studies have been conducted to determine the effects of environmental factors on Nguni cattle under these particular conditions. These estimates are required to adjust performance records of an individual animal to increase the accuracy of the selection of breeding animals and to facilitate the analysis of data.

The aim of this study was to evaluate factors contributing to the variation in birth, 205-, 365- and 540-day weight of Nguni cattle at the Bartlow Combine Breeding Station in order to derive a model needed to estimate genetic and phenotypic parameters for the calculation of breeding values and the development of selection procedures.

3.2 Material and methods

The data used for the analyses has been discussed in Chapter 2.4. Analyses of variance were conducted using least-squares mixed model procedures (Harvey, 1988). Preliminary analyses included sires nested within breeding lines, year of birth, sex of calf, the interaction between year and sex as well as the linear and quadratic regressions of age of dam and inbreeding of calf and dam on performance.

It was decided to fit the following model:

$$Y_{ijkl} = \mu + r_i + y_j + s_k + b_1X + b_2X^2 + e_{ijkl}$$

where

Y_{ijkl} = observation on the l'th calf of the k'th sex, born in the j'th year from sire i,
μ = overall mean,
r_i = random effect of the i'th sire with zero mean and variance $I\sigma^2_r$.
y_j = fixed effect of the j'th year of birth (j = 1,..,32),
s_k = fixed effect of the k'th sex (k = 1, 2),
b_1, b_2 = linear and quadratic regression coefficient of difference between age of dam of the l'th calf (X) and mean age of dams (X) in population,
e_{ijkl} = random error with zero mean and variance $I\sigma^2_e$.

3.3 Results and discussion

Analysis of variance for the various traits is presented in Tables 3.1.1 and 3.1.2. All effects included in the final model were found to be highly significant (P<0.001) sources of variation for all the traits under study. Estimates of least-squares and standard errors are reported in Tables 3.2.1 and 3.2.2.

Breeding lines were found to be a non-significant effect and sires were subsequently included as the only random effect to make provision for genetic differences among calves. It was also found that in many cases animals were genetically more related to animals in other "lines" than their own. In the planning stages of this research project, one of the main objectives identified was to compare genetic progress in the different "lines". One of the first findings was that

different "lines" do not exist.

The effect of inbreeding of the calf as a linear regression on birth and 205-day weight was not significant, but was significant (P<0.005) for 365- and 540-day weight. Alexander & Bogart (1961) also found inbreeding of the calf not to have a significant effect on birth weight. However, significant effects have been reported on birth weight (Swiger *et al*, 1961) and weaning weight (Koch, 1951; Burgess *et al*, 1954). Inbreeding of dam was significant (P<0.05) for 205-day weight as a linear regression. Similar effects were reported by Burgess *et al* (1954), Koch (1951) and Swiger *et al* (1961). The importance of inbreeding of the dam on 205-day weight indicates the effect it has on her milk production during the preweaning growth phase of her calf. The inbreeding coefficients were relatively low with a mean of 0.5% and 1.6% for calves and dams

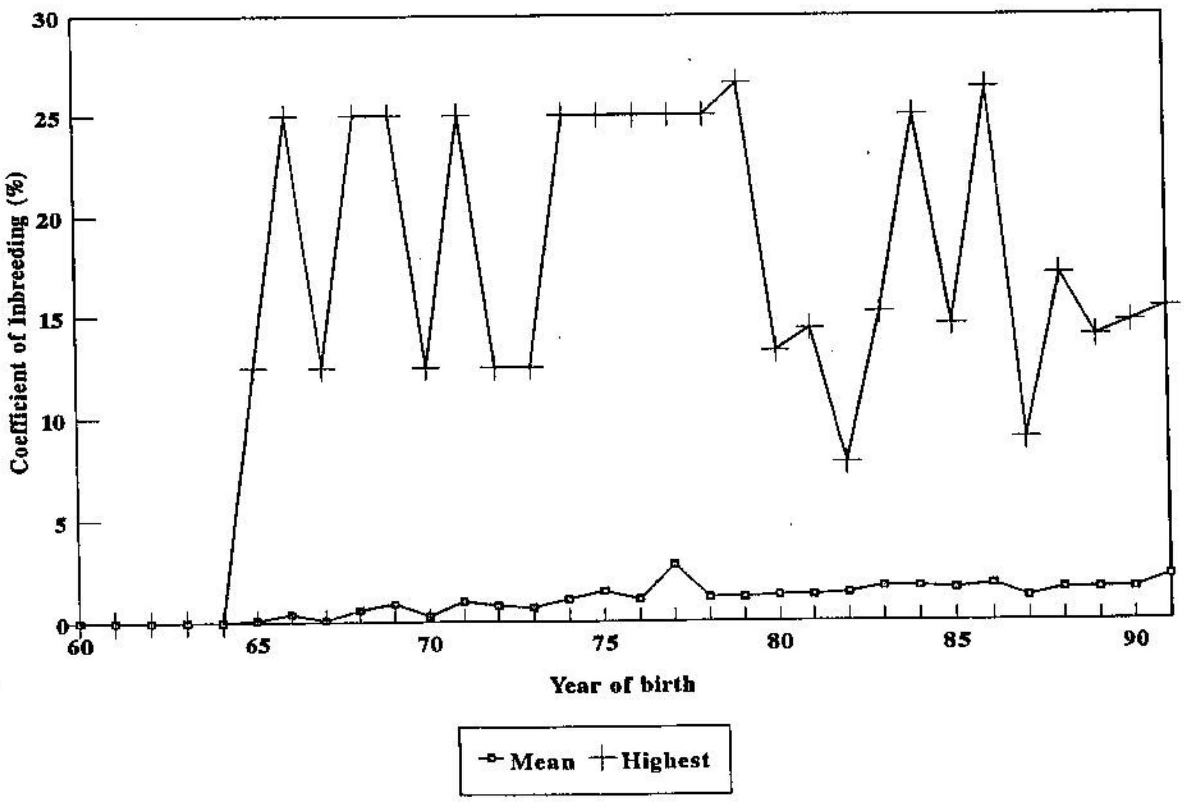

Figure 3.1: Annual mean and highest coefficient of inbreeding.

respectively. In total, 94.3% of the calves had a coefficient of less than 5%. The annual mean and highest coefficient of inbreeding are presented in Figure 3.1. It is possible that the coefficients were higher than estimated as it was assumed that the base population was non-inbred. The interaction between year of birth and sex of calf was found to be significant ($P<0.005$) for birth and 205-day weights. However,

Table 3.1.1: Analysis of variance of birth and 205-day weight

Source		Birth weight		205-day weight	
		df	MS	df	MS
Sire		241	72.44	241	1 406.94
Year		31	511.01	31	10 909.93
Sex		1	10 492.28	1	483 789.22
Age of dam	b_1	1	1 034.65	1	62 959.74
	b_2	1	1 815.76	1	33 148.06
Error		12 150	11.91	11 732	287.22

Table 3.1.2: Analysis of variance of 365- and 540-day weight

Source		365-day weight		540-day weight	
		df	MS	df	MS
Sire		144	1 033.77	122	1 219.14
Year		16	50 383.95	16	50 320.00
Sex		1	200 866.17	1	92 842.42
Age of dam	b_1	1	22 130.54	1	5 865.73
	b_2	1	16 409.51	1	9 343.43
Error		4 881	309.21	3 456	494.66

df = degrees of freedom; MS = mean squares; linear (b_1) and quadratic (b_2) regressions. For all values: $P<0.001$.

Table 3.2.1: Least-squares mean for birth and 205-day weight

Effect		Birth weight		205-day weight	
		n	LSM±SE (kg)	n	LSM±SE (kg)
μ		12 426	26.51±0.13	12 008	152.98±0.57
CV (%)			14.55		12.54
Sex	♂	6 269	27.44±0.13	6 036	159.40±0.59
	♀	6 157	25.58±0.13	5 972	146.55±0.60
Age of dam	b_1		0.50×10^{-3} $\pm 0.05 \times 10^{-3}$		3.52×10^{-3} $\pm 0.24 \times 10^{-3}$
	b_2		-3.1×10^{-7} $\pm 0.2 \times 10^{-7}$		-13.4×10^{-7} $\pm 1.3 \times 10^{-7}$

Table 3.2.2: Least-squares mean for 365- and 540-day weight

Effect		365-day weight		540-day weight	
		n	LSM±SE (kg)	n	LSM±SE (kg)
μ		5 045	181.32±0.80	3 598	245.51±1.46
CV (%)			12.78		11.37
Sex	♂	2 161	188.19±0.86	1 408	251.23±1.56
	♀	2 884	174.44±0.82	2 190	239.80±1.49
Age of dam	b_1		3.93×10^{-3} $\pm 0.47 \times 10^{-3}$		2.53×10^{-3} $\pm 0.73 \times 10^{-3}$
	b_2		-16.8×10^{-7} $\pm 2.3 \times 10^{-7}$		-15.4×10^{-7} $\pm 3.6 \times 10^{-7}$

LSM = least-squares mean; SE = standard error; CV% = coefficient of variation.

the effects of inbreeding of calf and dam and interaction between year of birth and sex of calf were excluded from the final model since they reduced the residual variance only marginally while increasing the standard errors of the main

effects.

Differences between year of birth were highly significant ($P<0.001$) for all traits under study. This may be expected due to the prevailing extensive farming conditions. Year effects are mainly caused by climate and its influence on the availability and quality of the pasture (Harricharan *et al*, 1976; Carles & Riley, 1984) and milk production of the dam (Shelby *et al*, 1955). Also, several people were involved in the management of the stud during the period of study which could contribute to environmental fluctuations. Year effects are discussed in Chapter 6.

Bull calves were 7.3%, 8.8%, 7.9% and 4.8% heavier than heifers at birth, 205 days, 365 days and 540 days of age, respectively. The significant influence of sex of calf on weight has been reported in various studies (Pahnish *et al*, 1961; Andersen & Plum, 1965; Bair *et al*, 1972; Bailey *et al*, 1972).

Age of dam fitted as a quadratic regression was found to be highly significant ($P<0.001$). Most reports indicate a curvilinear relationship between age of dam and weight of her calves with the highest values from 6 to 10 years for *Bos indicus* (Venter, 1977). Gregory *et al* (1985) also found that age of dam affects birth and weaning weight significantly ($P<0.01$), whereas Swanepoel & Heyns (1988) and Bosman & Harwin (1967) found no significant effect of age of dam on weaning weight in the case of Afrikaner cattle. Because some selection had already taken place at weaning and records of the inherent productivity of cows born in later years were not included, postweaning traits are biased under a sire model with no relationships other than half-sibs.

3.4 Conclusions

Year of birth, sex of calf and age of dam were found to be

highly significant ($P<0.001$) sources of variation of weight in the Nguni stud at Bartlow Combine which must be taken into consideration when selection procedures are developed. Inbreeding of the calf and dam, as well as interaction between year of birth and sex of calf was also highly significant in some of the traits under study. It is not recommended that these effects are included in a model to describe the data as it reduced the residual variance marginally while the standard errors increased. The inconsistency of published results indicates the importance of estimating factors that affect traits within a specific stud and environment.

CHAPTER 4

VARIANCE COMPONENT AND HERITABILITY ESTIMATES

4.1 Introduction

Improvement of performance through selection is largely dependant on the effective utilization of additive genetic variation and therefore requires accurate estimation of genetic parameters for the traits to be selected. Growth performance is widely used as a selection criterion in evaluating performance of beef cattle since live weight is of economic importance and can easily be measured.

As pointed out, indigenous cattle breeds, such as the Nguni, are gaining in popularity in southern Africa because of their natural ability to produce and reproduce under extensive conditions without much additional managerial inputs or changes to the environment. This ability could possibly be improved even further by the use of more sophisticated techniques of breeding value prediction, provided that they are used with discretion, especially as far as the traits to be considered are concerned.

Numerous variance components and heritability estimates of growth traits for both direct additive and maternal additive components have been reported for beef cattle (Table 4.1). However, no published results are available for Nguni cattle. This is a serious limitation since these specific estimates are needed for the formulation of breeding plans and the prediction of breeding values. Investigations into the maternal additive component of the traits is of particular significance in this case as the Nguni stud at Bartlow Combine is reasonably representative of the breed and an important source of genetic material. The possibility of genetic improvement in the

Table 4.1: Heritability estimates for direct (a), maternal (m) and total (T) additive genetic components and correlation (r_{am}) between direct and maternal components.

Birth weight

Breed	n	h^2_a	h^2_m	h^2_T	r_{am}	Reference
Her	789	0.56	0.30	0.36	-0.58	Brown & Galvez (1969)
Ang	932	0.14	0.25	0.17	-0.37	Brown & Galvez (1969)
Her	4 060	0.44	0.10	0.56	0.07	Koch (1972)
Sim	11 552		0.11		-0.24	Burfening *et al* (1981)
Her	1 012	0.36	0.82		-0.51	Nelsen *et al* (1984)
Lim	78 088	0.22	0.05		-0.16	Bertrand & Benyshek(1987)
Brn	20 750	0.25	0.13		-0.12	Bertrand & Benyshek(1987)
Her	4 423	0.16	0.18	-0.01	-1.03	Cantet *et al* (1988)
Her	4 423	0.27	0.63	0.05	-0.86	Cantet *et al* (1988)
Ang	16 345	0.37	0.13	0.32	-0.34	Trus & Wilton (1988)
Her	65 376	0.39	0.13	0.32	-0.39	Trus & Wilton (1988)
Shh	5 092	0.27	0.20	0.56	0.55	Trus & Wilton (1988)
Cha	10 048	0.42	0.17	0.35	-0.39	Trus & Wilton (1988)
Sim	23 784	0.34	0.20	0.36	-0.22	Trus & Wilton (1988)
Her	5 488	0.38	0.14	0.47	0.05	Meyer (1992)
Ang	4 036	0.34	0.10	0.47	0.27	Meyer (1992)

Weaning weight

Breed	n	h^2_a	h^2_m	h^2_T	r_{am}	Reference
Bra	725	0.18	0.15	0.25	0.00	Deese & Koger (1967)
Her	2 618	0.23	0.34	0.28	-0.28	Hohenboken & Brinks(1971)
Lim	53 494	0.16	0.15		-0.30	Bertrand & Benyshek(1987)
Brn	46 661	0.28	0.20		-0.29	Bertrand & Benyshek(1987)
Her	4 423	0.31	0.33	0.10	-0.79	Cantet *et al* (1988)
Her	4 423	0.26	0.67	0.20	-0.63	Cantet *et al* (1988)
Her	7 003	0.14	0.46	0.14	-0.59	Meyer (1992)
Ang	3 465	0.19	0.18	0.33	0.20	Meyer (1992)

Ang = Angus; Bra = Brahman; Brn = Brangus; Cha = Charolais; Her = Hereford; Lim = Limousin; Shh = Shorthorn; Sim = Simmental

maternal ability of the Nguni should be of interest since the breed is widely suggested as a dam line in terminal crossbreeding (Hofmeyr, 1974; Scholtz, 1988).

The objective of this study was to estimate genetic parameters in this stud for subsequent use in genetic evaluation and the formulation of breeding plans. Special reference is made to the parameters effecting possible future improvement in maternal ability.

4.2 Material and methods

The number of records for each trait is given in Table 4.2. The editing procedures has been reported in Chapter 2.4.

Analyses were conducted by means of Derivative Free Restricted Maximum Likelihood (DFREML) procedures using the programme of Meyer (1989, 1991) and fitting the following model:

$$\mathbf{y} = \mathbf{X}\mathbf{b} + \mathbf{Z}_1\mathbf{a} + \mathbf{Z}_2\mathbf{m} + \mathbf{e}$$

where

$\mathbf{y}$ = a vector of observations;
$\mathbf{X}$ = a known incidence matrix relating observations to fixed effects;
$\mathbf{b}$ = a vector of fixed effects consisting of year of birth, sex and the linear and quadratic regression of age of dam on year of birth;
$\mathbf{Z}_1$; $\mathbf{Z}_2$ = known incidence matrices relating elements of $\mathbf{a}$ and $\mathbf{m}$ to $\mathbf{y}$;
$\mathbf{a}$ = a random vector of direct additive genetic effects;
$\mathbf{m}$ = a random vector of maternal additive genetic effects;
$\mathbf{e}$ = a random vector associated with residual errors.

The starting values for iteration were obtained from preliminary analyses using Henderson's method III (Harvey, 1988).

4.3 Results and discussion

The estimates of variance components and heritabilities are presented in Table 4.2. These results allow an assessment of the relative importance of the two sources of variation. The direct additive variances (σ^2_a) and heritabilities (h^2_a) were larger than the respective maternal values (σ^2_m; h^2_m) for all

Table 4.2: Estimates of variance components and heritabilities for direct additive and maternal additive components

Parameters	Weigh traits (days)			
	Birth	205	365	540
n	12 673	12 002	5 273	3 886
σ^2_a	5.559	96.298	88.310	96.376
σ^2_m	2.147	66.264	28.484	1.640
σ_{am}	−1.692	−31.049	−3.825	12.247
σ^2_e	7.596	196.332	224.760	405.363
σ^2_p	13.611	327.845	337.729	515.626
h^2_a	0.409	0.294	0.262	0.187
S.E.	0.057	0.032	0.047	0.040
h^2_m	0.158	0.202	0.084	0.003
S.E.	0.022	0.021	0.028	0.028
h^2_T	0.442	0.401	0.335	0.214
σ_{am}/σ^2_p	−0.124	−0.095	−0.011	0.024
S.E.	0.016	0.024	0.029	0.026
r_{Gam}	−0.490	−0.389	−0.076	0.974

the traits under study. This relationship has also been reported by Burfening *et al* (1981), Quaas *et al* (1985), Bertrand & Benyshek (1987), Trus & Wilton (1988) and Meyer (1992) for birth weight; Quaas *et al* (1985), Bertrand & Benyshek (1987) and Herd (1990) for weaning weight, and Herd (1990) and Meyer (1992) for yearling weight. Larger maternal values than direct values have been reported in studies by Brown & Galvez (1969), Nelsen *et al* (1984) and Cantet *et al* (1988) for birth weight and Hohenboken & Brinks (1971), Cantet *et al* (1988) and Meyer (1992) for weaning weight.

The covariance and genetic correlation between direct and maternal components for weight at birth, 205 days and 365 days of age were found to be negative, reducing the total heritability.

The antagonism between these components appears to be common in beef cattle for preweaning growth traits (Hohenboken & Brinks, 1971; Van Vleck *et al*, 1977) and also occurs in yearling weight (Mavrogenis *et al*, 1978; Meyer, 1992). However, positive correlations have been reported by Koch (1972), Trus & Wilton (1988) and Meyer (1992) for birth weight and Deese & Koger (1967) and Meyer (1992) for weaning weight. Van Vleck *et al* (1977) illustrated that genetic improvement will be difficult with a large negative covariance as an increase in one component could result in a decline in the other.

Koch (1972) reported that the total maternally related variance is likely to account for 15 to 20% of the phenotypic variance in birth weight. The present study estimated the proportion of σ^2_m and σ_{am} to be roughly 16 and 12%, respectively. The correlation between direct and maternal effects is in close agreement with the literature averages by Koch (1972) and Baker (1980). The estimates of direct, maternal and total heritability for birth weight are in general agreement with the literature as indicated in Table 4.1.

The proportion of maternal additive variance and covariance to the phenotypic variance was 20 and 10% for 205-day weight respectively, which corresponds closely with the estimates for σ_{am} of 8% by Hohenboken & Brinks (1971) and Meyer (1992) in Hereford cattle. The estimate of direct heritability is supported by Preston & Willis (1974) and Woldehawariat *et al* (1977), while the maternal heritability is considerably lower than the values reported by Koch (1972) and Baker (1980). The r_{Gam} for 205-day weight is lower than the mean values of -0.55, -0.72 and -0.65 calculated by Koch (1972), Baker (1980) and Cantet *et al* (1988) respectively. Hohenboken & Brinks (1971) and Bertrand & Benyshek (1987) reported correlations in the order of -0.30.

The estimates of total heritability and the genetic correlation between the direct and maternal components for birth and 205-day weight suggest that a response to selection can be obtained if both direct and maternal breeding values are considered in a selection programme. This is of particular interest since the selection for maternal ability creates the opportunity for developing dam lines. The expected progress in maternal ability would, however, be slow due to the relatively low maternal heritabilities of these traits.

Little information exists in the literature on maternal additive genetic components for postweaning traits. Meyer (1992) found the maternal component significant in yearling and final weight of Hereford and Zebu-cross cattle. In the present study, the maternal variance contributed 8.4 and 0.3% to the phenotypic variance of 365- and 540-day weight respectively, indicating that the maternal component is of less importance in these traits. The estimate of direct heritability for 365-day weight is considerably lower than the mean values calculated by Preston & Willis (1974) and Petty & Cartwright (1966) which are in the order of 0.50. The genetic correlation between the direct and maternal components for 365-day weight suggests that there is little association between them, while

Meyer (1992) reported an average of -0.41.

The proportion of covariance between direct and maternal genetic components for 365- and 540-day weight suggests that genetic progress can be achieved, although the response to 540-day weight may be slow due to a low direct heritability. There would be little value in selecting for maternal ability because maternal heritability of these traits is low.

4.4 Conclusions

The results of this study indicate that early growth traits in the Nguni can be improved by selection, utilizing both the direct and maternal additive components of genetic variance. However, the negative covariance between these components poses some limitations on the total response expected. Best Linear Unbiased Prediction (BLUP) of direct and maternal breeding values, using the parameters obtained in this study and the model specified in Chapter 4.2, can be used as a basis for future selection.

Later growth traits will be more difficult to improve by selection. In practical terms, this should not be viewed unfavourably, since it is doubtful whether these traits need "improvement" in this breed. Increasing mature body weight could simply lead to increased maintenance requirements.

CHAPTER 5

RELATIONSHIPS BETWEEN GROWTH TRAITS

5.1 Introduction

In order to develop breeding plans, knowledge of the various properties of the traits under consideration is required. It is also useful to know how the improvement in one trait will cause simultaneous changes in others and how such correlated responses can be incorporated in the breeding plan to achieve optimum efficiency.

Table 5.1: Genetic correlations

Reference	BxW	BxY	BxF	WxY	WxF	YxF
Koch & Clark (1955)	0.63	0.40		0.54		
Lasley *et al* (1961)	0.99					
Swiger (1961)	0.69					
Brinks *et al* (1964)	0.60		0.59			
Vesely & Robison (1971)	0.49					
Koch *et al* (1974)	0.48	0.60		0.71		
Preston & Willis (1974)	0.68					
Bourdon & Brinks (1982)	0.61	0.62		0.89		
Alenda & Martin (1987)	0.57	0.75				
Swanepoel & Heyns (1988)	0.79					
Bergh (1990)	0.64	0.65	0.47	0.99	0.69	0.71
Koster (1992)	0.51	0.91				
Present study	0.26	0.45	0.61	0.74	0.66	0.93

B = Birth-; W = 205-; Y = 365-; F = 540-day weight.

Correlated responses in beef cattle have been reviewed by Barlow (1978, 1984), Koch *et al* (1982) and Scholtz & Roux (1984) and the adverse effect of increased growth on fertility and other important traits should not be underestimated. Estimates for correlations between growth traits have been reported for beef cattle (Table 5.1). It was considered necessary to estimate correlations between growth traits in the stud as most estimates have been calculated from small populations and have large standard errors. Also, no estimates are available for Nguni cattle.

The objective of the study was to investigate genetic, phenotypic and environmental correlations among birth, 205-, 365- and 540-day weight in the Nguni cattle stud at Bartlow Combine to be used for the formulation of breeding plans for this stud.

5.2 Material and methods

The records were edited as reported in Chapter 2.4. The number of records used to estimate relationships between the respective traits under consideration, is given in Table 5.2.

Analyses were conducted by means of Henderson's method III (Harvey, 1988) and fitting the model as described in Chapter 3.2.

5.3 Results and discussion

The estimates of phenotypic, genetic and environmental correlations between the traits under consideration are presented in Table 5.2.

The genetic correlations between birth and 205-day weight and birth and 365-day weight were found to be considerably lower

than estimates reported in the literature (Lasley *et al*, 1961; Vesely & Robison, 1971; Koch *et al*, 1974; Preston & Willis, 1974; Bourdon & Brinks, 1982; Alenda & Martin, 1987; Bergh, 1990). The correlation between birth and 540-day weight is in close agreement with Brinks *et al* (1964) but is somewhat higher than the estimate by Bergh (1990). The correlations between birth, 365- and 540-day weight ($r_g \geq 0.45$) support the findings of Dawson *et al* (1947), Koch *et al* (1974) and Woldehawariat *et al* (1977) that birth weight may be a good indicator of postweaning weights. Selection for weight at 365 days or 540 days of age may increase birth weight due to possible indirect selection response and the estimated heritability (h^2_a) of birth weight of 0.41 (Table 4.2) and the effect that this may have on dystocia (Barlow, 1978), should not be overlooked.

Table 5.2: Phenotypic (r_p), genetic (r_g) and environmental (r_e) correlations between growth traits

Weight traits (days)	n	r_p	r_g ± S.E.	r_e
Birth x 205	12 008	0.254	0.258 ± 0.074	0.254
Birth x 365	5 042	0.283	0.454 ± 0.093	0.207
Birth x 540	3 593	0.287	0.609 ± 0.098	0.172
205 x 365	4 960	0.608	0.739 ± 0.055	0.553
205 x 540	3 556	0.507	0.660 ± 0.086	0.461
365 x 540	3 523	0.703	0.973 ± 0.029	0.625

The genetic correlation between 205- and 365-day weight corresponds closely with Koch *et al* (1974) which is considerably lower than the value reported by Bergh (1990).

Selection for weaning weight is expected to improve yearling

weight (Irgang *et al*, 1985) and live weight at all other ages from birth to maturity (Barlow, 1978). However, the results of the present study indicate low phenotypic, genetic and environmental correlations between birth and 205-day weights.

The genetic correlation between 365- and 540-day weights was found to be close to unity, indicating a part-whole relationship between these traits. Although the heritability for 540-day weight is relatively low (h^2=0.19), the high genetic correlation indicates that selection for an increase in 365-day weight may successfully increase weight at 540-days of age.

Hanrahan (1976) has indicated that the prediction of correlated responses to selection should take into account maternal genetic effects. This may be of significance when a response between birth and 205-day weight is required as these traits have been shown to be influenced by maternal additive genetic effects. In the case of 365- and 540-day weight which are not subject to major maternal effects, a correlated response in these traits can be obtained without taking these effects into consideration when selection is for either birth or 205-day weight.

5.4 Conclusions

The estimates of genetic correlations between the various traits under study were found to be positive and moderate to high. The correlation between birth and 205-day weight suggests that both traits should be included in a selection programme to prevent an undesirable increase in birth weight. The correlation between 205-, 365- and 540-day weights suggest that only one trait should be included in a breeding plan to increase weight for these traits.

CHAPTER 6

GENETIC AND ENVIRONMENTAL TRENDS

6.1 Introduction

Genetic improvement through selection is largely dependent on the effective use of genetic variation and requires accurate quantification of reliable genetic parameters. Response to selection can be determined by means of mixed model methodology (Henderson, 1975). Sorensen & Kennedy (1986) have shown that, without the use of a control line, mixed model analyses can lead to unbiased estimates of genetic and environmental trend under several cycles of selection under the following conditions: (i) the model used is the correct one; (ii) the ratios of the variances of the random effects are known prior to selection; (iii) selection is on a linear function of the records and is invariant to the fixed effects in the model, namely, $L'X = 0$ (Henderson, 1975) where X is an incidence matrix and L' is a matrix describing selection and (iv) the relationship matrix is complete.

Wilson & Willham (1986) considered within-herd trend lines useful in breeding programmes as genetic trends are evidence of selection response and environmental trends of management effects and(or) climatic changes.

The objective of this study was to partition the phenotype into its genetic and environmental components and to determine direct genetic, maternal genetic, phenotypic and environmental trends in birth, 205-, 365- and 540-day weight in the Nguni cattle stud at Bartlow Combine.

6.2 Material and methods

The editing procedures of records has been reported in Chapter 3. Full pedigree records were available. The number of records used for analyses is indicated in Table 6.1.

Table 6.1: Linear regression analyses of mean annual direct additive breeding values (D), environmental values (E), phenotypic values (P), and maternal additive breeding values (M) on year of birth

Traits and study period	Value	b	R^2	P-value
Birth weight (1960-1991) n = 12 673	D	0.032	0.750	0.0000
	E	0.241	0.714	0.0000
	P	0.273	0.763	0.0000
	M	-0.004	0.138	0.0365
205-day weight (1960-1990) n = 12 002	D	0.330	0.928	0.0000
	P	0.294	0.074	0.1378
	M	0.021	0.100	0.0836
365-day weight (1974-1990) n = 5 273	D	0.328	0.752	0.0000
	E	-2.319	0.409	0.0057
	P	-1.991	0.347	0.0129
	M	0.068	0.739	0.0000
540-day weight (1975-1990) n = 3 886	D	0.304	0.701	0.0001
	E	-1.729	0.182	0.0999
	P	-1.425	0.134	0.1626
	M	0.038	0.704	0.0001

The data were analyzed using a direct animal additive and maternal additive genetic model as described in Chapter 4.2,

assuming that both genetic effects arise from a large number of additive loci. Direct and maternal breeding values were obtained as a by-product from the DFREML programme of Meyer (1989, 1991) used in the estimation of variance-covariance components (Chapter 4).

The annual mean breeding values were calculated as the simple average of records of both sexes born in a particular year. Genetic trends were estimated as the regression of mean predicted direct and maternal breeding values on year of birth. Environmental values were calculated by subtracting the annual mean predicted direct breeding values from the annual least-squares means (phenotypic values) to compensate for unequal subclasses.

6.3 Results and discussion

The results of the linear regression analyses of mean direct and maternal breeding values, mean phenotypic values and mean environmental values (excluding 205-day weight) on year of birth for weight at birth, 205 days, 365 days and 540 days of age is presented in Table 6.1. Breeding values, being predictions, are presented as deviations from zero. The annual mean direct and maternal breeding values and linear regressions for weight on year of birth are presented in Figures 6.1.1, 6.2.1, 6.3.1 and 6.4.1. Figures 6.1.2, 6.3.2 and 6.4.2 illustrate the annual mean phenotypic and environmental values and linear regressions of environmental values on year of birth. In the case of 205-day weight, a cubic regression was fitted (Figure 6.2.2).

The direct genetic trends were all positive and significantly ($P<0.001$) different from zero with little evidence of plateauing. The linear regression representing genetic trend for 205-day weight (Figure 1) produced a good fit ($R^2=0.93$) with an annual mean increase of 0.33 kg. As pointed out in

Chapter 2.3, weaning weight was an important selection criterium in the stud. The genetic trends for birth, 365- and 540-day weight did not produce such good fits ($R^2 \leq 0.75$). The regression coefficients indicate a relatively small annual mean direct genetic increase of approximately 0.03, 0.33 and 0.30 kg, being 0.12, 0.18 and 0.12% of the overall mean phenotype for birth, 365- and 540-day weight respectively. This represents a total genetic increase of nearly 0.9, 5.3 and 4.5 kg for the various periods of study. No attempt was made to estimate the phenotypic progress in 205-day weight as a linear regression produced a poor fit ($R^2=0.07$).

The environmental trends were highly significant for birth, 205- and 365-day weight ($P<0.01$) while the R^2 values varied considerably. Environmental conditions had a consistent positive influence on birth weight from 1960 to 1991 and produced a relatively good fit for an environmental trend ($R^2=0.71$) which suggests that birth weight was less susceptible to changes in external environmental conditions in comparison with the other traits under study. The cubic regression representing environmental trend for 205-day weight produced a more appropriate fit ($R^2=0.62$). It showed a decrease from 1960 and an increase from 1964 to 1979. Reversed conditions prevailed subsequently to 1990 (Figure 6.2.2). The following equation described the cubic regression:

$$Y = 2760.124 + (-112.52 \times X_n) + (1.598 \times X_n^2) + (-0.008 \times X_n^3)$$

where Y = weight (kg) and n = year of birth.

Fits for environmental values, as produced for 205-, 365- and 540-day weight ($0.18 \leq R^2 \leq 0.62$), may be expected under fluctuating climatic conditions and the effect that they have on the availability and quality of the natural grazing. It was possible to relate extraordinary low peaks to relatively dry years. Also, several people were involved in the management

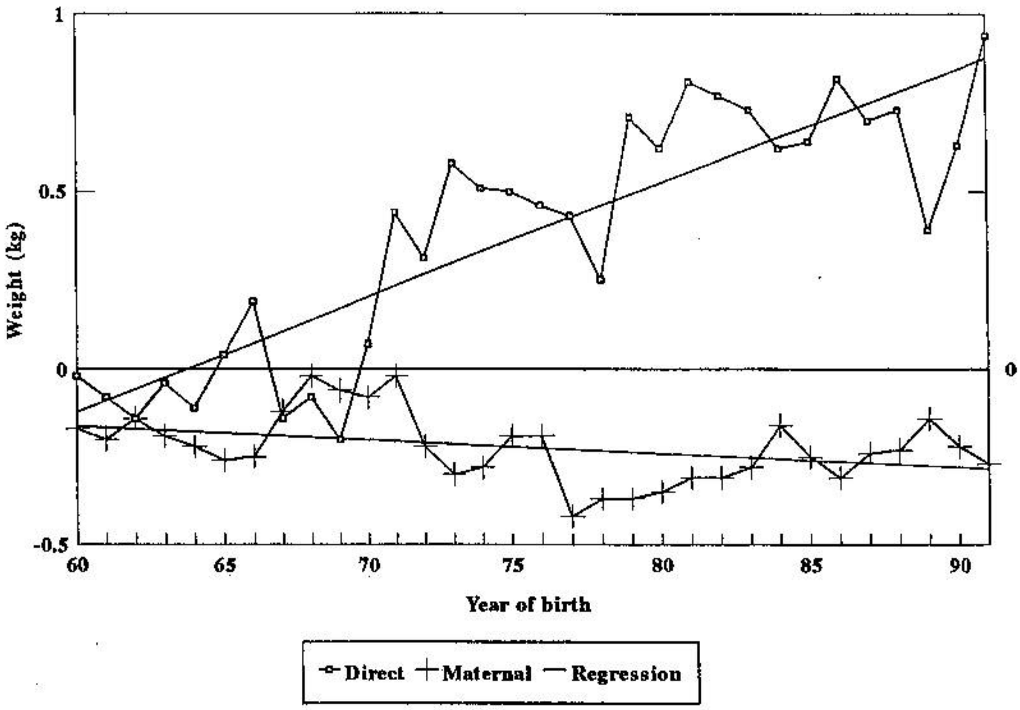

Figure 6.1.1: Annual mean direct and maternal breeding values and regressions on year of birth for birth weight.

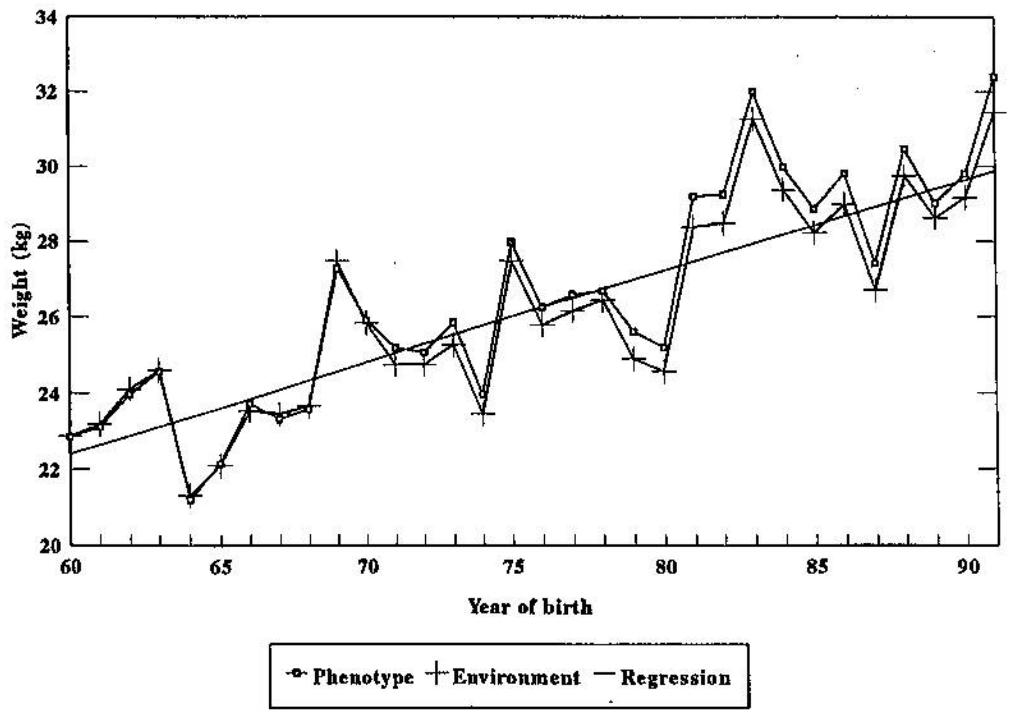

Figure 6.1.2: Annual mean phenotypic and environmental values and regression of environmental values on year of birth for birth weight.

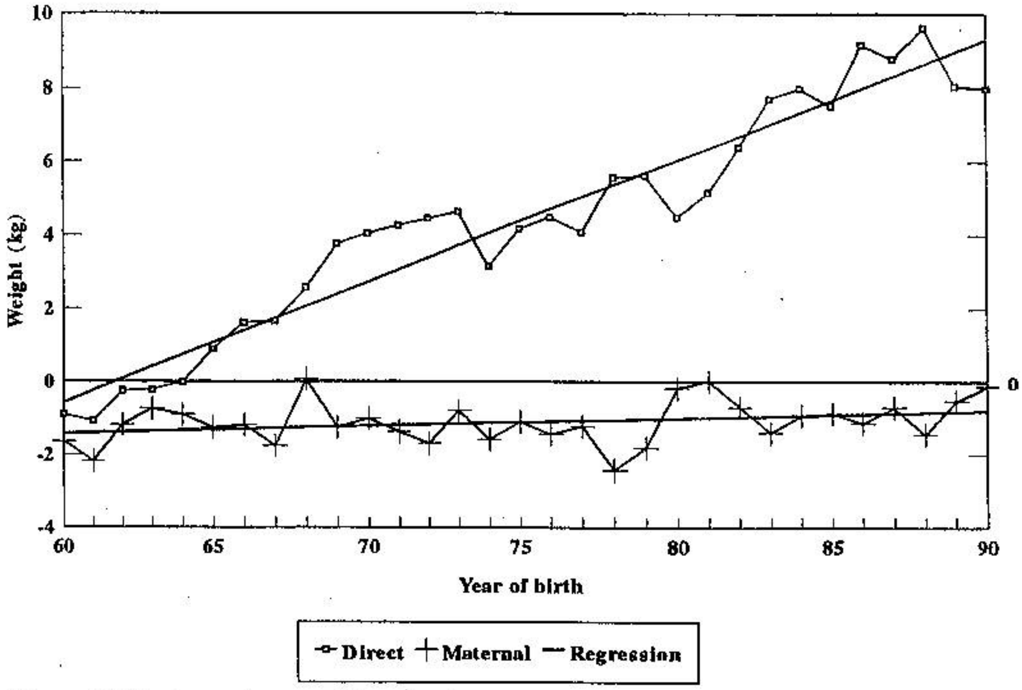

Figure 6.2.1: Annual mean direct and maternal breeding values and linear regressions on year of birth for 205-day weight.

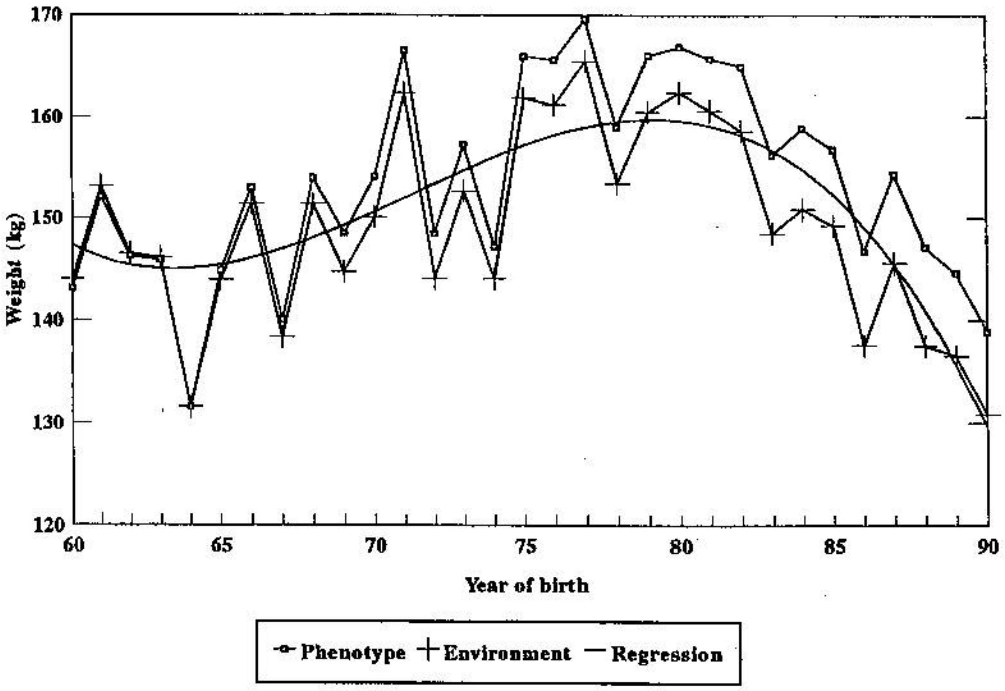

Figure 6.2.2: Annual mean phenotypic and environmental values and cubic regression of environmental values on year of birth for 205-day weight.

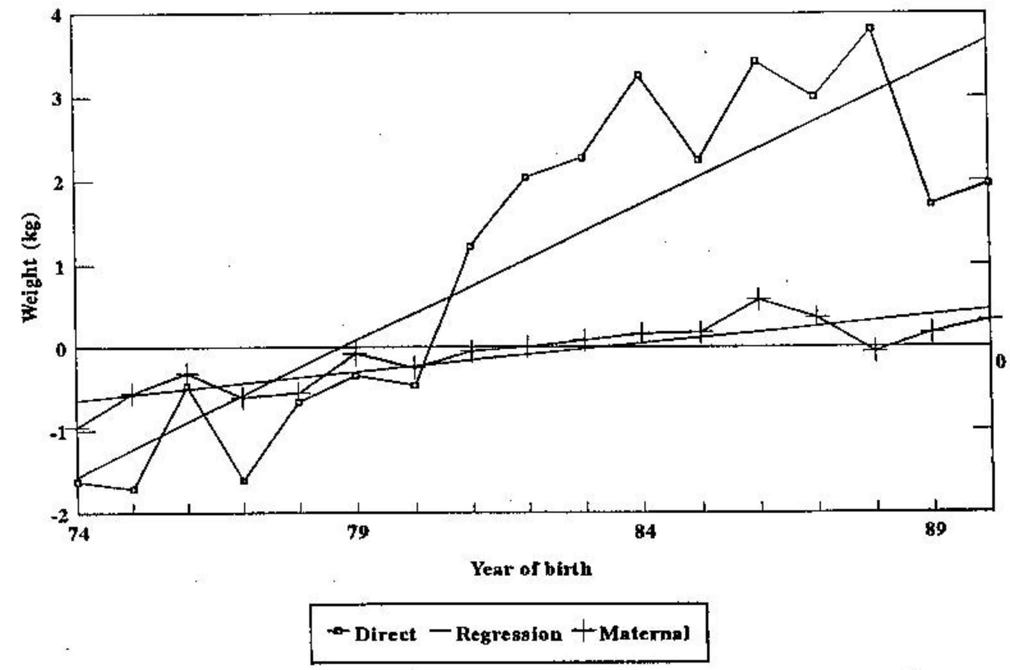

Figure 6.3.1: Annual mean direct and maternal breeding values and regressions on year of birth for 365-day weight.

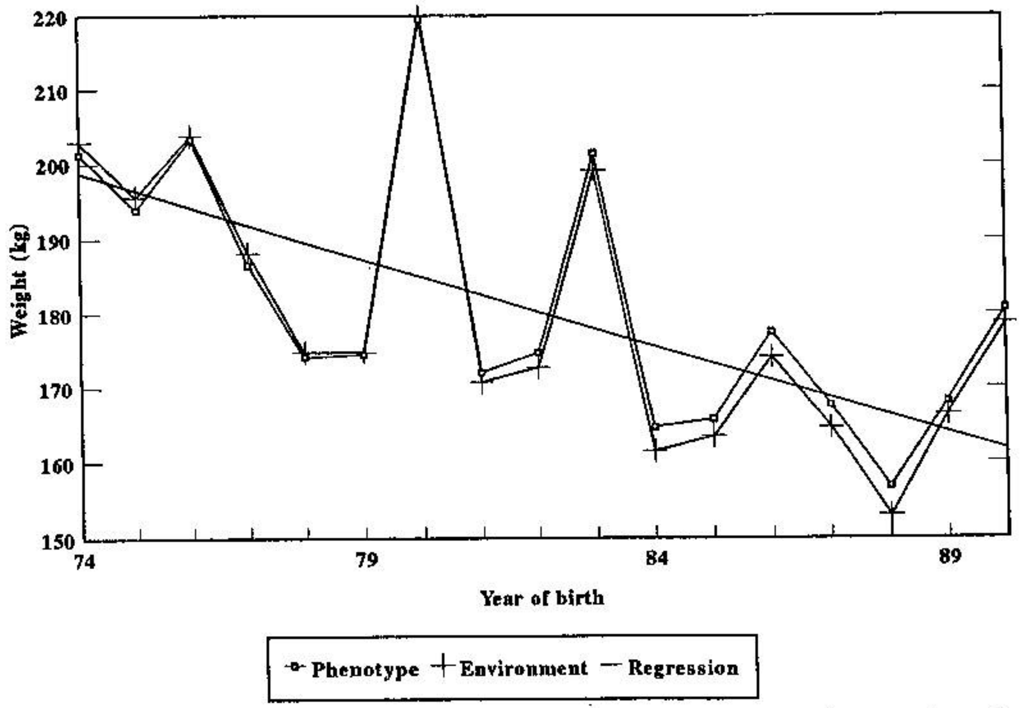

Figure 6.3.2: Annual mean phenotypic and environmental values and regression of environmental values on year of birth for 365-day weight.

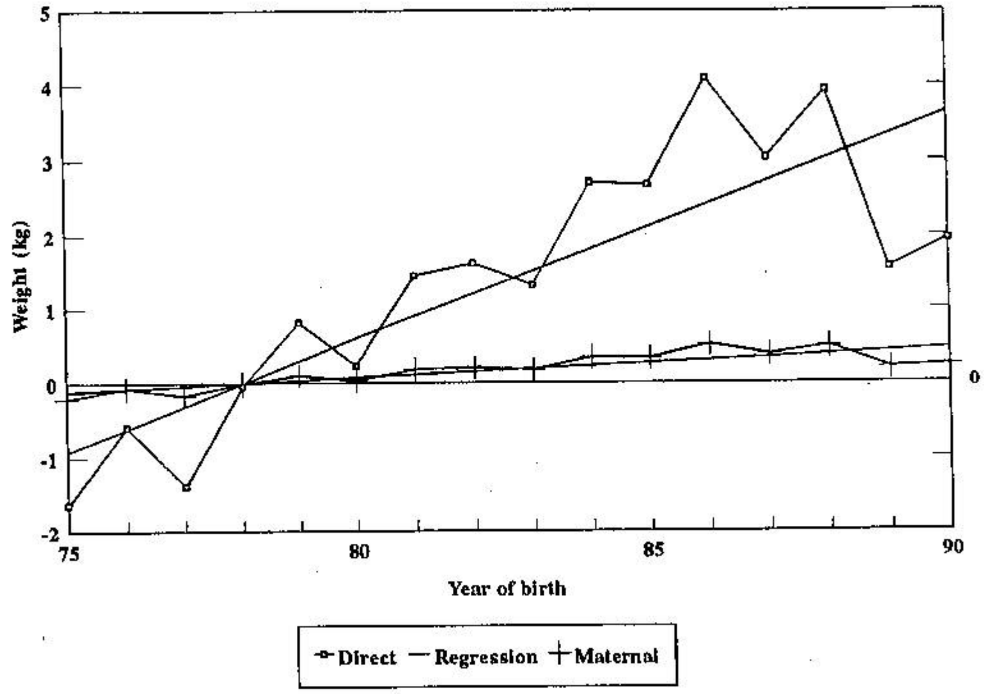

Figure 6.4.1: Annual mean direct and maternal breeding values and regressions on year of birth for 540-day weight.

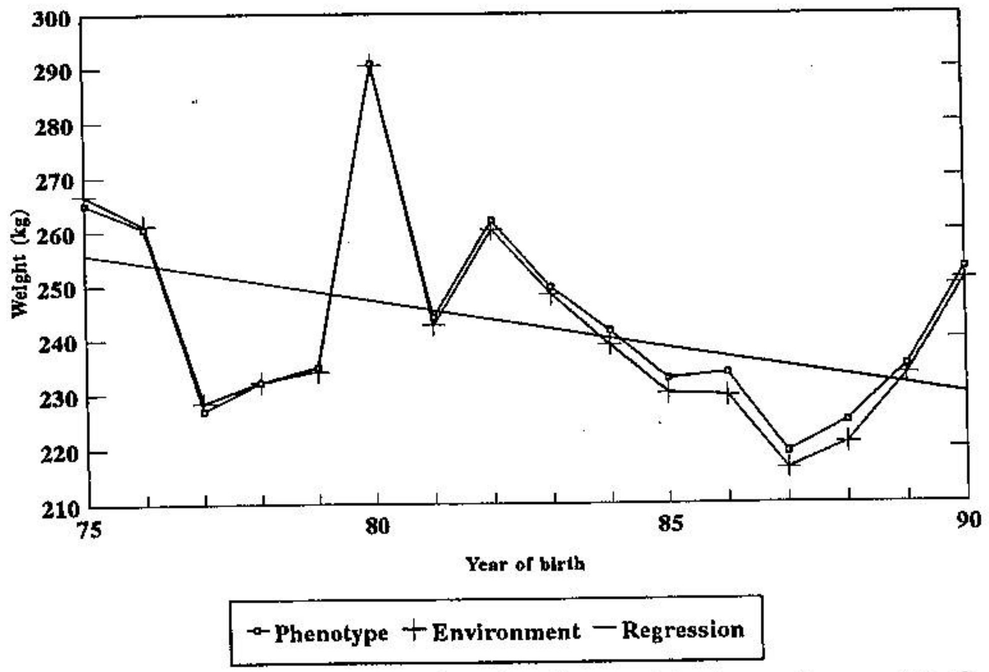

Figure 6.4.2: Annual mean phenotypic and environmental values and regression of environmental values on year of birth for 540-day weight.

of the stud during the period of study which could contribute to environmental fluctuations.

The environmental and phenotypic trends for 205-, 365- and 540-day weight from approximately 1978 to 1990, followed roughly similar patterns, indicating a deterioration of the environmental conditions. This may be ascribed to an increase in bush density without appropriate adjustment of the grazing intensity. The poor fit produced by the linear regression of 540-day weight on year of birth (R^2=0.18) suggests that this trait is strongly influenced by environmental fluctuations.

The small positive contribution of genetic values to the phenotypic values for 205-, 365- and 540-day weight, counteracted a larger decrease in environmental values, which resulted in a nett phenotypic change of about -1.99 and -1.43 kg per year for 365- and 540-day weights respectively (Table 6.1). Due to the discrepancy of a linear regression analysis of 205-day weight, phenotypic estimates are excluded. In the case of birth weight, environmental values had an accumulative effect on genetic values.

Chapter 4 reported on covariance between direct and maternal additive genetic components for the traits under study. The results in Table 6.1 indicate a significant negative trend ($P<0.05$) in maternal ability of animals for birth weight while being insignificant for 205-day weight. The improvement in the annual mean direct breeding value has resulted in the maternal breeding value of 205-day weight being maintained due to the negative covariance between the direct and maternal components.

6.4 Conclusions

The results obtained in this study indicate that optimum improvement has not been achieved in the traits under study.

Although the direct genetic component improved, the environment which includes factors such as climate, grazing conditions and management, had a consistent negative effect on 205-, 365- and 540-day weight from 1978 to 1990. This indicates that these traits can be successfully increased by improving environmental conditions. Birth weight was not affected to the same extent by environmental effects as the other traits under study.

A disconcerting result obtained is the general negative environmental trend. The dramatic decline in the environment during the last ten years of the study, as depicted in Figures 6.2.2, 6.3.2 and 6.4.2 is of particular concern. If this trend were to continue, the stud could soon face serious difficulties. Sadly, this situation is by no means unique in drought-stricken Africa.

Maternal additive genetic variance which is important in birth and 205-day weight (Chapter 4), has not been utilized. The maternal genetic trend indicates a decline in the maternal ability for birth weight while it remained constant for 205-day weight. Since the Nguni cattle breed is widely suggested as a dam line, an opportunity exists to improve the maternal ability for birth and 205-day weight by selection on maternal additive breeding values.

CHAPTER 7

GENERAL CONCLUSIONS AND RECOMMENDATIONS

Mixed model methodology, using the full additive relationship matrix, was used to investigate genetic properties and to partition the genetic and environmental components for birth, 205-, 365- and 540-day weight in the Nguni stud at Bartlow Combine. This approach is a considerable improvement in comparison to traditional methods of estimation and selection. Furthermore, the accuracy of these estimates will improve as more data and sophisticated procedures for analysis become available. The accurate collection of field data is an important facet since analyses are based on the available information.

The results obtained from the study such as the direct and maternal breeding values of individual animals should be seen as a further step in understanding the genetics of the stud. Some of the results obtained may also be applicable to the Nguni breed as a whole, since the stud at Bartlow Combine has formed the foundation of a number of Nguni studs. It is necessary that other important traits such as reproduction rate (which is probably the most important) also be investigated to develop suitable breeding programmes.

The difference in performance and genetic relationship between the seven "breeding lines" was found to be non-significant. The effort in trying to keep these "lines" separate should be revised in view of these findings.

Although inbreeding of the calf and dam had a significant effect on some of the traits, the level of inbreeding was generally low and is at this stage of little concern. It is suggested that some form of cyclic mating be practised to

prevent excessive future inbreeding.

A small but steady increase occurred in the mean direct additive genetic values of birth, 205-, 365- and 540-day weight. A considerable larger increase occurred in 205-day weight in comparison with the other traits, suggesting that other selection criteria have also been used to select herd replacements. The utilization of breeding values of individual animals in breeding programmes may improve selection response but should be used with discretion.

Maternal additive genetic variance was shown to be important in birth and 205-day weight. The trends indicate a decline in the maternal ability for birth weight while it remained constant for 205-day weight. Since the Nguni cattle breed is widely suggested as a dam line, fertility should be an important selection criterium while the opportunity definitely exists to improve the maternal ability for birth and 205-day weight even at the expense of inherent growth ability.

The dramatic decline in the environment during the last ten years of the study period is of particular concern. If this trend were to continue, the stud could soon face serious difficulties. It is recommended that immediate attention be given to the development of a suitable veld management programme.

Two major shortcomings in these studies are immediately evident. Firstly, the genetics of reproduction was not addressed and, secondly, the relationships between growth traits were analyzed using, what can currently be termed "yesterday's methodology". It is, however, hoped that the knowledge and experience gained from these humble studies will provide the impetus for meaningful future research.

ABSTRACT

Data collected from Nguni calves born at the Bartlow Combine Breeding Station were used to investigate factors affecting live weights at birth (1960–1991), 205 days (1960–1990/91), 365 days (1974–1990) and 540 days (1975–1990) of age.

Sire, year of birth, sex of calf and age of dam were found to be highly significant ($P<0.001$) sources of variation affecting these traits. The effects of interaction between year of birth and sex of calf and the inbreeding of the calf and dam were significant for some traits but their relative effects were small and were subsequently ignored. A suitable model to describe the data for the respective traits which can be used to calculate genetic parameters and breeding values is constructed and discussed.

The data were analyzed to estimate direct and maternal additive genetic variances and resulting heritabilities. The estimates of direct heritability were 0.41, 0.29, 0.26 and 0.19; maternal heritability 0.16, 0.20, 0.08 and 0.00 and total heritability 0.44, 0.40, 0.34 and 0.21 for birth, 205-, 365- and 540-day weight, respectively. The correlation between the direct and maternal components were -0.49, -0.39, -0.08 and 0.97. It is suggested that both direct and maternal breeding values be included in a selection programme for birth and 205-day weight. Because of the classification of the Nguni as a dam line, the improvement in the maternal component is of particular interest. The results for 365- and 540-day weight indicated that the maternal component is of less importance and a response in these traits may be successful with selection for direct additive values.

Genetic, phenotypic and environmental correlations were

estimated. All correlations between these traits were found to be positive. The genetic correlation between birth and 205-day weight was low (0.26) and between 365- and 540-day weight, close to unity (0.97). The other genetic correlations were medium. The phenotypic correlations between birth weight and other traits were small (≤0.29) while the correlations between 205-, 365- and 540-day weight were medium to high (0.51 to 0.70). The results suggest that selection for an improvement in 205-day weight will result in an increase in 365- and 540-day weight with the possibility to control birth weight.

Best Linear Unbiased Predictions (BLUP) of breeding values were obtained by Restricted Maximum Likelihood (REML) procedures fitting a direct and maternal additive genetic model. Annual mean values were calculated to determine direct genetic, maternal genetic and environmental trends. The linear regression representing genetic trend indicated an increase of 0.12, 0.22, 0.18 and 0.12% per year for birth, 205-, 365- and 540-day weight respectively. The environmental trend was consistently positive for birth weight. A cubic regression produced a relatively good fit for the environmental values of 205-day weight (R^2=0.61). Environmental values for 205-, 365- and 540-day weight decreased from approximately 1978, suggesting that the environmental conditions had a negative effect on the phenotype of these traits. The nett phenotypic change was 0.27, -1.99 and -1.43 kg per year for birth, 365- and 540-day weight respectively. The trend of maternal ability for birth weight declined significantly (P<0.001) and was insignificant for 205-day weight.

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