Relationship between linear type traits and fertility in Nguni cows

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Declaration

I, **Titus Jairus Zindove**, vow that this dissertation has not been submitted to any other University other than the University of KwaZulu-Natal and that it is my original work conducted under the supervision of Professor Michael Chimonyo. All assistance towards the production of this work and all the references contained herein have been duly accredited.

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List of abbreviations

AFC	Age at first calving
BD	Body depth
BCS	Body condition score
CI	Calving interval
DLC	Days from last calving
FC	flank circumference
GLM	Generalised linear model
HG	Heart girth
LCI	Lower confidence interval
LSD	Least significant difference
MSA	Kaiser measure for sampling adequacy
NH	Navel height
NL	Body length
SAS	Statistical Analysis Systems
SD	Standard deviation
s.e.	Standard error
ST	Body stature
TCL	Total number of calves lost before weaning
UCI	Upper confidence interval

Abstract

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The broad objective of the study was to determine the relationship between linear type traits and fertility in Nguni cow herds. Data collected from 300 Nguni cattle owning households from two municipalities (150 each) were used to compare trait preferences of Nguni cattle owners located in semi-arid and sub-humid production environments. A total of 1017 records from 339 cows of Venda, Pedi, Swazi and Makhatini ecotypes were used to investigate sources of variation of linear traits in Nguni cows of different ecotypes. A total of 1559 Nguni cows kept under thornveld, succulent karoo, grassland and bushveld vegetation types were used to determine the relationship between six linear type traits (body stature, body length, heart girth, navel height, body depth and flank circumference) and fertility traits (calving interval and age at first calving) in Nguni cow herds under natural rangelands. Relationships between the linear type traits and incidences of still births and abortions in Nguni cow herds were determined using 250 Nguni cows from two sites experiencing sub-humid and semi-arid environments (125 cows each). Cows with at least Parity 3 were used in the study.

Nguni cattle owners located in sub-humid areas mostly preferred fertility traits (calving interval and age at first calving) whilst those from semi-arid regions preferred traits reflective of adaptation to harsh conditions. In sub-humid areas, calving interval (CI) and age at first calving (AFC) were ranked first and second, respectively. Although lowly ranked, linear traits were considered by communal farmers in selecting Nguni cows for breeding stock. Cow fertility problems were mainly experienced in semi-arid areas compared to sub-humid areas. Semi-arid areas had more households (32.7 %) with cows with extended CI (2 and 3 years) than sub-humid areas (19.1 %). Body depth, flank circumference and heart girth were influenced ($P < 0.05$) by parity of cow, season of measurement and body condition score (BCS). Body depth, flank circumference and heart girth increased with increase in parity of cow. Cows in Parity 7 had the deepest bodies and navels hanging closest to the ground. Venda cows had the same flank circumference and heart girth across all seasons ($P > 0.05$). Body stature, body length, heart girth, navel height, body depth and flank circumference varied with ecotype of cow ($P < 0.05$). Venda cows had significantly higher body depths. Cows with deeper bodies had navels near the ground ($r = -0.32$) and longer bodies ($r = 0.46$; $P < 0.05$). Cows raised on the succulent karoo rangelands had shortest calving interval, calved earliest, deepest bodies, widest chests and flanks. Linear type traits under study can be grouped into two distinct factors, one linked to body capacity (body depth, flank circumference and heart girth) and the other to the frame size of the cows (body stature, body length and navel height). Calving interval and age at first calving decreased linearly with increase of body capacity ($P < 0.05$). There was a quadratic increase in age at first calving as frame size of cows increased ($P < 0.05$). As the body depth increased the likelihood of the incidence of still births and abortions in cows decreased (odds ratios 1.15 and 1.15, respectively). It was concluded that small-framed cows with large body capacities had short calving intervals, calved early and were less likely to abort or experience still births.

Keywords: linear traits; body capacity; calving interval; age at first calving; Nguni cows.

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Dedication

To God, from whom all blessings flow.

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Chapter 1: General Introduction

In sub-Saharan Africa, there has been genetic erosion of indigenous cattle due to the introduction of unsuitable imported breeds. These imported breeds are assumed to be more productive basing on performances in environments that are conducive to them (Scholtz and Theunissen, 2010). In recent years, there have been increased efforts to restore the once eroded native genetic resources (Strydom *et al*., 2001). The Nguni, an indigenous Sanga type breed, is increasingly becoming important to communal and commercial beef production in Southern Africa. Studies have shown that there are various Nguni ecotypes in Southern Africa separated on the basis of their genetic distancing. Bester *et al*. (2003) suggested that interaction between the different environments and the genotype over a period of years probably led to different Nguni ecotypes found in Southern Africa. In South Africa, different Nguni ecotypes are distributed among the nine provinces. These include the Pedi, Swazi, Bartlow and Venda ecotypes. Although no studies have been conducted to compare the performance of these Nguni ecotypes in South Africa, Maciel *et al*. (2011) showed differences in reproductive performance of different Nguni ecotypes in southern Mozambique.

Under harsh environmental conditions of the sub-Sahara conditions, Nguni cattle productivity outcompetes the imported breeds. The Nguni performs better under extreme temperatures and forages of low nutritive value (Mapiye *et al.*, 2009). Several studies have pointed out that the Nguni cattle can survive and reproduce competently under semi-arid conditions and still give higher quality beef compared to exotic breeds (Bester *et al*., 2003; Muchenje *et al*., 2008). This could be attributed to low maintenance feed requirements of the Nguni breed (Mapiye *et al*., 2010) as compared to the exotic breeds. Nguni attributes include resilience on fragile and marginal land; and in drought and stress conditions for longer periods. Furthermore, they have long productive lives with cows producing 10 or more calves, calving regularly (Bester *et al.*, 2003). Acknowledgment of these adaptive attributes led to the initiation of programmes to reintroduce the Nguni breed in different South African provinces. However, this valuable and adapted breed still constitutes a small percentage of the beef sector in the sub-Sahara (Scholtz and Theunissen, 2010) due to the quest for fast-growing imported breeds by commercial farmers and lack of proper breeding practices.

Reproduction traits are the major determinants of productivity and efficiency in beef cattle (MacNeil *et al.*, 1994). Consequently, improvement of reproductive efficiency of beef herds is currently a major subject in several countries. In the sub-Sahara, this could be due to the fact that fertility of beef cows is a real challenge due to poor nutritional quality during the dry season and limited feed intake during the summer when ambient temperatures are extremely high. There are suggestions that the best way to improve cow fertility is through manipulating management practices (Hess *et al*., 2005). It has, however, been reported that subfertility in cows is not entirely dependent on management practices but is also influenced by genetic variation (Rust and Groeneveld, 2001). Success of direct selection for commonly used fertility traits such as calving interval (CI) and age at first calving (AFC) have been reported to be slow due to their low heritability ranging between 0.03 and 0.08 (Pryce *et al*., 2000). Gutierrez *et al.* (2002) reported heritability estimates of 0.17 and 0.36 for calving rate and number of calves over a cow's lifetime in beef cattle, respectively. This shows that improving cow fertility using selection is slow. Thus, both genetic and non-genetic strategies of improving fertility must be used simultaneously to increase beef productivity.

Fertility is a complex trait because of the various traits which it encompasses and the fact that it is influenced by a wide range of factors. The challenge is to weigh the value of the various measures of fertility to pinpoint the most suitable and appropriate to maximize production. Traits which are often considered by most farmers and breeders for genetic evaluation of fertility include CI, AFC, calving rate and longevity. Longevity is the length of the reproductive life of a cow which is culled from the breeding herd because she is incapable of continuing as a productive cow (Forabosco *et al.,* 2004).

Although fertility is economically important in beef production, long generation intervals are a challenge to its genetic improvement through selection. Use of linear traits as indirect indicators of fertility to improving reproductive performances could be an option to reducing generation interval since it allows early selection. Little work has, however, been conducted on the relationship between linear traits and fertility traits in Nguni cattle. Gutierrez *et al*. (2002) reported significant genetic correlations between body depth and calving date, CI and AFC. Linear type traits describe measurements for a range of visual characteristics of an animal (Berry *et al.*, 2004). One suggestion that reflects the relationship between type traits and fertility is that the higher the flank circumference is than the heart-girth, the higher the reproductive ability of the beef cow (Zaborski *et al*., 2009). This could be because the flank is located right on the hindquarters of a cow. Cows with larger relative heart girths have more energy available for milk production and meet energy requirements for breeding cows. Cows with small relative heart girths have long post-partum anoestrous periods after their first calf (De Haas *et al*., 2007). Being able to identify cows that have low chances of re-breeding is a huge economic advantage.

South African Nguni farmers include linear type traits in their breeding programmes. This is despite lack of substantive evidence indicating the usefulness of linear type traits as predictors of fertility in Nguni cows. There is need to ascertain the relationship between linear type traits and fertility in Nguni cows to justify if indirect selection for fertility using linear type traits can improve accuracy of selection. There have been suggestions that, in addition to hardiness, some of the linear traits such as body depth and small body size make them highly fertile under harsh conditions experienced in the sub-Saharan region (Bayer *et al.*, 2006). To date, relationships between the linear traits and fertility traits in Nguni cows has not been published. The major drawback in selection of type traits is that they are difficult to record with high degrees of accuracy and precision to provide uniform and standardised information. In beef production, the same traits could be measured in a slightly different way across regions due to lack of international assessment standards of linear traits. Low accuracy of selection lowers the response to selection. These difficulties in trait recording may impede genetic progress of the possible breeding scheme for linear type traits in Nguni cows and calls for the need to harmonise the scale of scoring linear traits in Nguni cows once they are included in the breeding objective.

1.1 Justification

There is a general lack of proper breeding programmes to increase fertility of Nguni cattle. Determining the association between linear and fertility traits can help introduce a genetic evaluation system for linear type traits. Fertility traits such as CI, stayability and longevity of a cow can only be recorded at a later stage and, thus, finding an early predictor of such traits could be important for breeders. Linear type traits could be used as an early predictor of fertility traits once the relationship between these traits has been determined. Depending on the relationship between linear type traits and age at classification, there is a possibility that farmers managing Nguni breeding cow herds could select for linear traits at the same time selecting for fertility indirectly considering that it is easier and faster to select for linear type traits. Early selection, based on linear traits, combined with early breeding could be a useful tool towards reducing generation interval. Trait importance can change for different production systems and, since the Nguni breed has become popular in the communal and commercial production systems, it is necessary to determine the relationship between linear traits and fertility in both production systems. The relationship between linear traits and fertility of the Nguni cows is also expected to differ with production systems since management systems are different.

Although farmers use visual appraisal to select for Nguni cows, there is no uniform and standardised information selection of linear traits. Enlightening the possibility of including linear type traits in Nguni breeding programmes to improve fertility could be used as a catalyst to establishing national harmonised definitions for linear traits in Nguni cows to provide uniform and standardised information and do away with subjective assessment. Determining the phenotypic relationship between linear traits and fertility traits can also be a pulling factor to an expanded supply of linear type traits data and, thus, determination of the genetic relationships between the linear traits and fertility in Nguni cows.

1.2 Objectives

The broad objective of the study was to explore indirect selection for fertility of Nguni cows using linear type traits. The specific objectives were to:

1. Compare trait preferences of Nguni cattle owners located in semi-arid and sub-humid production environments;
2. Explore factors associated with body depth, body stature, body length, flank circumference, heart girth and navel height in Nguni cows;
3. Determine the relationship between linear type traits and fertility traits in Nguni cows kept under natural rangelands under extensive production systems;
4. Determine the relationship between linear type and fertility traits in Nguni cows kept under semi-arid and sub-humid communal rangelands; and
5. Assess the reduction in dimensionality of six linear traits and determine the relationships between the extracted factors and fertility of Nguni cows.

1.3 Hypotheses

The hypotheses tested were that:

1. Trait preferences of Nguni cattle owners located in semi-arid and sub-humid production environments are similar;
2. Ecotype of cow, parity of cow and season of measurement affects body depth, body stature, body length, flank circumference, heart girth and navel height in Nguni cows;
3. There is a negative linear relationship between linear type traits (body depth, body length, stature heart girth, flank circumference and navel height) and fertility traits (calving interval and age at first calving) in Nguni cows kept under commercial rangelands;
4. There is a negative relationship between linear type traits and fertility traits in Nguni cows kept under communal rangelands;
5. A relationship exists between the linear traits and their underlying latent construct(s).

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Chapter 2: Review of Literature

2.1 Introduction

The South African beef cattle industry consists of a large number of breeds, mostly run under extensive range conditions. Under extensive beef production, optimal reproductive performance is a function of the forage quality and nutritional needs of the reproductive cow (DelCurto *et al*., 2000). In the Sub-Sahara, reproductive performance of beef cows suffers due to adverse climatic and nutritional conditions. In the quest for improvement, there has been a shift from use of imported breeds towards breeding with indigenous breeds which are adapted to the adverse climatic and nutritional conditions. The Nguni and Bonsmara cattle, for example, increased exponentially over the last decade in South Africa. The Nguni and Bonsmara breeds had the highest number of cows registered under the National Beef Recording and Improvement Scheme in 2008, totalling 23,298 and 52,924 cows, respectively (Strydon, 2008). Managing and optimizing cow fertility, however, still remains one of the most significant challenges of extensive beef producers in the sub-Saharan Africa. This could be due to the fact that fertility is a very complex trait. It is difficult to define, record and select for all the components of fertility. This review discusses fertility traits in beef cattle, its complexities and possible alternative selection strategies with particular attention to South Africa's indigenous Nguni cattle.

2.2 The South African Beef industry

The South African beef industry is mainly comprised of two major sectors, the communal sector and the commercial sector. The commercial sector was previously pre-dominated by synthetic and crossbreeds. Indigenous breeds have been gaining much ground in recent years totalling 41.8 % of the total beef population in 2008 (Scholtz *et al*., 2008) compared to 37 % in 2002 (NDA, 2003). Most of the beef production systems are based on the cow-calf production system, where cows are bred and produce calves which are then fattened for slaughter. Despite the fact that the climate, soil and terrain are not best suited for forage production, the bulk of South African beef is produced under extensive conditions where cattle are mainly fed on natural grazing lands with supplements provided where possible. The South African feedlot industry is also under increasing pressure due to exceptionally high grain prices (Strydom, 2008). The average producer price of maize grain, for example, has increased by 8 % from 2008 to 2013 [National Department of Agriculture (NDA), 2011]. The feedlot industry is also under the spotlight due to its routine use of antibiotics to resist bacterial infections. Antibiotic residues in meat have been reported to have adverse effects on human health such as cancer risk and a possible enhancer of antibiotic resistance in human disease causing organisms (Alla *et al*., 2011). This has caused many beef producers to opt for the more viable extensive cattle grazing. Approximately 69 % of South African agricultural land is used for extensive cattle grazing (NDA, 2011). The demand for breeds suitable for production systems under use dictates the breed numbers in the beef industry. In addition to production systems, vast variation in the climate and vegetation of South Africa also plays a significant role in dictating the type of breed used in different regions. Various ecotypes have also emerged within breeds due to mutational adaptations towards different environments found across the country.

The total beef cattle population in South Africa includes about 6.67 million cattle owned by commercial farmers and 5.69 million beef cattle owned by emerging and subsistence communal farmers (NDA, 2011). Commercial beef production is generally based on indigenous breeds, imported breeds, synthetic breeds and/or crossbreds. The communal beef herds are mostly comprised of indigenous and non-descript types. Common beef production systems in South Africa are highly suited to converting low quality roughage to products of a higher economic value. Indigenous breeds are widely acknowledged to be the outstanding for optimal production under harsh African conditions. It is this ability that has seen the indigenous breeds gaining momentum under the Sub-Saharan conditions.

2.3 South African indigenous breeds

There has been genetic erosion of indigenous cattle due to the introduction of unsuitable imported breeds in the sub-Saharan Africa. These imported breeds are assumed to be more productive based on performances in environments that are conducive to them (Scholtz and Theunissen, 2010). The mistaken perception of the inferiority of African indigenous breeds led to them being washed away from the commercial sector and massive genetic dilution of these breeds through uncontrolled crossbreeding and interbreeding in communal production systems (Bester *et al*., 2003). As a result, to-date, the South African communal beef sector is still predominated by non-descript breeds. Non-descript breeds are the crossbred cattle that are produced through indiscriminate crossbreeding. The introduction of imported breeds in communal production systems was followed by a decline in productivity which is attributed to the high prevalence of diseases and parasites and lack of feed resources (Musemwa *et al.*, 2008). Thus, it can be rendered that efforts to introduce imported cattle breeds in the communal sector have been a failure largely due to the fact that these breeds cannot withstand the harsh environmental conditions as compared to the sturdy, disease-resistant and hardy indigenous breeds. In recent years, there have been increased efforts to restore the once eroded native genetic resources in South Africa and other African countries (Strydom *et al*., 2001).

The quest for a fast growing, highly fertile and hardy breed resulted in the creation of the Bonsmara in South Africa, an indigenous synthetic breed which is adapted to a sub-tropical environment. The Bonsmara originated from 5/8:3/8 combination of the Afrikaner and Hereford breeds (Strydom, 2008). Even after the Bonsmara was introduced to the beef sector, there was continued motivation through research outputs that native breeds such as the Nguni when raised under low input management systems, compete favourably with imported and synthetic beef breeds in terms of reproductive efficiency, meat quality and growth rate (Strydom *et al*., 2001; Muchenje *et al*., 2008). Modern South African indigenous cattle population is predominated by the synthetic, Zebu and Sanga types which are adapted to hot climates (Strydom et al., 2001). These include The Nguni, Afrikaner, Bonsmara, Drakensberger and the Tuli cattle. In recent years, it is the Nguni breed which has received much revering from scientists, breeders, commercial farmers and even communal farmers. As a result, it has shown great resurgence in both the communal and commercial beef sector of late. The Nguni breed constitutes 35 % of the emerging and communal sector (Scholtz *et al.,* 2008) and had second highest number (23,298), after the Bonsmara (52,924), of cows registered with the National beef Recording Scheme in 2008 (Strydom, 2008).

2.4 Re-introduction of the Nguni cattle in the South African beef sector

As evident from the beef cattle statistics, the Nguni breed is increasingly becoming a popular breed to communal and commercial beef production in South Africa. This is a result of collaborative efforts by the government, livestock associations and academic institutions to restore this once eroded native genetic resource. The recognition of its adaptive traits has increased interest to use Nguni cattle in the commercial sector (Nowers and Welgemoed, 2010). Various Nguni associations have since been formed at national and provincial levels to promote production, marketing of the breed and organisation of Nguni cattle auctions for selling and buying breeding stock.

Although Nguni productivity in the commercial sector is at acceptable levels, production levels in the communal and emerging beef farmers are still low mainly due to low fertility (Strydom et al., 2001). Various infrastructure and support systems for re-introduction of the hardy low-maintenance Nguni breed in communal production systems are already in place. Basically, the Nguni project, launched in most of South African rural areas, involves a university which collaborates with the Department of Agriculture and the Industrial Development Corporation (IDC) to work with emerging farmers. Selected farmers are given about 10 heifers each and one or two bulls per community. After five years, the beneficiaries are expected to have returned the same number of heifers and bulls which are then passed on to the next selected farmer using the "pass on the gift concept" (Raats *et al*., 2004).

2.5 Challenges for Nguni cattle production in South Africa

Although the Nguni project is expected to be of much success in the near future, the progress to be made is subject to various loopholes are being addressed. The success of the project is reliant on vigilant monitoring and/or management of the herds, which is a great challenge in the rural communities. Non-descript breeds still dominate the cattle herds in the communal production systems (Scholtz and Theunissen, 2010). Imported breeds, such as the Brahman, are also still very common among the communal herds (Scholtz *et al.*, 2008). There is still a trend to use imported bulls by many communal farmers and these breeds dilute the effect of the introduced Nguni bulls. The major breeding challenge in these areas is that there is uncontrolled mating. As a result, owners of the Nguni cows are often not able to choose the breed of bull they want to sire the heifers and cows in their herds.

The main management issues which may hinder productivity amongst communal Nguni farmers include lack of proper grazing and reproductive management. There is diminutive grazing management in communal production systems which results in a generally low level of nutrition, which, in turn, affects reproductive performance of both bulls and cows. Reproductive performance is the major determinant of productivity of any beef enterprise (Gebeyehu *et al.*, 2005). To correct for the negative effect of low levels of nutrition on reproductive performance in communal Nguni farming, there is need to select for highly fertile cows under these adverse conditions and/or educate farmers on proper grazing management. The latter has been implemented in the Nguni project with extension staff deployed in most rural communities but success rates were low due to difficulties in changing or controlling community-based decisions and grazing habits (Bester *et al.*, 2003). The next best way could be to establish proper selection programmes for cow fertility, in addition to improved grazing management. Selection, however, heavily depends on animal identification and the keeping of regular records which is generally perceived as unimportant by communal farmers who barely keep animal records.

Besides long calving intervals and late calving in communal production systems, poor reproductive performance is also still a huge economic burden for extensive commercial beef producers (Sheldon and Dobson, 2003). Commercial Nguni farmers are no exception. Although most of the commercial Nguni farmers do keep records, genetic improvement of reproductive traits by use of fertility records, which is what most commercial Nguni breeders are limited to, is difficult. Fertility traits in beef cows have low heritability estimates ranging from 0.03 to 0.05 (Gutierrez and Goyache, 2001), thus response to selection is very low. The fact that fertility traits are lowly heritable and there are no fertility records in communal production systems suggests that improving Nguni cattle production, in both communal and commercial sectors, through directly selecting for fertility traits is difficult. For these reasons, it may be necessary to select for improved fertility through other traits that are highly correlated with reproduction traits but are more highly heritable.

2.6 Reproductive measures for beef cows

The productivity of every beef herd largely depends on the reproductive performance of the cows (Gebeyehu *et al*., 2005). The lifetime productivity of a cow is mainly influenced by fertility traits such as longevity, CI and AFC. Together, these three factors are the main determinants of the reproductive efficiency of a beef herd (Weigel, 2006). Thus cow fertility is critical to beef production.

2.6.1 Longevity

Longevity measures the length of the reproductive life of a cow in a herd. It is the age at which a cow is culled from the herd due to her inability to continue as a productive dam (Rogers *et al*., 2004). Longevity is a trait that has great economic importance to beef cattle producers. High longevity increases selection intensity because only a few replacement heifers have to be chosen each year. Thus, high longevity reduces the cost of herd replacements, increases the number of animals available for marketing and increases the proportion of the high-producing, mature animals in the breeding herd. Nevertheless, this trait is rarely recorded by beef producers mainly because it is expressed late in life. A strategy to indirectly select for longevity in beef cows at an early age will be a huge breakthrough. Some of the determinants of cow longevity in beef production include calving ease, milk production, ability to endure weather extremes, ability to harvest forage, consume feed, and maintain body condition, fertility, health and mothering ability. Heritability estimates of longevity range from 0.02 to 0.23 (Weigel, 2006).

2.6.2 Calving interval

Calving interval is the number of days between successive calvings. Calving interval has been traditionally used as a measure of reproductive efficiency in both commercial and communal beef production. Calving interval alone is, however, not a true reflection of a cow's fertility. Cows with a short CI but with later AFC and short reproductive life are not desirable in a beef herd. Thus, CI is best used as a measure of cow fertility when incorporated into selection indices involving other fertility component traits such as AFC and longevity. Heritability estimates of CI range from 0.03 to 0.37 (Gutierrez and Goyache, 2001). Causes of long calving intervals within a herd include poor nutrition, shortage of bulls (Ndebele *et al*., 2007). In South Africa, CI for indigenous cows average 12 months in commercial production whilst it is usually longer than 13 months in cows in communal production systems (Nqeno, 2008).

2.6.3 Age at first calving

First calving marks the beginning of a cow's productive life. There is a high genetic correlation between AFC and calving interval (Gutierrez and Goyache, 2001). Cows which calve at an early age have been reported to have short subsequent calving intervals signaling high productivity. Thus, cows that have their first calf at an early age are more desirable. As a result, AFC is routinely recorded in by most commercial beef producers to evaluate heifer fertility. Heritability estimates for AFC are low to moderate, ranging from 0.01 to 0.27 (Gutierrez and Goyache, 2001), indicating that it is highly influenced by environmental factors. Of the environment and management determinants of AFC, the quality and quantity of feed available plays a major role. Quality and quantity of feed available affects growth rate hence time taken by an animal to attain puberty and sexual maturity in turn affects AFC. In the sub-Saharan Africa, problems of feed quality and quantity for free ranging beef production are well documented (Scholtz and Theunissen, 2010). This implies that AFC also suffers since it is heavily influenced by nutrition.

In addition to the fact that fertility traits are lowly heritable, fertility is a very complex trait, which is difficult to record, to define and to evaluate. As a result, reproductive efficiency of beef cattle production is still suboptimal worldwide. In the sub-tropics, the situation is worsened by low quantity and quality nutrition during the dry season and limited intake of feed during the hot and humid summer months. Adapted indigenous beef breeds, particularly the Nguni, play a particularly important role in addressing the effects of harsh conditions on fertility. There is, however, ample within-breed variation in these indigenous breeds such that selection for fertility traits can have an important impact on herd profitability. Considering that low heritability and complexity of fertility traits are drawbacks for direct selection, there is need to come up with new strategies to improve fertility of these indigenous beef breeds if productivity is to be increased.

2.7 Selection strategies to improve reproductive performance in Nguni cattle

Several management plans have been on the ground since the re-introduction of the Nguni cattle into the South African beef sector. Basically farmers and project coordinators have been concentrating on short term strategies to improve reproductive performance in Nguni cows. These include heifer development programmes, reducing incidences of dystocia, nutritional management and early weaning. Genetic selection to improve herd reproductive performance is also under practice in commercial Nguni farming but very little, if any, is being done by communal Nguni farmers. Ideally, all these strategies should be used in collaboration to obtain the maximal benefit. Considering the fact that record keeping is a challenge within communal Nguni farmers and that fertility traits are lowly heritable, there is need to come up with an easier and faster way to select for fertility. Moreover, since the assessment of a cow's reproductive performance is usually determined in the later stages of its life, early indicators of fertility might be useful in hastening the process. As already suggested, highly heritable traits which are correlated to reproductive traits can be used to indirectly select for fertility in cows. One potential selection target could be the use of linear traits, because their estimated heritability has been reported to be relatively high, which provides an opportunity for selection. Heritability estimates ranging from 0.26 to 0.53 for various linear type traits for beef cattle under extensive grazing have been reported (Vesela *et al*., 2005).

In dairy cows, there is a relationship between the conformation traits such body depth and heart girth circumference and its reproductive performance (Vacek *et al*., 2006; Dubey *et al.,* 2012). In dairy cattle, type traits are already in use as early predictors of longevity (Brotherstone, 1994; Vollema, 1998; Larroque and Ducrocq, 2001) and as indirect selection criteria for herd life (Gutierrez and Goyache, 2001). Though research on dairy cows has shown that linear traits are associated with reproductive performance on a phenotypic scale, linear traits have received little attention in beef cattle breeding despite their potential usefulness in improving fertility. Forabosco (2004) reported that there is a general association between linear type traits and productive life span (longevity) of Chianina beef cows. Larroque and Ducrocq (2001) reported similar findings in Holstein cows. Though Forabosco (2004) did not determine the relationship between linear type traits and other fertility traits such as calving interval and birth weight of calves, it can be presumed that cows with desirable fertility traits such as shorter calving intervals are more profitable for the breeder so they remain in the herd longer than do cows with longer calving interval. Thus, basing on this assumption, there could be a useful relationship between linear type traits and fertility traits other than longevity in beef cows. There is not enough evidence about the relationship between linear traits and reproductive function in beef cows to make recommendations so far; thus, there is need to ascertain the relationships between linear type traits and fertility before basing selection decisions on linear traits with the intention of enhancing fertility in Nguni or any other beef cows. Commonly reported indirect fertility indicators of fertility in dairy cattle include body depth, flank circumference, heart girth circumference, stature and length of the cow (Berry *et al*., 2004; Zink *et al.,* 2011). Basing on these reports and other physiological arguments it may be hypothesized that these linear traits are also indirect fertility indicators in beef cows.

2.7.1 Body depth

Body depth is defined as the distance between the top of the spine and the bottom of the deepest point of the rear rib (Dubey *et al*., 2012). It has been suggested that body depth of an animal is an indicator of its body capacity. Cows with deep bodies in addition to wide, well-sprung ribs are said to have a large body capacity (Hansen *et al*., 1999). Large body capacity is associated with plenty space for the rumen and digestive system, and this, in turn, affects the food ingestion, digestion and assimilation capacity of a cow (Dubey *et al*., 2012). Cows with little body capacity are more likely to struggle to meet nutritional requirements during pregnancy when fed on natural pastures of poor nutritional value. This is because the gut size is limited by the abdominal capacity. Deep wide bodies with wide open ribbing provide lots of room for the rumen to expand and digest large amounts of high-fibre; lower protein feeds along with plenty of water. Cows with deeper bodies, hence large capacity, are capable of using low quality forage efficiently due to potentially longer passage rates and consequently more thorough digestion compared to those with shallow bodies. This highly suits the sub Saharan environmental conditions where there is poor quality forages since animals need to consume large amounts of feed to meet their nutritional requirements.

During late gestation, cows reduce dry matter intake as a consequence of constraints in rumen fill and digestion (Van Saun and Sniffen, 1996). Cows with shallow bodies have no enough room for the rumen to expand or for the foetus to be carried comfortably without displacing other organs. During pregnancy, as the foetus is growing in the uterus it fills a large portion of the cow's body cavity, thus displacing rumen capacity. Thus reduced forage intake during late gestation could be partly a result of restricted rumen capacity caused by space limitations in the abdominal cavity due to the presence of the foetus, placenta, and associated fluids. Under-nutrition due to limited feed intake during late gestation (prepartum) has detrimental effects on subsequent reproductive efficiency. Reproductive performance is closely linked to the amount of available energy reserves a cow has especially during gestation. Reduced forage intake during pregnancy impairs energy balance, hence foetal growth and body condition score of the cow at calving will be affected. Nutritional status of the cow at the time that she calves also determine if and when she returns to estrus hence calving interval. Cows with deeper bodies have sufficient body cavity capacity for forage intake to meet nutritional requirements during pregnancy and are more likely to calve heavier calves than cows with shallow bodies. Thus body depth affects ruminal capacity, which affects pre-partum intake hence subsequent reproductive efficiency.

Despite its potential usefulness, body depth is presented in literature less frequently. A few studies conducted on body depth reported that it is generally moderately heritable, with estimates ranging from 0.2 to 0.37 (Gutierrez and Goyache, 2001; Berry *et al.,* 2004). In addition, body depth has moderate to strong genetic correlations with various fertility measures in both beef and dairy cows (Berry *et al.*, 2004). The existence on moderate genetic correlations between body depth and fertility traits in cows justifies the potential usefulness of type traits in predicting fertility in beef cattle. The correlations between body depth and fertility traits are genetically controlled. Phenotypic correlations are influenced by a combination of underlying environmental and genetic relationships. Thus, considering that the environment plays a great role on the reproductive performance of beef cows, there is need to ascertain the phenotypic relationships between body depth and fertility traits.

2.7.2 Flank circumference, heart girth circumference and body length

Flank circumference refers to the linear distance around the body taken just in front of the hook bones, immediately after the udder (Taiwo *et al*., 2010). Though there is no empirical evidence on the relationship between flank circumference and fertility in cows, there is strong credence that it is a fertility and maternal trait indicator in cows. This is due to the fact that flank circumference is indicative of body capacity which is typically associated with production and performance traits. Scientific reports have emphasised on the combined effect of body length, flank circumference and heart girth on reproductive efficiency in dairy cows (Dubey *et al*., 2012). Whether these three traits have individual effects on reproductive performance in beef cows remains unknown.

Heart girth circumference refers to the total distance around of the animal's heart girth. A large girth is needed as maximum space is desired for adequate heart, lung and gland capability. The larger the heart girth, the more efficient, adaptable and vigorous the cow is (Hoffmann, 2010). Insufficient heart girth is likely to be linked with susceptibility to stress and high maintenance requirements hence reproduction suffers. Cows with good capacity will also be long bodied. Taiwo *et al*. (2010) defined body length as the distance from the middle dip in vertebrate between the shoulder blades to back of rump.

2.7.3 Body stature

There is a difference in feed efficiency between small-framed cows and large-framed cows of the same breed with small-framed cows generally performing better on natural pastures (Owens *et* *al*., 1993; Vargas *et al*., 1999). Small-framed cows require lower amounts of maintenance, which is more easily met by the available veld (Bester *et al*., 2003). Meeting the nutrient requirements of the productive cow is a key factor in reproductive success. Thus, under natural pastures, small-framed cows are more fertile than large-framed cows as it is an adaptive attribute. On the contrary, large-framed cows are difficult to maintain and less able to thrive on natural pastures of poor nutritive value without supplementation, hence reproduction suffers. Frame-size scoring in beef is usually based on stature of the animal [Beef Improvement Federation (BIF), 2010]. Stature is measured as the height of the cow at her hips (Mwacharo *et al*., 2006).

Body stature has been reported as one of the most heritable linear traits, with heritability estimates ranging from 0.40 to 0.50 (Gutierrez and Goyache, 2001; Berry *et al*., 2004; Zink *et al*., 2011). After finding moderately high unfavorable genetic correlations between stature and various fertility traits in dairy cows, Zink *et al*. (2011) concluded that large-framed cows have low body condition score at calving followed by extended post-calving anestrous period hence poor reproductive performance. Thus, basing on the findings of studies on dairy cattle, it can be presumed that stature can be a reliable indicator of fertility in beef cattle especially those on extensively managed rangelands where there are periods of poor nutrition.

2.8 Factors affecting linear traits in beef cows

Considering that indirect selection for fertility using linear type traits is expected to give better results than direct selection, it is necessary to have an in-depth understanding of the factors affecting them. Despite various reports on the association between linear type traits and production in dairy cows, there is dearth of information on the factors affecting linear traits in cows. Various linear type traits have been reported but only information relevant to this study will be reviewed herein. Both genetic and non-genetic factors do influence linear traits.

Much of the variation in linear type traits in cattle populations is due to variations in environmental factors, although genetics also plays a significant role. When describing linear traits, non-genetic effects need to be considered to produce unbiased estimates in genetic evaluations. A few studies that have been conducted have found that non-genetic factors such as parity, herd, age at classification, physiological status and breed influence linear type traits in cows (Taiwo *et al*., 2010). Flank circumference, heart girth circumference and height at hips vary with breed, age at classification and body condition score.

There are suggestions that adaptation to the different habitual climates of different areas by cattle results in the development of different ecotypes with different conformation. For example, differences in climates have resulted in the emergence of various ecotypes such as the Venda, Swazi, Makatini, Kapriv and Pedi amongst the Nguni breed (Bester *et al*., 2003). Thus the environment shaped the Nguni breed into different ecotypes which vary in size and shape. However, there are no scientific reports on the differences between the ecotypes for fertility and/or linear traits.

Conformation traits are also influenced by genetic groups. There is wide variation of conformation between and within different breeds. Afolayan *et al*. (2007) reported that crossbreds differ significantly from their purebred counterparts in terms of length, height and body capacity among other conformation traits even when kept under the same environment.

Geographic variations in places where cattle are habituating usually impose analogous genetic variation within the same breed resulting in ecotypes. These different ecotypes will have developed adaptive traits to their specific environments. Genetic variability in form of polymorphism of the loci among populations explains phenotypic differences including variation in linear traits (Cole *et al*., 2010).

2.9 Summary

Reproductive efficiency is the driving force in a cow-calf beef enterprise. Although there is a current shift from use of exotic breeds towards breeding with more adapted indigenous breeds in Sub- Saharan Africa, there is still room to improve reproductive efficiency in the indigenous beef herds. Genetic improvement programs for reproductive traits have been slow due to many factors which include complexities of fertility as a trait and low heritability estimates of its component traits. To implement sound and effective selection procedures for improvement of fertility in beef cows, there is need to come up with simplified alternative strategies. The use of heritable and easy to measure linear traits is one possible alternative pending ascertainment of the relationship between linear traits and fertility in beef cattle. The broad objective of the study was to determine the relationship between linear type and fertility traits in Nguni cows.

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Chapter 3: Comparison of trait preferences of Nguni farmers located in semi-arid and sub-humid environments

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Abstract

The objective of the study was to compare trait preferences of Nguni cattle owners located in semi-arid and sub-humid production environments. Data were collected from a total of 300 Nguni cattle owning households from two municipalities (150 each) using structured questionnaires. The odds ratios of a household preferring stature, body depth and body length were highest for production environment, followed by age and education status of head of household. Stature, body depth and body length were preferred more in sub-humid areas than in semi-arid areas. Educated Nguni cattle owners preferred linear traits more when selecting breeding cows than uneducated ones whilst uneducated Nguni owners preferred fertility traits (calving interval, age at first calving and mothering ability) more than educated ones. The elderly Nguni owners preferred linear traits (chest size, stature and sheath height) more than young people. Farmers in sub-humid environments were more likely to highly prefer calving interval (CI) and age at first calving (AFC) first than farmers from semi-arid areas. Farmers from sub-humid environments mostly preferred CI, AFC being ranked first and second, respectively. The odds ratio estimates of households experiencing cow fertility problems were highest for production environment. Abortions and birth of weak calves were mainly experienced in sub-humid areas compared to semi-arid areas. Semi-arid areas had more households with cows with extended CI (2 and 3 years) than sub-humid areas. Farmers in sub-humid areas mostly preferred fertility traits (CI and AFC) whilst those from semi-arid regions preferred traits reflective of adaptation to harsh conditions.

Keywords: Fertility traits, Linear traits, Semi-arid, Sub-humid

3.1 Introduction

There are on-going efforts to bring back the once eroded sturdy, disease resistant and hardy indigenous breeds in the Sub-Saharan communal areas (Strydom *et al*., 2001). This follows the realisation that imported cattle breeds cannot withstand the harsh environmental conditions such as extreme temperatures, frequent droughts, poor nutrition and high-parasite burden in these areas (Musemwa *et al.*, 2008). There is evidence that reproductive efficiency of Nguni cattle grazed on natural rangelands in sub-Saharan Africa compete favourably with imported beef breeds (Strydom *et al*., 2001; Muchenje *et al*., 2008). Modern Sub-Saharan indigenous cattle population is predominated by breeds such as Nguni, Afrikaner, Drakensberger and the Tuli which are adapted to hot climates (Strydom et al., 2001). It is the Nguni breed which has gained enormous popularity amongst both commercial and communal farmers in recent years because of its adaptive traits and multiple colours (Mapiye *et al*., 2009; Nowers and Welgemoed, 2010).

Unlike in commercial farms, production levels for Nguni cattle communal farmers is low mainly due to low fertility as a result of poor breeding practices (Strydom et al., 2001). Calving interval, mothering ability, and age at first calving are common indicator traits of cow fertility in communal areas (Cushman *et al*., 2008). Calving intervals of nearly two years and late age of first calving between two and four years have been reported (Nqeno *et al*., 2011). Poor selection is one of the major poor breeding practices by communal Nguni farmers resulting in low fertility (Mapiye *et al*., 2009; Tada *et al*., 2013). Often, indigenous livestock keepers define their breeding objectives without consideration of the environment (Takele *et al*., 2011), since the indigenous breeds are considered to be well adapted to their local environmental conditions. The Nguni cattle breed is considered adapted to the Sub-Saharan conditions. There is, however, a wide range of environments within the sub-Saharan Africa. Of the various environments, semi-arid and semi-humid zones support the highest concentrations of livestock (Mohammed-Saleem, 1995). The semi-arid and semi-humid agro ecological zones have adverse climatic conditions and vegetation types. The sub-humid regions are characterised by hot-dry and cool-wet seasons and typically grasslands whilst the semi-arid regions are characterised by erratic rainfall and large daily temperature ranges supporting scrubby vegetation dominated by shrubs.

To date, there are no studies showing whether the Nguni cattle are adapted to specific agro-ecological zones in sub-Saharan Africa. It is not clear whether the geographic and climatic gradients across the sub-Saharan African region affect Nguni cattle production. It is also not clear whether the Nguni cattle keepers consider the environment when selecting their cows. Defining breeding objectives without consideration of the specific production environment within the sub-Sahara could have a negative impact on productivity. Economically important traits in livestock are influenced by variation in the production environment (Wollny, 1995). Farmers from different regions are expected to execute coping breeding strategies which suit their environment and possible climate oscillations.

Given the importance of selection in improvement of fertility levels, which is still a concern with communal Nguni farmers, it is crucial that the elements likely to affect selection programmes in the communal areas be well understood. Identifying trait preferences of Nguni communal farmers in different environments will help enlighten on possible errors in selection caused by genotype-environment interactions. It is the starting point to define and set up appropriate informed decisions on selection strategies to address the perceived problem of poor selection by

Nguni cattle keepers in communal areas. Success of any potential livestock improvement programme can be best achieved through participation of intended beneficiaries for it depends upon the engagement of the livestock keepers who use and adapt the animals to their needs. The current study was, therefore, conducted to compare trait preferences of Nguni cattle owners located in semi-arid and sub-humid production environments. It was hypothesised that trait preferences of Nguni cattle owners located in semi-arid and sub-humid production environments are similar.

3.2 Materials and methods

3.2.1 Study site

The study was conducted in Msinga and Jozini local municipalities in KwaZulu-Natal province, South Africa. The two locations were selected based on climatic conditions. They represent two adverse climatic conditions and vegetation types. Jozini local municipality is situated in uMkhanyakude district in extreme north of the KwaZulu-Natal Province, South Africa. The municipality lies at an altitude of between 150 to 600 m above sea level. The area is classified under sub-humid climate characterised by hot-dry and cool-wet seasons. Annual rainfall averages 600 mm. Although the area receives rainfall throughout the year, most rains are received between January and March, with the months of June and July being dry and cool. Highest mean monthly temperature is recorded in January (30°C) and lowest in July (11°C). The vegetation type of the area is mainly coastal sand veld, bush veld and foothill wooded grasslands (Morgenthal *et al*., 2006). Agricultural practices in the district consist of field crop, vegetables and extensive livestock production. In contrast, Msinga local municipality is located in a semi-arid climate characterised by erratic rainfall and large daily temperature ranges. The area is situated in a drier region of uMzinyathi district of KwaZulu-Natal, with extremely hot summers with highest mean monthly maximum temperature of 37°C in January. The area experiences severe cold with frost, with mean monthly minimum temperatures ranging between 4-8°C between May and July. The area is prone to droughts. The vegetation type is semi-arid savanna with steep and stony mountains predominated by aloes, thorn bush and some hardwood (Whelan, 2001).

3.2.2 Sampling procedure

A total of 300 households that owned Nguni cattle were selected and interviewed; 150 from each municipality. The respondents were selected based on number of Nguni cows owned. Farmers who had at least one Nguni cow which had calved at least once in their herd were considered. The snowball sampling technique was used to identify possible participants for the interview. Interviewers would confirm whether farmers had any Nguni cows in their herd before proceeding with the interview.

3.2.3 Data collection

Farmers were interviewed at their homesteads using a pre-tested structured questionnaire (see Appendix 1) from August to October 2013. The interviews were conducted in the Zulu vernacular by trained enumerators. Data collected included age, sex and level of education of head of household, number and type of livestock owned, cattle breeding practices (selection, breeding systems and trait preferences). Each farmer was asked to rank the purposes for keeping cattle, trait preferences when selecting breeding stock and perceived reasons behind any cow fertility problems. The study was granted the ethical clearance certificate (HSS/0164/013D) by the University of KwaZulu-Natal's Humanities and Social Sciences Research Ethics Committee (see Appendix 2).

3.2.4 Statistical analyses

All data were analysed using SAS 9.2 (2008). Mean rank scores for, purposes for keeping cattle, trait preferences when selecting breeding stock and perceived reasons for low fertility were determined for each environment using PROC MEANS of SAS (2008). An ordinal logistic regression (PROC LOGISTIC) was used to estimate the probability of a household preferring a particular trait and the probability of household experiencing cow fertility problems (SAS, 2008). The logit model fitted predictors, production environment (sub-humid; semi-arid), household size, and head of household's demographic factors such as age, education level, employment status and marital status. The logit model used was:

In $[P/1-P] = \beta 0 + \beta 1X1 + \beta 2X2 \ldots + \beta tXt + \varepsilon$

Where:

P = probability of (household preferring a particular trait; household experiencing cow fertility problem)

$[P/1-P]$ = odds ratio (the odds of household experiencing fertility problems; the odds of a household preferring a particular trait)

$\beta 0$ = intercept;

$\beta 1X1 \ldots \beta tXt$ = regression coefficients of predictors;

ε = random residual error.

When computed for each predictor (β_1... βt), the odds ratio was interpreted as the proportion of households experiencing cow fertility problems versus those that did not experience any cow fertility problem and the proportion of households preferring a particular trait versus those that did not prefer the trait.

3.3 Results

3.3.1 Household characteristics

Household characteristics of the two study environments are shown in Table 3.1. There were no significant associations attributed to production environment on education level, gender and age of household heads ($P > 0.05$). More than 60 % of the household heads responsible for the Nguni cattle production in both environments were above 45 years of age. In both environments, the majority (> 50 %) of the household heads received no formal education.

3.3.2 Livestock species kept and purposes for keeping cattle

Households from both environments mainly raised cattle, goats, chicken and rarely sheep. The flock sizes for chickens were larger ($P < 0.05$) in sub-humid areas than semi-arid areas. Mean flock size for goats was higher ($P<0.05$) in semi-arid areas compared to sub-humid areas (Table 3.1). Table 3.2 shows rankings of major purposes of cattle. Farmers in semi-arid and sub-humid areas ranked purposes of keeping cattle differently ($P<0.05$). In sub-humid areas, the most important purpose for keeping cattle was milk production. In contrast, semi-arid areas ranked milk production fourth, with traditional ceremonies being ranked first. Farmers from both production environments ranked sales third.

Table 3.1: Household characteristics of the respondents and mean herd/flock sizes (± SD) of livestock species

Class	Sub-humid	Semi-arid
Farmer age (%)		
<30	7.24	6.76
31-45	27.0	24.3
46-60	58.6	39.9
>60	7.24	29.1
Highest education (%)		
No Education	62.5	50.0
Primary	27.6	31.8
Secondary	9.21	16.2
Tertiary	0.66	2.03
Gender (%)		
Males	77.6	75.7
Females	22.4	24.3
Livestock species		
Cattle	23 ± 36.9^{a}	12 ± 11.1^{b}
Goats	12 ± 11.9^{a}	20 ± 16.9^{b}
Chickens	35 ± 23.5^{a}	22 ± 13.2^{b}

^{ab}Values with different superscripts, within a row, are statistically different (P<0.05).

Table 3.2: Mean rank score (ranks) on purposes of keeping cattle in semi-arid and sub-humid environments

Reason	N	Sub-humid	Semi-arid	significance
Meat	280	2.55 (3)	2.31 (2)	NS
Milk	249	2.19 (1)	3.09 (4)	**
Draught power provision	102	3.83 (5)	5.05 (8)	**
Manure	43	4.71 (6)	4.47 (6)	NS
Skin	58	4.90 (7)	4.70 (7)	NS
Sales	244	2.31 (2)	2.72 (3)	*
Social status	116	4.91 (8)	3.20 (5)	**
Ceremony	273	3.39 (4)	2.12 (1)	**

The lower the mean rank score (rank) of a use the greater it is used.

*p < 0.05; **p < 0.01; NS-p > 0.05

3.3.2 Breeding practices and preferred traits

Preferred traits for cows varied with production environment (P<0.05) (Table 3.3). Calving interval and age at first calving were ranked as the most preferred traits by farmers in sub-humid environments, while age of the cow and body condition score (BCS) were mostly preferred in semi-arid areas. Length of the cow, body depth, chest size and body height were less preferred in both environments. Mating was uncontrolled and calving mostly occurs during the rainy season. In sub-humid areas, most farmers did not keep bulls and relied on other farmers' bulls during communal grazing whilst most farmers from semi-arid areas kept locally bred bulls in their herds. In both production environments, farmers mainly used locally bred cows for breeding with bought in cows coming as a second option.

The odds ratios of preferred cow traits are shown in Tables 3.4 and 3.5. The odds ratios of a household preferring body depth and body length were significant for production environment (P < 0.05). Body depth and body length were preferred more in sub-humid areas than in semi-arid environments (Table 3.4). As shown in Table 3.5, farmers in sub-humid areas were 20 times more likely to rank CI first than farmers from semi-arid areas. Households in sub-humid environments also preferred AFC more than those in semi-arid environments. Educated Nguni cattle owners preferred linear traits (body depth, body length and chest size) more when selection breeding cows than uneducated ones (Table 3.4), whilst uneducated Nguni owners preferred fertility traits (CI and AFC) more than educated ones (Table 3.5). Old Nguni owners preferred CI more than young people (Table 3.5).

Table 3.3: Mean rank scores (rank) of traits preferred by communal cattle farmers for breeding Nguni cows in semi-arid and sub-humid environments

Trait	N	Sub-humid	Semi-arid	Significance
Chest size	75	4.21 (8)	3.91 (4)	NS
Height	94	4.35 (9)	4.33 (9)	NS
Length	26	3.69 (5)	6.40 (11)	**
Body depth	90	3.76 (6)	5.35 (10)	**
Sheath height	32	3.00 (3)	4.00 (6)	**
BCS	133	3.13 (4)	4.20 (2)	NS
colour	131	4.93 (10)	3.95 (5)	**
Age	181	5.12 (11)	2.08 (1)	**
Calving interval	188	1.81 (1)	4.26 (8)	**
AFC	137	2.40 (2)	3.86 (7)	**
Mothering ability	226	3.78 (7)	2.42 (3)	**

The lower the mean rank score (rank) of a trait the more it is preferred.

*p<0.05; **p<0.01; NS-p>0.05

BCS = Body condition score

AFC = Age at first calving

Table 3.4: Odds ratio estimates, lower (LCI) and upper confidence (UCI) interval of ranking linear traits first in Nguni breeding cows

	Chest size			Stature			Body depth			Sheath height			Body length		
Predictor	Odds	LCI	UCI	Odds	LCI	UCI	Odds	LCI	UCI	Odds	LCI	UCI	Odds	LCI	UCI
Environment (Sub-humid vs. semi-arid)	0.71^{ns}	0.26	1.96	1.43^{ns}	0.48	4.27	11.58*	4.16	32.25	0.32^{ns}	0.01	15.94	10.18*	5.02	23.11
Gender (Male vs. female)	1.77^{ns}	0.50	6.24	1.03^{ns}	0.39	2.76	0.57^{ns}	0.20	1.63	3.33^{ns}	0.54	20.40	0.54^{ns}	0.06	5.29
Age (young vs. old)	2.25^{ns}	0.83	6.09	1.31^{ns}	0.54	3.20	0.99^{ns}	0.40	2.43	2.50^{ns}	0.36	17.47	0.84^{ns}	0.16	4.35
Marital status (married vs. not married)	1.06^{ns}	0.42	2.65	0.48^{ns}	0.19	1.18	0.48^{ns}	0.19	1.22	2.69^{ns}	0.36	20.10	0.48^{ns}	0.08	3.00
Education (uneducated vs. educated)	0.61^{*}	0.24	0.57	0.90^{ns}	0.39	2.09	0.68^{*}	0.28	0.64	0.46^{ns}	0.09	2.35	0.61^{*}	0.10	3.59
Employment status (employed vs. unemployed)	1.00^{ns}	0.36	2.81	0.29*	0.11	0.77	1.09^{ns}	0.35	3.40	1.78^{ns}	0.24	13.28	0.23^{ns}	0.02	3.24
Residence (at the farm vs. away)	1.08^{ns}	0.31	3.69	0.42^{ns}	0.09	2.00	0.12*	0.02	0.72	0.20^{ns}	0.01	14.55	0.03^{ns}	0.01	1.61

Higher odds ratio estimates indicate greater difference in preference between levels of predictors.

$^{ns}P > 0.05$; * $P < 0.05$

Table 3.5: Odds ratio estimates, lower (LCI) and upper confidence (UCI) interval of ranking fertility traits first in Nguni breeding cows

	CI			AFC			Mothering ability		
Predictor	odds	LCI	UCI	odds	LCI	UCI	odds	LCI	UCI
Production system (Sub-humid vs. semi-arid)	20.75*	9.74	44.16	11.17*	5.11	24.42	0.21*	0.12	0.36
Gender (male vs. female)	0.88*	0.45	0.70	0.99^{ns}	0.44	2.24	1.52^{ns}	0.86	2.68
Age (young vs. old)	0.51*	0.27	0.95	1.44^{ns}	0.68	3.05	1.47^{ns}	0.84	2.55
Marital (married vs. not married)	0.98^{ns}	0.54	1.79	2.43*	1.18	4.97	0.65^{ns}	0.38	1.10
Education (uneducated vs. educated)	1.05^{*}	0.51	0.75	1.16^{*}	1.55	2.44	1.22^{ns}	0.72	2.07
Employment (employed vs. unemployed)	0.68^{ns}	0.31	1.46	0.87^{ns}	0.33	2.28	1.27^{ns}	0.67	2.41
Residence (at the farm vs. away)	0.66^{ns}	0.20	2.10	0.61^{ns}	0.13	2.83	1.70^{ns}	0.83	3.49

Higher odds ratio estimates indicate greater difference in preference between levels of predictors.

$^{ns}P > 0.05$; * $P < 0.05$

3.3.3 Cow fertility problems and reasons for infertility

In sub-humid areas, the majority of the respondents (80.2 %) indicated that their Nguni cows calved every year, a sizeable number (19.1 %) had an average of 2 years and very few farmers (0.7 %) indicated that they calved after 3 years. Likewise, in semi-arid areas, the majority of the respondents (67.4 %) indicated that their Nguni cows calved every year, while 31.3 % had an average of 2 years and very few farmers (1.4 %) indicated that they calved after 3 years. The odds ratios of household experiencing cow fertility problems were highest for production environment followed by employment status and provision of supplementary feed (Table 3.6). Cow fertility problems were mainly experienced in sub-humid compared to semi-arid environments. The odds ratio of 2.0 indicates that farmers who did not receive any formal education had cows more susceptible to fertility problems than those who received formal education. More than 65 % of the respondents indicated long calving intervals as one of their major fertility problems. More households reported the incidence of dystocia and long calving intervals in semi-arid areas than those in sub-humid areas. Abortion and weak calves were experienced more in sub-humid areas than semi-arid areas (Figure 3.1). Table 3.7 shows farmers' rankings for possible causes of the reported fertility problems in their Nguni cows. There were differences in ranking of causes of fertility between the environments ($P<0.01$). Whilst households in sub-humid areas ranked high prevalence of diseases as the major cause of cow fertility problems, those in semi-arid areas considered it a minor cause. Poor nutrition was the most common cause of cow fertility problems in semi-arid environments.

Table 3.6: Odds ratio estimates, lower and upper confidence interval (CI) of households experiencing cow fertility problems

Predictor	Odds ratio	Lower CI	Upper CI
Production environment(sub-humid vs. semi-arid)	4.33*	1.82	10.28
Supplementary feeding (yes vs. no)	1.91^{ns}	0.87	4.20
Gender (male vs. female)	1.37^{ns}	0.68	2.75
Age of head (young < 50 vs. old ≥50 years)	0.59^{ns}	0.31	1.13
Marital status (married vs. not married)	0.84^{ns}	0.45	1.56
Education (uneducated vs. educated)	2.00^{*}	0.20	0.68
Employment status (employed vs. unemployed)	0.37^{ns}	0.94	4.27
Residence of household head (at the farm vs. away)	0.49^{ns}	0.20	1.23

$^{ns}P > 0.05$; * $P < 0.05$

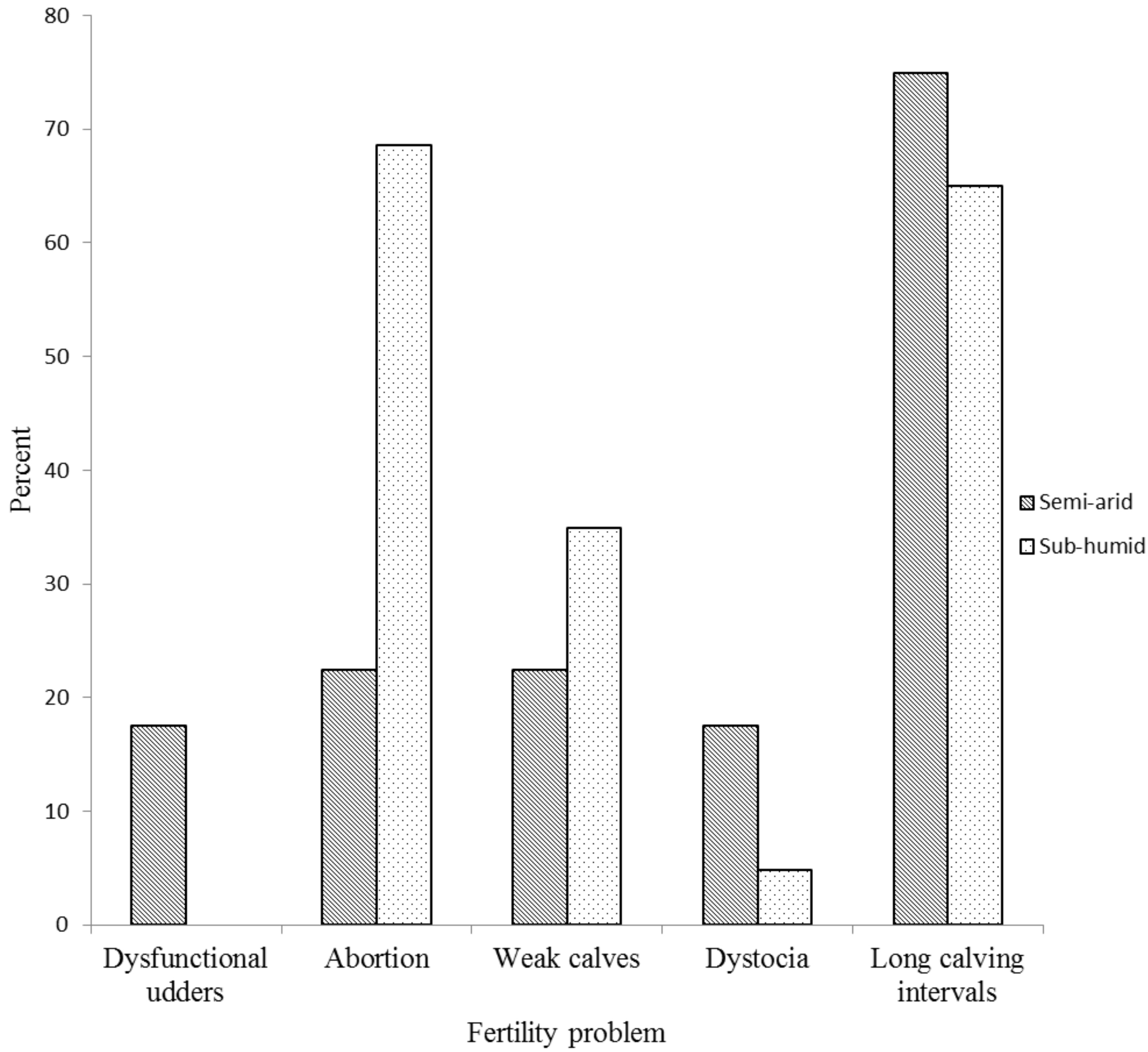

Figure 3.1: Cow fertility problems experienced by Nguni farmers in sub-humid and semi-arid environments

Table 3.7: Mean rank score (ranks) possible causes of low fertility in Nguni cows in semi-arid and sub-humid environments

Reason	Sub-humid	Semi-arid	Significance
Old age	2.38 (4)	2.33 (2)	NS
Poor nutrition	1.75 (3)	1.31 (1)	**
High prevalence of diseases	1.13 (1)	1.58 (3)	**
Low bull to cow ratio	1.33 (2)	1.61 (4)	NS

The lower the mean rank score (rank) of a cause the more important the reason.

*p<0.05; **p<0.01; NS: not significant (p>0.05)

3.4 Discussion

Understanding the purpose for keeping livestock is essential for deriving effective breeding goals for any livestock farming system. The roles Nguni cattle play in communal areas are manifold. Though ranked differently, the four major purposes farmers in both environments keep cattle are meat production, milk production, ceremonies and sales. Differences in rankings of purposes of keeping cattle can be attributed to differences in cultures, food preferences and frequency of natural disasters such as drought and hunger (Mekonnen *et al*., 2012; Terefe *et al.*, 2012). Considering that the study sites had similar cultural groups, the differences in purposes of keeping cattle observed could be largely attributed to environmental conditions. Farmers from semi-arid areas use cattle mainly for saving functions, whereby during drought or famine, the cattle can be sold or exchanged for food. Differences in purposes for keeping cattle results in differences preferred traits since farmers have different breeding objectives.

Variation in preferred traits for cattle breeding stock across the two areas observed in this study is similar to previous reports (Mapiye *et al*., 2009). The high odds ratio estimates for the effect of production environment on trait preference can be attributed to varying vegetation types, climatic conditions, production activities and available resources. Environment affects breeding objectives and, hence, trait preferences. Semi-arid areas are more prone to droughts than sub-humid areas, hence, farmers there tend to prefer cows with good body condition score as a sign that the animals are hardy and able to withstand the severe environmental conditions. Body condition of the cows is associated with drought tolerance and a sign that the cows are resistant to the environmental constraints associated with feed and water resources. The finding that farmers from both environments had high preference for reproductive performance traits in cows agrees with Ouma *et al*. (2005). Farmers' main purposes of keeping cattle may explain their preference of reproductive traits, they want to increase herd size so as to increase off take. However, selection through the preferred traits such as age at first calving and calving interval could be a challenge due to lack of proper records.

The relatively high odds ratio estimate for the effect of age and education level of household head on trait preference can be attributed to differences in understanding of the cattle breeding practices. Cattle keepers who attain some level of formal education are more likely to adopt better livestock breeding practices compared to the less educated. Education increases farmer's ability to obtain, analyse and interpret cow performance. Tada *et al*. (2013) reported a significant relationship between years of formal education and trait preference in Nguni cattle farmers. The low percentage of those with formal education can adversely influence implementation of recommended management practices. The unexpected finding that uneducated farmers had cows which were less susceptible to fertility problems can be because farmers without formal education still use indigenous knowledge which help improve fertility of their cows.

Low preference for linear traits could be because farmers are not well informed of the ease and benefits of selecting for such traits. To be more effective and sustainable, maybe future livestock breeding policies should be aiming at encouraging farmers to employ more viable traits such as linear or conformation traits. Unlike in this study where calving interval, age at first calving and age of cows were highly preferred, Nguni farmers in the Eastern Cape showed that performance and age were least considered whilst body conformation was highly ranked. Differing results could be because Mapiye *et al*. (2009) did not specify the preferred component conformation and reproductive traits.

The response by a sizable amount of respondents that Nguni cows had long calving intervals (2 and 3 years) agrees with Nqeno *et al*. (2011). The high odds ratio estimate for the effect of production environment on fertility problems can be attributed to nutritional differences between the study areas. The finding that more farmers experienced long calving intervals in semi-arid areas than those from sub-humid areas can be due to differences in breeding practices and production environment. Poor nutrition and heat stress in semi-arid areas could be the major cause of long calving interval. The semi-arid areas are subjected to frequent droughts as compared to sub-humid environments. The contradicting results that whilst majority of farmers in sub-humid areas had cows which calved every year, cows in sub-humid environments were more likely to experience fertility problems shows although cows in sub-humid areas calved every year they had other fertility problems such as a calving weak calves.

Long calving intervals in cows was the greatest fertility problem faced by farmers. Similar findings were reported by Gusha *et al*. (2013) for communal farmers in Zimbabwe with Sanga breeds kept under the semi-arid regions. Low bull to cow ratio and disease prevalence were perceived as major causes of infertility. Kgosikoma *et al*. (2012) stressed that, although there are many causes of long calving intervals in cows, nutritional limitations exacerbates the problem in semi-arid regions. Thus, poor nutrition could be the reason why farmers from semi-arid areas were more likely to experience long calving interval than those from sub-humid regions. To counter the nutritional limitations, farmers should go for functionally efficient cows. Considering that there is uncontrolled mating which, to some extent, helps reduce inbreeding rates, the birth of weak calves could be attributed mostly to nutritional stress during gestation and diseases. Few farmers reported dystocia as a fertility problem which indicates the ease with which Nguni cows calve. This agrees with Scholtz and Theunissen (2010) who reported that dystocia will be negligible when the Nguni is used as a dam line.

3.5 Conclusions

Nguni cows in semi-arid areas had relatively poor fertility caused by high prevalence of diseases, low bull to cow ratio and poor nutrition. Although trait preference also varied with education level and age of head of household, environment was the most important factor. Calving interval and age at first calving were the most preferred traits by farmers in sub-humid areas while age of the cow and BCS were mostly preferred in semi-arid areas. The odds ratio estimates of households experiencing fertility problems were highest for production environment. Although, Nguni cows are adapted to poor nutritional conditions, there is need to develop strategies to maximise their potential under semi-arid environments. Since there are no proper fertility records in communal systems, a strategy to indirectly select for fertility is required. The use of highly heritable and easy to measure linear traits is one possible strategy. It is, however, essential to understand sources of variation of the linear traits first before encouraging farmers to put emphasis on these when selecting for fertility.

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Chapter 4: Variation in linear type traits in Nguni cows of different ecotypes

Abstract

The objective of the study was to investigate sources of variation of linear traits in Nguni cows from four different ecotypes. Body stature, body length, heart girth, navel height, body depth and flank circumference were measured once in the cool-dry, hot-wet and post-rainy seasons. A total of 1017 records from 339 cows of Venda, Pedi, Swazi and Makhatini ecotypes with at least Parity 3 were used. Body depth, flank circumference and heart girth increased with increase in parity of cow. Cows in Parity 7 had the deepest bodies and navels hanging closest to the ground. Parity of cow had no effect on body stature ($P > 0.05$). Ecotype of cow had significant effect on body stature, body length, heart girth, navel height, body depth and flank circumference. Venda cows had significantly higher body depths. Body depth, flank circumference and heart girth were influenced by season ($P < 0.05$). Venda cows had the same flank circumference and heart girth across all seasons ($P > 0.05$). Body depth had strong positive correlations with flank circumference ($r = 0.69$) and heart girth ($r = 0.53$) ($P < 0.05$). Cows with deeper bodies had navels near the ground ($r = -0.32$) and longer bodies ($r = 0.46$; $P < 0.05$). In conclusion, linear traits were influenced by ecotype, season, parity and BCS of cow.

Keywords: Body depth; Nguni cows; ecotype

4.1 Introduction

Nguni cattle, a small-framed breed indigenous to Southern Africa, have been gaining ground as a beef breed in recent years. As a result, there have been widespread efforts to improve its productivity in the Sub-Saharan Africa. Over the years, emphasis in beef production has been put on yearling weights, growth rate and bigger cattle rather than functional efficiency, with the prime goal of beef producers being to use the fast growing calves. In free-range beef production, profitable cows are the ones that raise and wean healthy calves every year (Tedeschi *et al*., 2006). One of the reasons for the increasing popularity of Nguni cattle is their high functional efficiency compared to other cattle breeds, especially under the extensive harsh conditions of the Sub-Saharan Africa. Nguni cattle can calve yearly and yield a favourable cow-calf ratio at weaning, with less feed requirements compared to large-framed breeds (Schoeman, 1989; Strydom *et al.*, 2001; Mapiye *et al*., 2007). As a result, it is more efficient and appropriate to feed a larger Nguni herd than fewer large framed cows which consumes more feed and need high amounts of inputs and care.

Functional efficiency is directly related to the reproductive efficiency of a cow (Bonsma, 1983), a critical determinant of success in cow-calf beef production. A functionally efficient cow is one that reproduces and weans healthy calves with minimum feed intake (Visagie, 2012). Fertility of Nguni cows vary with production environment (Chapter 3). Selection for phenotypic characteristics that impacts the cow's ability to adapt to the environment help improve functional efficiency (Bonsma, 1983). To increase productivity of Nguni herds, the Nguni Society of South Africa encourages farmers to identify functionally efficient cows using conformation traits combined with production records and pedigree analyses. Linear trait evaluation is widely used in dairy herds to predict fertility and potential to produce milk in heifers (Larroque and Ducrocq, 2001). Despite their widespread use in objective visual evaluation of cows, information on factors affecting these traits in Nguni cattle is scanty.

Climate and vegetation type influence the conformational features of cows (Mwambene *et al*., 2012). Environmental effects on linear traits are evident in Nguni cattle where adaptations to different environments have resulted in the development of ecotypes, which differ in their conformational features. The most common Nguni ecotypes in the sub Saharan Africa are Makhatini, Swazi, Venda and Pedi (Bester *et al*., 2003). The conformation features of these ecotypes are not documented and are, thus, not used in selection of Nguni cows. The contribution of these factors to the variation in linear traits is not known, making it difficult to adjust factors in genetic evaluation. When selecting cows, it is, therefore, important to adjust measurements for known environmental factors which mask the genetic expression of traits. The objective of the study was to explore factors influencing body depth, body stature, body length, flank circumference, heart girth and navel height in Nguni cows from different ecotypes. It was hypothesised that ecotype of cow, parity of cow and season of measurement affect body depth, body stature, body length, flank circumference, heart girth and navel height in Nguni cows.

4.2 Materials and methods

4.2.1 Study sites and cows

The study was conducted on four predominant Nguni ecotypes in South Africa; Makhatini, Pedi, Swazi and Venda. Farms located in four areas, each dominated by one of the four ecotypes, were selected using stratified random sampling technique. For each of the location, only cows of the dominant ecotype were measured. Table 4.1 shows the identities of the ecotypes, location, climatic conditions and the number of cows from each ecotype. The cows were raised without any supplementary feeds such as protein concentrates, minerals and feed additives. For all farmers who participated in the study, bulls were left with the herd all the time.

4.2.2 Data collection

A total of 1017 records from 339 cows of at least parity 3 were used. Trained personnel visited identified farms and measured linear type traits on each cow between December 2012 and November 2013, once in the cool-dry (June and August 2013), hot-wet (December 2012 and November 2013) and post-rainy (March to May 2013) season. Selection of cows of specific ecotypes was based on farmer's records. Measurements were taken between 0700 and 1000 hours before cows had started grazing. The body stature was measured from top of the spine in between hips to ground. Body depth was measured as distance between the top of spine and bottom of barrel at last rib (the deepest point) measured from the left side of the cow. Heart girth was defined as circumference of the body taken just behind the shoulders. Flank circumference was defined as the linear distance around the body taken just in front of the hook bones. Navel height was measured from the ground to the navel of the cow. Body length was measured from the hindmost part of the cow to the valley in front of the second thoracic vertebrae just ahead of the centre of the shoulders (Funk *et al*., 1991).

Table 4.1: Ecotypes, farms, climatic conditions and the number of cows used in the study

Ecotype	Vegetation type	Location	Coordinates	n	Annual rainfall (mm)	Mean annual temperature (ºC)	Altitude (m)
Swazi	Grassland	Newcastle	27.7442° S, 29.9372° E	79	784	19	1240
Venda	Arid bush veld	Thohoyandou	22.5851° S, 30. 2621° E	80	600	22.5	724
Makhatini	Thorn veld	Hluhluwe	28.0189° S, 32.2675° E	100	590	20	640
Pedi	Mixed bush veld	Louis Trichardt	23.0500° S, 29.9000° E	80	500	20	950

Body depth, heart girth, body length and flank circumference were measured using a plastic tape measure. An aluminium extending measuring stick was used to measure navel height and body stature. To ensure consistency, all measurements were taken by the same individual. In addition to linear traits measurement, records on identification, age of cow at classification, date of birth, days from last calving and parity were collected.

4.2.3 Statistical analyses

Factors affecting linear measurements were analysed using the General Linear Model procedures (SAS, 2008) for repeated measures, assuming fixed models with all possible first-order interactions. The model for the final analysis was obtained after eliminating interactions that were not significant (P>0.05). The fixed factors considered were the parity of cow, ecotype, season when measurements were taken and body condition score (BCS) of cow at the time of measurement. Age of cow at the time of measurement and days from last calving (DLC) were fitted as covariates where it was relevant. Age of cow at the time of measurement had no effect on any on the dependent variables in this study and was, therefore, removed from the final model. The final model used was:

$$Y_{ijklm} = \mu + P_i + EC_j + S_k + BCS_l + (PxEC)_{ij} + (ECxS)_{jk} + \beta_1(\mathrm{D}) + E_{ijklm}$$

Where:

Y_{ijklm} = response variable (body size, body depth, heart girth, flank circumference, navel height and body length);

μ = mean common to all observations;

P_i = effect of the i^{th} parity of cow;

EC_j = effect of j^{th} ecotype;

S_k = effect of K^{th} season of measurement;

BCS_l = effect of the l^{th} body condition score of cow at the time of measurement;

$(P \times EC)_{ij}$ = effect of parity of cow × ecotype interaction;

$(EC \times S)_{jk}$ = effect of ecotype × season of measurement interaction;

β_1 = partial linear regression coefficient of the dependent variable on days from last calving;

E_{ijklm} = residual error ~ N $(0; I\sigma^2)$.

Correlation analyses among linear traits and DLC were performed using the PROC CORR procedure (SAS, 2008). Mean separation was performed using the LSMEANS using the PDIFF option (SAS, 2008).

4.3 Results

4.3.1 Summary statistics and significance levels

Table 4.2 shows the summary statistics of the traits studied. The cows used in the study were aged between 32 and 214 months, averaging 91.1 months. There was much variation in the age of the cows used for the study with a standard deviation of 39.2 months. Much variation, as determined by the standard deviation (SD), existed in linear measurements; the largest SD was for flank circumference (11.7 cm) while the smallest SD was for navel height (4.2 cm).

Table 4.2: Summary statistics for linear measurements, age and days from last calving (DLC) for cows used in the study

Variable	N	Mean	SD	Minimum	Maximum
Body depth (cm)	1017	103.9	8.07	55	130
Body stature (cm)	1017	126.9	5.11	112	142
Body length (cm)	1015	130.5	9.07	89	200
Flank circumference (cm)	1017	180.2	11.70	116	212
Heart girth (cm)	1017	167.4	9.83	117	199
Navel height (cm)	1011	49.6	4.22	40	61
DLC	991	194.1	141.22	1	871
Age (months)	996	91.1	39.26	32	214

Body depth had a standard deviation of 8.1 cm. Table 4.3 summarises the levels of significance for fixed effects on body depth, body stature, body length, flank circumference, heart girth and navel height. Parity of cow, ecotype, season of measurement and BCS, all significantly influenced body depth, flank circumference and heart girth. Except body depth, all the other linear traits were not influenced by the interaction between ecotype and parity of cow ($P < 0.05$). The interaction between ecotype and season of measurement had significant effects on body depth, flank circumference and heart girth.

4.3.2 Effect of parity, season and ecotype on linear traits

The relationship between heart girth, flank circumference and parity is shown in Figure 4.1. The heart girth and flank circumference increased linearly with increase in parity ($b = 0.81$ and 1.08, respectively). The navel height decreased linearly with increase in parity ($b = -0.49$) (Figure 4.2). Table 4.4 shows the influence of ecotype on linear traits. Cows of the Venda ecotype were the shortest with navels nearest to the ground, deepest bodies, widest chests and flanks ($P < 0.05$). Swazi and Pedi cows had similar body depths, flank circumferences and heart girths ($P > 0.05$). Figure 4.3 shows the relationship between body depth and parity in cows of different Nguni ecotypes. The rate of increase of body depth with parity was highest in Swazi cows ($b = 2.55$) followed by Pedi cows ($b = 1.11$) then Venda cows ($b = 1.01$). Cows of the Makhathini ecotype had the lowest rate of increase of body depth with parity ($b = 0.75$).

Table 4.3: Levels of significance for fixed effects on body depth, body stature, body length, flank circumference, heart girth and navel height

Trait	Significance level					
	Body depth	Body stature	Body length	Flank circumference	Heart girth	Navel height
Parity of cow	**	NS	NS	**	**	**
Ecotype	**	**	**	**	**	**
Season	**	NS	NS	**	**	NS
BCS	**	NS	NS	**	**	NS
Ecotype x parity	**	NS	NS	NS	NS	NS
Ecotype x season	**	NS	NS	*	*	NS
DLC	**			*	**	**

**P* < 0.05; ***P* < 0.01;   *NS not significant (P > 0.05)*

BCS = body condition score

DLC = days from last calving

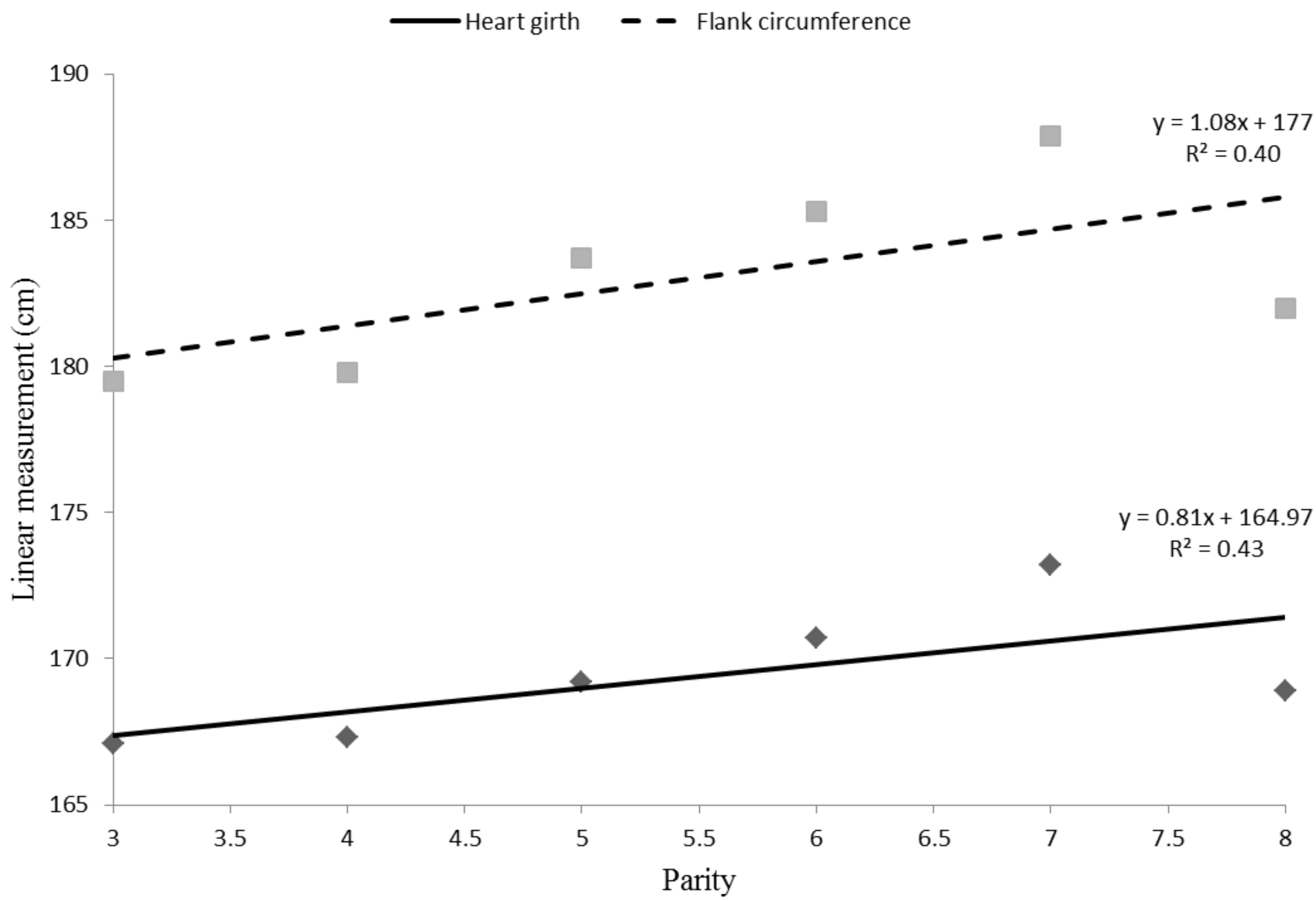

Figure 4.1: Relationship between heart girth, flank circumference and parity in Nguni cows

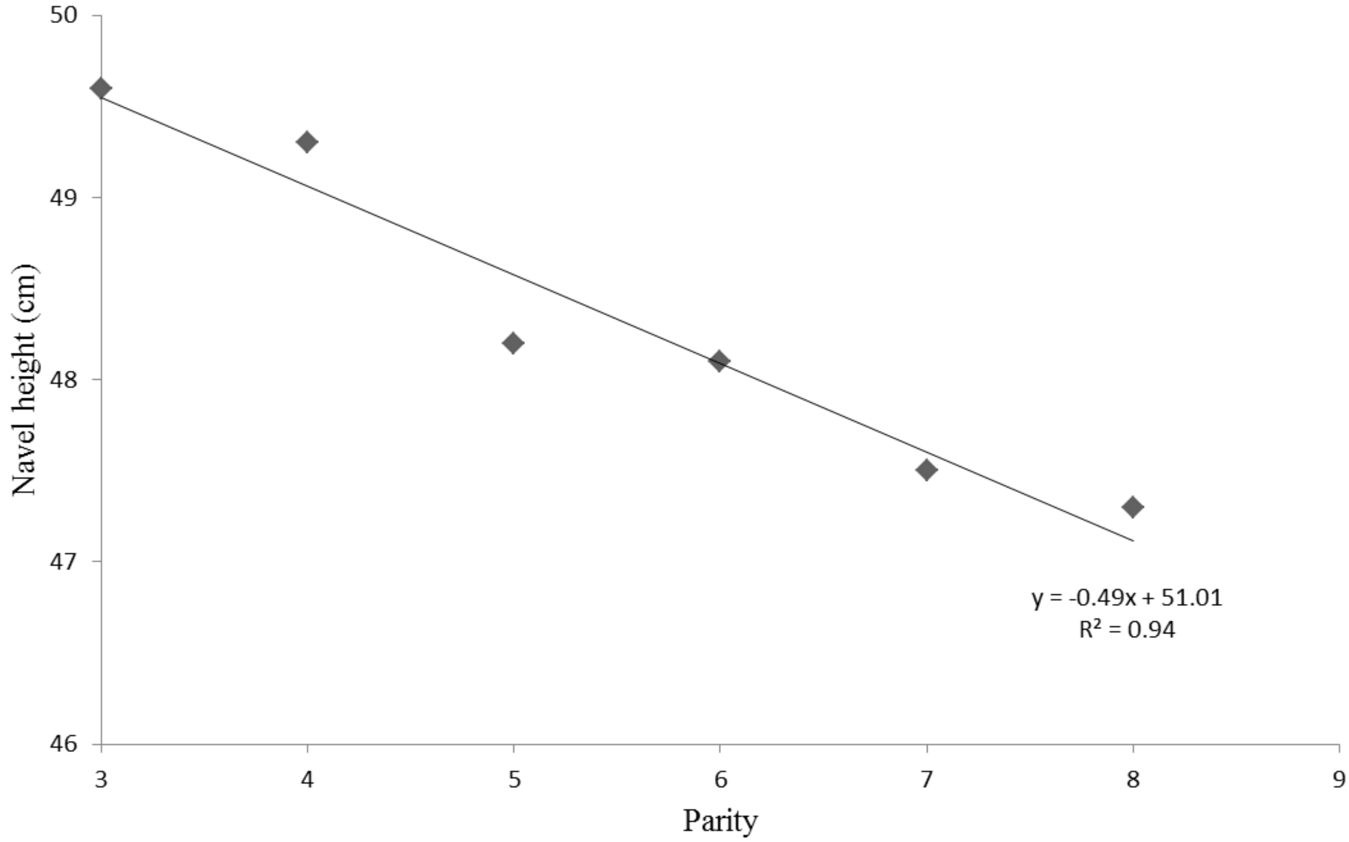

Figure 4.2: Relationship between navel height and parity of Nguni cows

Table 4.4: Least square means for the effects of ecotype on body depth, body stature, body length, flank circumference, heart girth and navel height

Ecotype	Body stature	Body length	Body depth	Flank circumference	Heart girth	Navel height
Swazi	126.5 ± 0.40^{b}	125.7 ± 0.68^{c}	102.5 ± 0.63^{c}	180.8 ± 0.96^{b}	167.5 ± 0.81^{b}	48.2 ± 0.34^{c}
Venda	125.4 ± 0.50^{ab}	130.2 ± 0.95^{ab}	110.3 ± 0.88^{b}	184.4 ± 1.33^{a}	170.2 ± 1.12^{a}	48.2 ± 0.47^{c}
Makhatini	125.0 ± 0.36^{a}	136.3 ± 0.62^{a}	104.6 ± 0.58^{a}	178.6 ± 0.87^{b}	165.9 ± 0.73^{b}	49.5 ± 0.31^{b}
Pedi	129.3 ± 0.32^{c}	129.4 ± 0.54^{b}	102.1 ± 0.51^{c}	179.7 ± 0.76^{b}	167.7 ± 0.64^{ab}	50.9 ± 0.27^{a}

^{abc}*Values in the same column with different superscripts differ (P < 0.05)*

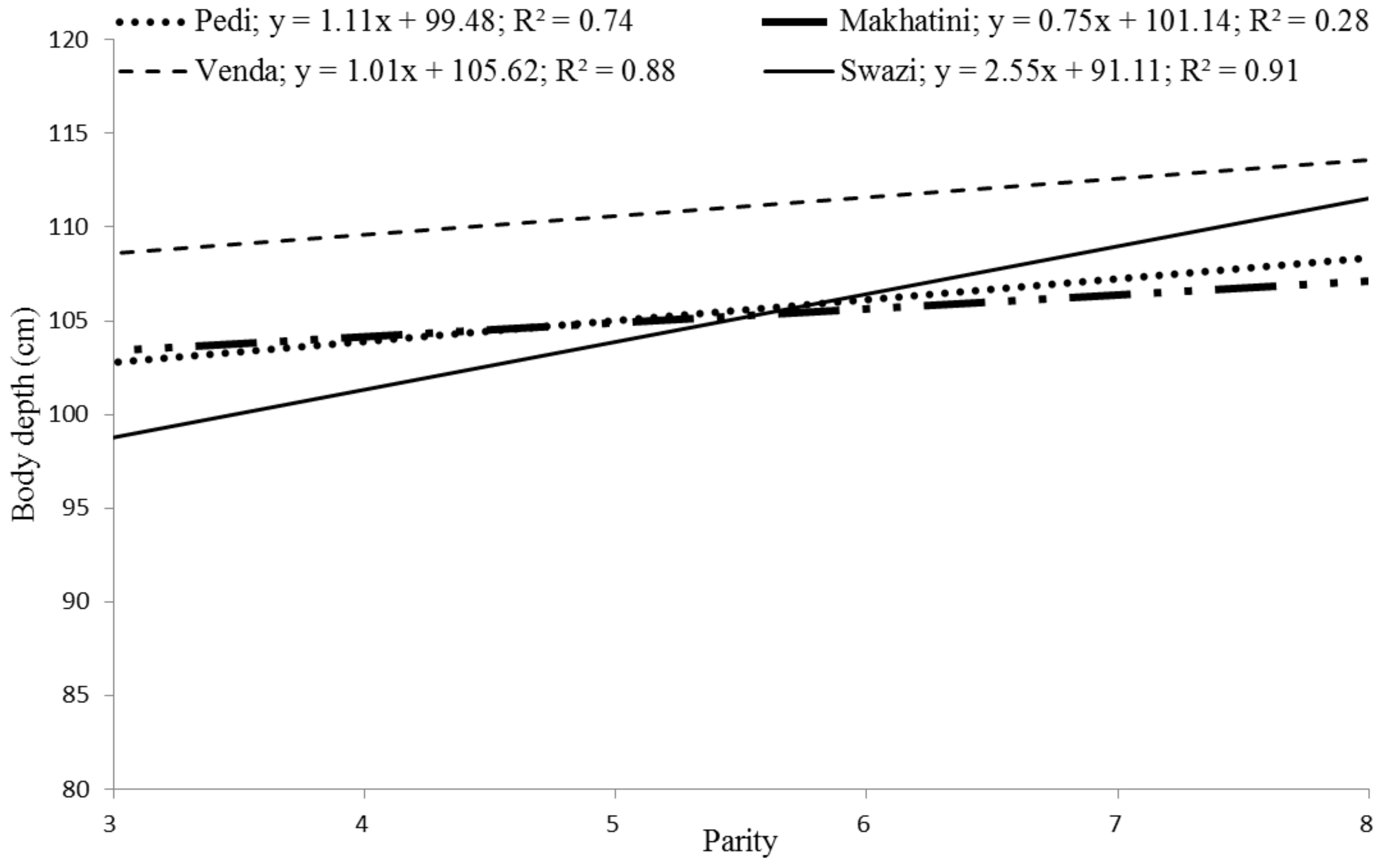

Figure 4.3: Relationship between body depth and parity of cows in different Nguni ecotypes

Figures 4.4, 4.5 and 4.6 show the seasonal changes in body depth, flank circumference and heart girth of Nguni cows in different ecotypes, respectively. Body depth, flank circumference and heart girth of Pedi, Makhatini and Swazi cows generally increased from cool-dry season to post-rainy season ($P < 0.05$). Venda cows had the same flank circumference and heart girth across all seasons ($P > 0.05$). Venda cows had the deepest bodies, widest flanks and heart girths ($P < 0.05$) across seasons. Much variation in flank circumference and body depth across ecotypes was observed during the cool dry season ($P < 0.05$).

4.3.3 Effect of BCS of cow on linear traits

The effects of BCS on linear traits are shown in Table 4.5. In general, the body depth, body length, flank circumference and heart girth increased ($P < 0.05$) with an increase in BCS. Cows with a BCS of 3 and 3.5 had no difference in body depth, flank circumference and heart girth ($P > 0.05$). Body stature, body length and navel height were not affected by BCS ($P > 0.05$).

4.3.4 Correlations

The DLC was negatively correlated with navel height and positively correlated with body depth; flank circumference and heart girth (Table 4.6). Cows with more DLC had navels hanging closer to the ground, deeper bodies and wider flanks and heart girth. Correlations between DLC and body depth, flank circumference and heart girth were relatively low. Body depth had strong positive correlations with flank circumference ($r = 0.69$; $P < 0.01$) and heart girth ($r = 0.53$; $P < 0.05$). Cows with deeper bodies had navels near the ground ($r = -0.32$; $P < 0.01$) and longer bodies ($r = 0.46$; $P < 0.05$). There was also a significant strong positive correlation between flank

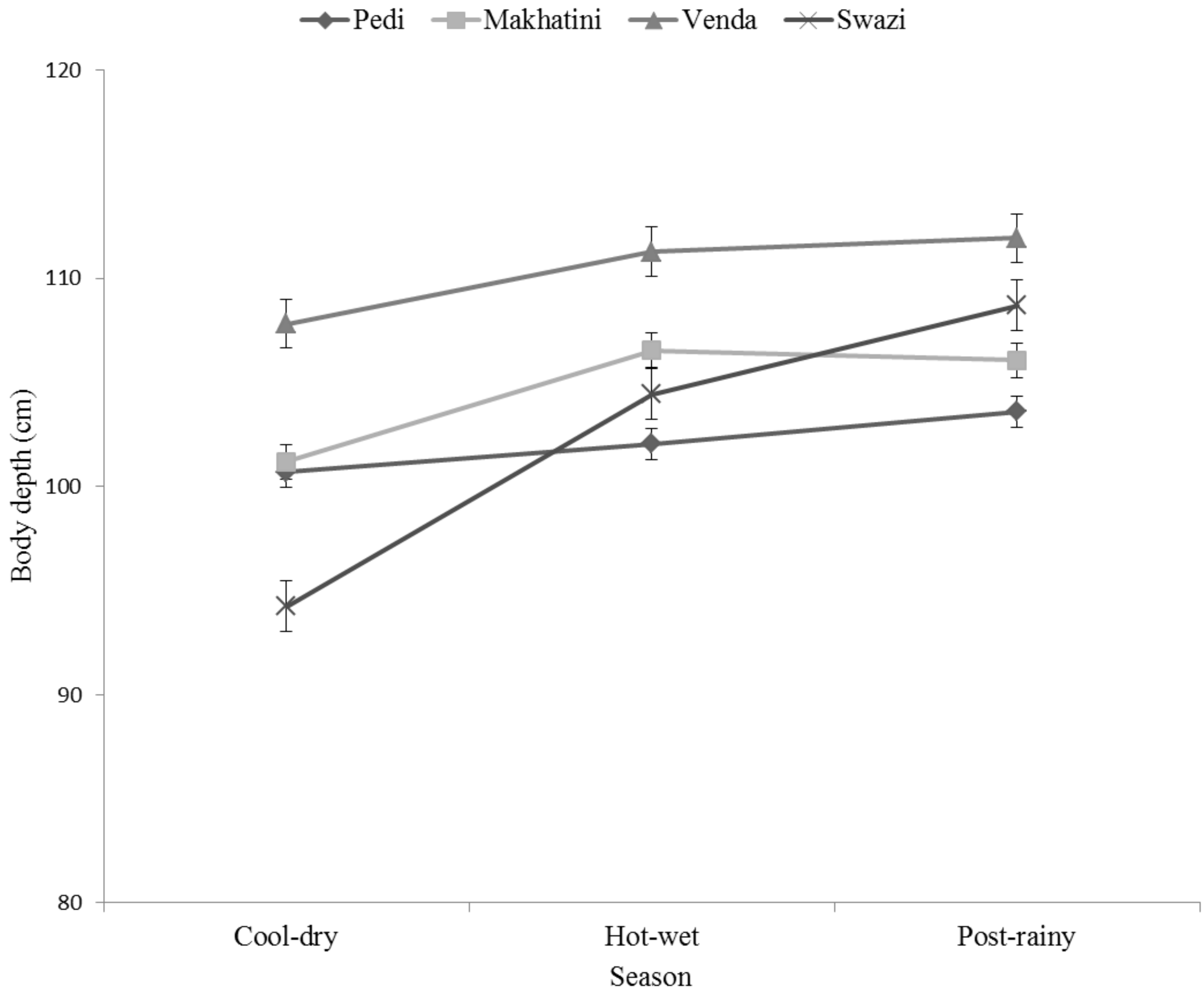

Figure 4.4: Seasonal changes in body depth of cows in different Nguni ecotypes. Error bars represent standard errors of the mean.

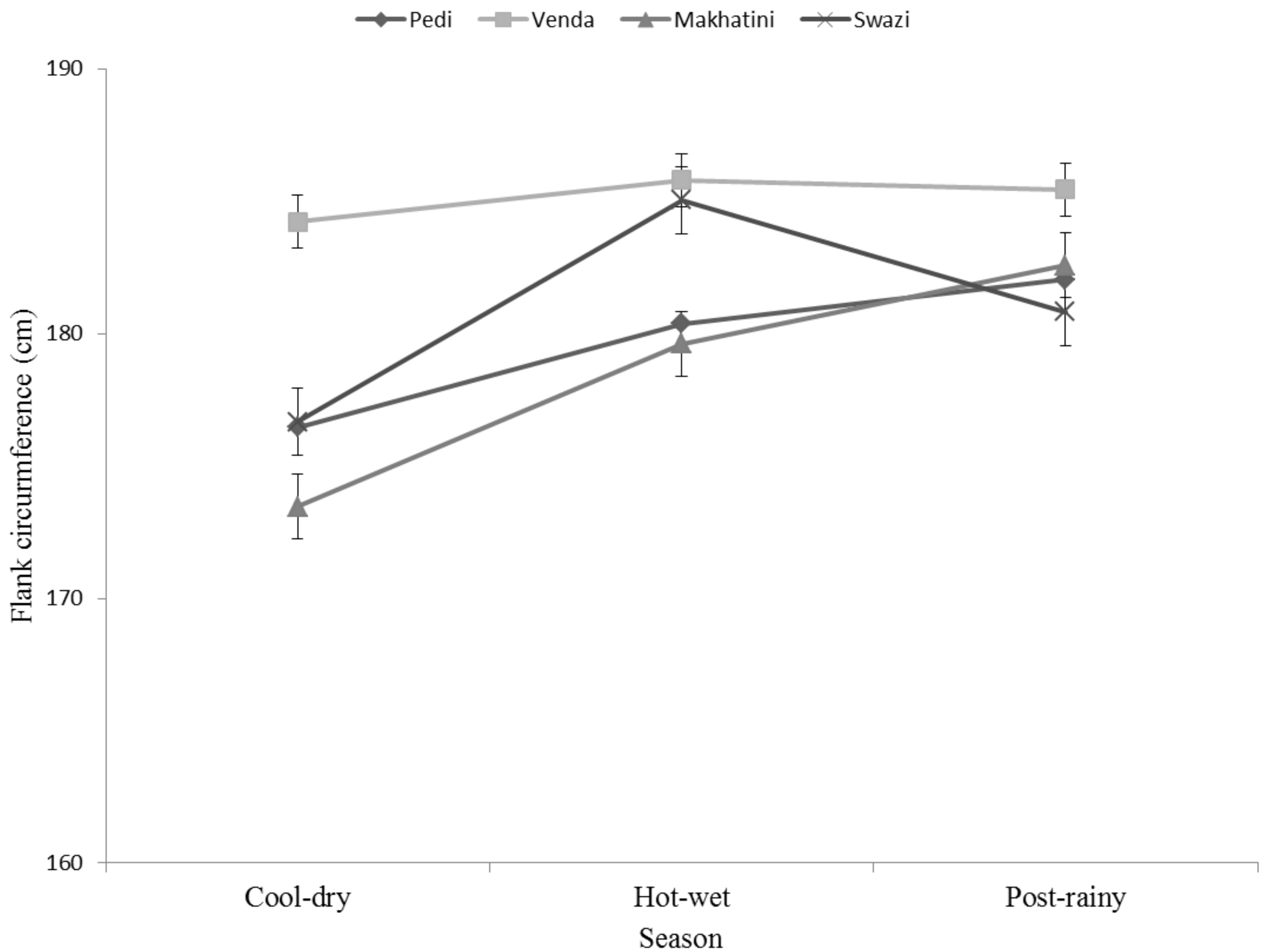

Figure 4.5: Seasonal changes in flank circumference of cows in different Nguni ecotypes. Error bars represent standard errors of the mean.

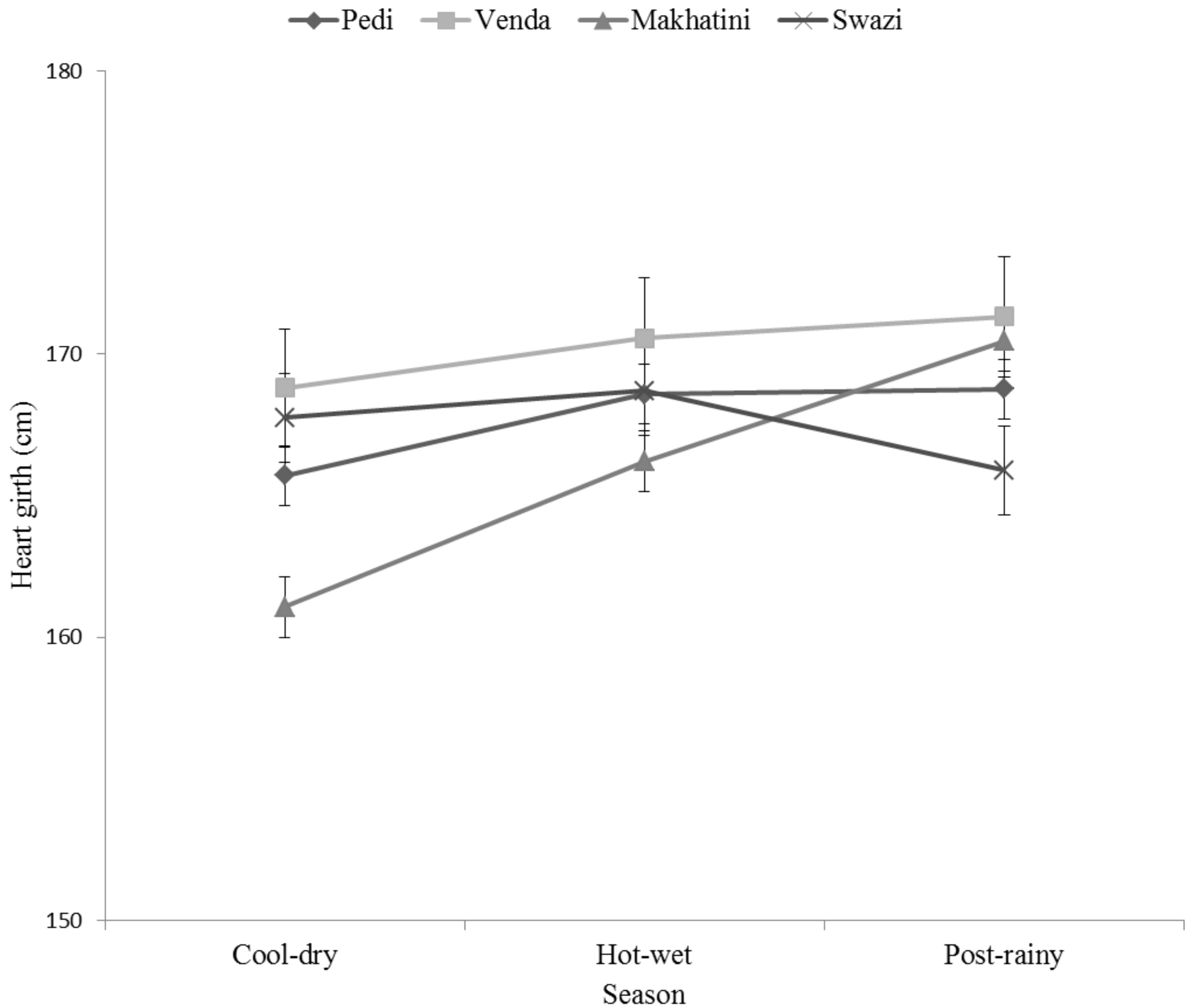

Figure 4.6: Seasonal changes in heart girth of cows in different Nguni ecotypes. Error bars represent standard errors of the mean.

Table 4.5: Least square means for the effects of body condition score (BCS) on body depth, body stature, body length, flank circumference, heart girth and navel height

BCS	Body depth	Flank circumference	Heart girth
2.5	99.1 ± 1.24^{a}	166.6 ± 2.08^{a}	160.6 ± 1.63^{a}
3	102.3 ± 0.96^{b}	177.2 ± 1.62^{b}	165.4 ± 1.27^{b}
3.5	102.7 ± 0.83^{b}	177.2 ± 1.40^{b}	166.2 ± 1.10^{b}
4	105.5 ± 0.94^{c}	182.9 ± 1.59^{c}	172.2 ± 1.25^{c}

[ab]*Values with different superscripts, within a row, are statistically different (P<0.05).*

Table 4.6: Correlations between days from last calving (DLC), body stature, body length, body depth, flank circumference (FC), heart girth and navel height

Variable	Body stature	Body length	Body depth	FC	Heart girth	Navel height
DLC	-0.13^{NS}	-0.09^{NS}	0.22**	0.19**	0.19**	-0.25**
Body stature		0.24**	0.22**	0.32**	0.37**	0.39**
Body length			0.46**	0.26**	0.20**	0.01^{NS}
Body depth				0.69**	0.53**	-0.32**
FC					0.72**	-0.26**
Heart girth						-0.19**

**P* < 0.05; ***P* < 0.01; *NS: not significant (P* > 0.05*)* circumference and heart girth ($r = 0.72$; $P < 0.01$). Cows with long bodies were associated with deep bodies, wide at the flanks, heart girth and the bottom of the belly was near the ground.

4.4 Discussion

The study was designed to explore factors affecting linear traits in Nguni cows. Environmental components make a relatively large contribution to the phenotype of linear traits, which are gaining ground in selection programmes of cows (Funk *et al*., 199). Large phenotypic standard deviations (SD) for body depth, flank circumference and heart girth shows that linear type traits vary considerably in cows hence response to selection should be high. Linear traits such as flank circumference and heart girth are expected to be affected by reproductive status of the cow. Determining pregnancy status in cows is expensive and time consuming. Considering the fact that Nguni cows have a high re-calving rate of over 80 % on natural pastures (Schoeman, 1989), the DLC is good indicator of the reproductive status of Nguni cows.

Body depth, flank circumference and heart girth increased with increase in parity. As parity increases, changes in linear traits are expected due to growth and development (Yanar, 1999). Cows in their early parities may still be growing and will be expected to increase in size hence linear traits. However, it was found in this study that age of cows under study did not affect variation in linear traits, thus, the observed effect of parity on linear traits can be deemed independent of growth and development of the animals. To our knowledge, no other studies have reported the effect of parity on body length, body depth, flank circumference and heart girth. Based on our findings, it is clear that parity is an important factor of linear traits in cows regardless of the age.

Differences in nutritional levels, coupled with climatic conditions may have resulted in the observed differences in linear traits across different ecotypes. Distinctive Nguni ecotypes developed as a result of adaptation to different ecological zones. Although the Nguni cattle are generally adapted to the Sub-Saharan Africa environments (Bester *et al*., 2003), there are radical differences in climate and veld type within Sub-Saharan Africa which have influenced the size and morphology of the Nguni cows. The cows' bodies and skeletons respond significantly to environmental stimuli as they grow and develop and, thus, cows of the same breed kept under different environments evolve into different ecotypes in the long run as a result of the interaction between the environmental factors and their individual genetic capacities (Maciel *et al*., 2013). Zulu (2008) reported that, in Zambian indigenous breeds, ecotypes found in the valleys were taller, longer and larger body capacity than those on plateaus. Such differences were attributed to differences in the availability and quality of feed. Lack of nutrients such as calcium and proteins necessary for bone development and growth of the animals might be the reason cows raised on plateaus are small-framed.

The finding that Venda cows had the deepest bodies, widest flanks and heart girths throughout the seasons could be a sign of adaptation. The different Nguni ecotypes were named based on migratory routes and their owners (Bester *et al*., 2003). The Venda ecotype is concentrated in areas predominated by semi-arid basins characterised by species unpalatable to domestic livestock, extremely high temperatures and erratic rainfall (Bester *et al*., 2003). Deep bodies, wide flanks and heart girth provides large body capacity hence lots of room to consume and digest large amounts of high-fibre; lower protein feeds along with plenty of water to meet the cows' nutritional requirements. Increase in flank circumference and heart girth from cool-dry to post-rainy season in Swazi, Makhatini and Pedi cows is most probably because both traits are affected by fat deposition which vary with pasture availability. There is not much seasonal dynamism in vegetation abundance in terms of total plant cover and biomass in the semi-arid areas (Bosing *et al*., 2014), where the Venda ecotype is mostly found, which could be the explanation why there was no significant variation in flank circumference and heart girth in Venda cows across seasons. Cows with long bodies are associated with deep bodies, wide at the flanks, heart girth and the bottom of the belly is near the ground, indicating large body capacity since length, width and depth of body all determine capacity in cows.

4.5 Conclusions

The observed existence of variation, indicated by relatively large standard deviation, in linear traits gives good opportunity to use the linear traits for indirect selection for fertility in Nguni cows. This study showed the strong influence of parity, season of measurement and ecotype on linear traits. It is, however, necessary to ascertain the relationships between linear traits and fertility traits before basing selection decisions on linear traits with the intention of enhancing fertility in Nguni cows.

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Chapter 5: Relationship between linear type and fertility traits in Nguni cows

(*In Press: Animal*)

Abstract

The relationship between six linear type traits (body stature, body length, heart girth, navel height, body depth and flank circumference) and fertility traits (calving interval (CI) and age at first calving (AFC)) was investigated in Nguni cow herds. The traits were measured between December 2012 and November 2013 on 1559 Nguni cows kept under thornveld, succulent karoo, grassland and bushveld vegetation types. The CI and age at first calving AFC decreased linearly as body depth increased (b = -2.1 and -0.2, respectively) ($P<0.05$). There was a quadratic decrease in both CI and AFC as flank circumference and heart girth increased ($P<0.05$). As the body length of cow increased, the CI and AFC also increased (b = 0.8 and 0.1, respectively) ($P<0.05$). It was, therefore, concluded that vegetation type affected linear traits, CI and AFC. Cows raised on the succulent karoo rangelands had the shortest CI, calved earliest, deepest bodies, widest chests and flanks. The body depth and body length had negative linear relationship with both CI and AFC. Flank circumference and heart girth circumference had negative quadratic relationships with CI and AFC.

Keywords: Nguni cows, body depth, calving interval, flank circumference, heart girth.

5.1 Introduction

Reproductive performance is the major determinant of the profitability of any cow-calf beef enterprise (MacGregora and Casey, 1999). Hence, improving reproductive performance is the prime aim of most beef producers globally. Longevity, calving interval (CI) and age at first calving (AFC) are among the most important indicators of fertility in cows (Cammack *et al*., 2009). Cows that calve early tend to have short calving intervals, stay in the herd longer and produce more calves in their reproductive life. Cow fertility in the tropics is strongly influenced by environmental effects such as nutrition and diseases (Mackinnon *et al*., 1989). Small-framed indigenous breeds, such as the Nguni, exhibit high reproductive fitness under poor nutritional conditions of the Sub-Sahara (Ndlovu *et al.*, 2007). Under the Sub-Saharan African conditions, small-framed Nguni cattle reach puberty at younger age (about 16 months) and have shorter calving interval (about 370 days) compared to larger framed beef breeds such as the Drakensberger and Bonsmara (Maciel *et al*, 2011). As a result of their reproductive fitness, small-framed breeds such as Nguni, Bonsmara and the Tuli have gained ground in the modern Sub-Saharan beef population (Strydom et al., 2001). It is the Nguni breed which has gained enormous popularity in recent years because of its adaptive traits and multiple colours (Mapiye *et al*., 2009).

The major challenge with selection for fertility traits is that the time interval required to record traits such as calving interval is long. This reduces the amount of available data, lengthens generation interval and decreases the reliability of the data for heifers and young cows. Increasing efficiency of any cow-calf herd requires improvement of fertility of both cows and replacement heifers. Considering that fertility traits are expressed late in cows, predicting heifer performance at an early age is difficult. Pedigree selection requires intensive record keeping and pedigree records are difficult where artificial insemination is not used. Considering that a long time interval is required to record longevity, CI and AFC, record keeping is slow, tedious, time consuming and expensive, early selection of replacement heifers is a challenge. Nguni farmers rarely record longevity and stayability mainly because they are expressed late in life. There is need to consider other ancillary traits which can be more easily measured early in the cow's life.

The Nguni Society of South Africa encourages farmers to put accent on visual appraisal for conformation traits to maximise fertility in Nguni cows. Linear type traits considered by Nguni farmers when selecting cows include body depth, flank circumference, heart girth circumference, body stature and length of the cow. Linear measurements are associated with both production and non-production traits in cattle, and thus with production efficiency (Berry *et al*., 2004). In dairy cows, there is a general relationship between the linear traits and reproductive performance (Larroque and Ducrocq, 2001). Although the relationship between linear traits and fertility traits have been established for large framed dairy cows, no studies have been conducted in Nguni cows. Dairy cattle production is mostly pasture-based whilst Nguni cattle are kept on different natural rangeland types. Common rangeland types supporting Nguni cattle production include grassland, succulent karoo, bush veld and thornveld (Mohammed-Saleem, 1995). Fertility and linear traits of Nguni cows vary with production environment (Chapter 3). It is not clear how the different rangeland types affect relationships between linear and fertility traits. Due to differences in frame sizes and production systems, relationships between linear traits and fertility traits in dairy and Nguni cows are expected to differ.

There is need to determine the relationships between linear type traits and fertility before basing selection decisions on linear traits with the intention of enhancing fertility in Nguni cows. Once the relationship between linear traits and fertility traits is ascertained, the reproductive ability of cows and/or heifers can be judged at an early age. Use of linear traits as indirect measures for fertility facilitates the selection of heifers at an early age. The objective of the study was to determine the relationship between linear type traits and fertility traits in Nguni cows. The hypothesis tested was that there is a negative linear relationship between linear type traits and fertility traits in Nguni cows.

5.2 Materials and methods

5.2.1 Study site

The study was conducted on Nguni cows kept under four distinct vegetation types in South Africa. Farms were selected from each vegetation type using stratified random sampling technique. Table 5.1 shows the identities of the vegetation types, farms, climatic conditions and the number of cows from each farm. Due to their adaptability to the local environment, the cows were raised on natural veld without any additional feeds such as concentrate, minerals and feed additives. The selection of farms was based on vegetation type and the willingness of the farmers to participate in the study. For all farmers who participated in the study, bulls were left with the herd all the time.

Table 5.1: Identities of vegetation type, climatic conditions and the number of cows from each vegetation type

Vegetation type	Location	Coordinates	n	Annual rainfall (mm)	Mean annual Temperature (ºC)	Altitude (m)
Thornveld	Hluhluwe	28.0189° S, 32.2675° E	133	590	20	310
	Newcastle	27.7442° S, 29.9372° E	79	784	19	1240
	Komga	32.5770° S, 27.8880° E	191	550	17	630
Grassland	Stutterheim	32.5667° S, 27.4167° E	232	600	16.5	900
	Memel	27.6833° S, 29.5667° E	235	750	17	1735
Succulent karoo	Venterstad	30.4634° S, 25.4800° E	221	400	18.5	1293
Bush veld	Thohoyandou	22.9500° S, 30.4833° E	217	550	20	618
	Louis Trichardt	23.0500° S, 29.9000° E	251	500	20	950

Sources: Acocks (1988); Mucina and Rutherford (2006)

5.2.2 Data collection

A total of 1559 cows from parity 3 to 8 were used. Trained personnel visited identified farms and measured linear type traits on each of the cows between December 2012 and November 2013. Measurements were taken between morning and mid-morning before cows had started grazing. The measurements taken were body stature, body depth, heart girth, flank circumference, navel height and body length. The measurements were recorded on a recording sheet (see Appendix 3). The body stature was measured from top of the spine in between hips to ground. Body depth was measured as distance between the top of spine and bottom of barrel at last rib (the deepest point) measured from the left side of the cow. Heart girth was defined as circumference of the body taken just behind the shoulders. Flank circumference was defined as circumference of the body taken just in front of the hook bones. Navel height was measured from the ground to the navel of the cow. Body length was measured from the hindmost part of the animal to the valley in front of the second thoracic vertebrae just ahead of the center of the shoulders (Alphonsus *et al*., 2012).

Body depth, heart girth, body length and flank circumference were measured, in centimetres, using a plastic tape measure. An aluminium extending measuring stick was used to measure navel height and body stature. All measurements were taken by the same evaluator. In addition to linear traits measurement, the following records were taken: date of birth, parity of cow and calving date. The age of the cow at classification, days to last calving (DLC), age at first calving (AFC) and calving interval (CI) were computed from the collected records. The AFC was calculated as the period, in days, between the heifer's birth date and its first calving date. Cows with AFC greater than 540 days and less than 1 460 days were included in the analyses. The CI was calculated as the period, in days, between two successive calvings. Calving intervals between 300 and 730 days were considered in the analyses. The DLC was calculated as the period between the last date of calving and date of linear trait measurement. The experiment was approved by the University of KwaZulu-Natal Animal Ethics Sub-Committee (Ref 078/13/Animal) (see Appendix 4).

5.2.3 Statistical analyses

The effects of vegetation type and parity of cow on linear traits, CI and AFC were analysed using the General Linear Model procedures (SAS, 2008). Days to last calving, age of cow at classification, body depth, flank circumference, heart girth, body length, navel height and body stature were fitted as covariates, were relevant. The DLC, a good indicator of the reproductive status in Nguni cows, was used to adjust for the reproductive status of the cows at classification. The following model was used:

$$Y_{ijk} = \mu + P_i + V_j + \beta_1(D) + \beta_2 (A) + \beta_3(ST) + \beta_4(BD) + \beta_5(HG)+ \beta_6(FC) + \beta_7(BL) + \beta_8(SH) + E_{ijk}$$

Where:

Y_{ijkl} = response variable (CI, AFC, body size, body depth, heart girth, flank circumference, navel height and body length);

μ = population mean common to all observations;

P_i = effect of the i^{th} parity of cow;

V_j = effect of the j^{th} vegetation type;

A = age of cow at classification;

D = days to last calving;

$\beta_1 - \beta_8$ = partial linear regression coefficients of the dependent variables on covariates age of cow at classification, body stature, body depth, heart girth, flank circumference, body length, sheath height respectively;

E_{ijk} = residual error ~ N (0; $I\sigma^2$).

The PROC REG (SAS, 2008) was used to test whether the relationships between AFC and CI and each of the independent variables were linear, quadratic or exponential.

Pearson correlations among dependent variables (AFC and CI) and the independent variables (body stature, body depth, heart girth, flank circumference, navel height and body length) were computed using the PROC CORR procedure (SAS, 2008).

5.3 Results

5.3.1 Summary statistics, levels of significance and estimates of fixed factors and covariates

The summary statistics for the traits analysed are shown in Table 5.2. The body depth, body stature, body length, flank circumference, heart girth and navel height showed low levels of variation as indicated by small standard deviation values. Cows used in the study were aged between 32 and 214 months, averaging 91.09 months. Table 5.3 summarises the levels of significance for fixed effects and relevant covariates on CI and AFC. Vegetation type affected body depth, body stature, body length, flank circumference, heart girth and navel height, CI and AFC ($P < 0.05$). Parity of cow had a significant effect on CI.

Table 5.2: Summary statistics for linear measurements, calving interval (CI), age at first calving (AFC), age of cow and days to last calving (DLC) for cows used in the study

Variable	N	Mean	SD	Minimum	Maximum
Body depth (cm)	1555	103.9	8.07	55	130
Body stature (cm)	1553	126.9	5.11	112	142
Body length (cm)	1154	130.5	9.07	89	200
Flank circumference (cm)	1559	180.2	11.70	11	212
Hearth girth (cm)	1559	167.4	9.83	117	199
Navel height (cm)	1553	49.6	4.22	40	61
CI (days)	1362	407.9	69.82	267	752
AFC (months)	1190	34.3	6.45	16	72
DLC (days)	1465	194.1	141.22	1	871
Age of cow (months)	1526	91.1	39.24	32	214

Table 5.3: Significance levels for fixed effects and covariates tested for statistical models used to estimate the impact of body stature (BS), body depth (BD), heart girth (HG), flank circumference (FC), navel height (NH) and body length (BL) on calving interval (CI) and age at first calving (AFC) in Nguni cows

	CI	AFC	BD	BS	BL	FC	HG	NH
BD	**	*	-	-	-	-	-	-
BL	*	**	-	-	-	-	-	-
FC	*	*	-	-	-	-	-	-
Age of cow	**	-	NS	NS	NS	NS	NS	NS
Parity	**	-	**	NS	**	**	**	**
Vegetation type	**	**	**	**	**	**	**	**

**$P < 0.01$.

*$P < 0.05$.

5.3.2 Effect of parity of cow and vegetation type on linear traits and cow fertility

Effects of vegetation type on linear and fertility traits are shown in Table 5.4. Cows raised on the succulent karoo rangelands were shortest in body stature, had the deepest bodies with widest chests and flanks. Cows raised on grasslands were tallest in body stature, had shallow bodies with narrow chests and flanks. Cows reared on the succulent karoo rangelands had the shortest CI whilst those on grassland ranges had the longest CI ($P < 0.05$). Cows reared on the succulent karoo rangelands had the shortest AFC whilst those on grasslands had the longest AFC ($P < 0.05$). The CI decreased with parity of cow from parity 3 to parity 4, and then increased in parity 5. The CI decreased from parity 5 to parity 8 (Figure 5.1).

5.3.3 Relationships between linear and fertility traits

Correlations between linear traits, CI and AFC are shown in Table 5.5. The body depth and flank circumference had significant negative correlations with CI. The correlation between AFC and body depth was relatively weak and negative (-0.27; $P < 0.05$). Body depth had strong positive correlations with flank circumference (0.69) and heart girth (0.53; $P < 0.05$). Cows with deeper bodies had navels near the ground ($r = -0.32$) and longer bodies ($r = 0.46$; $P < 0.05$). There was also a significant strong positive correlation between flank circumference and heart girth (0.72). Relationships between linear and fertility traits are shown in Table 5.6. The CI decreased linearly with increase in body depth and parity ($P < 0.05$). The AFC linearly decreased as body depth increased ($P < 0.01$). There was a quadratic decrease in CI and AFC as the flank circumference and heart girth increased ($P < 0.05$). As the body length increased CI and AFC increased linearly.

Table 5.4: Effect of vegetation type on body depth, body stature, body length, flank circumference, heart girth, navel height, calving interval (CI) and age at first calving (AFC) in Nguni cows

	Vegetation type					
Parameter	Thornveld	Succulent karoo	Grassland	Bushveld	RMSE	P value
Body stature	126.5^{b}	125.4^{ab}	125.0^{a}	129.3^{c}	4.78	*
Body length	125.7^{c}	130.2^{ab}	136.3^{a}	129.4^{b}	8.19	*
Body depth	102.5^{c}	110.3^{b}	104.6^{a}	102.1^{c}	7.65	*
Flank circumference	180.8^{b}	184.4^{a}	178.6^{b}	179.7^{b}	11.59	*
Hearth girth	167.5^{b}	170.2^{a}	165.9^{b}	167.7^{ab}	9.77	*
Navel height	48.2^{c}	48.2^{c}	49.5^{b}	50.9^{a}	4.06	*
CI	417.1^{c}	370.4^{a}	427.2^{c}	396.9^{b}	67.13	*
AFC	32.3^{b}	24.5^{a}	36.7^{c}	33.4^{b}	5.84	*

RMSE = root mean square error.

Values of each parameter in a row with different superscript differ significantly (P<0.05); *P <0.01.

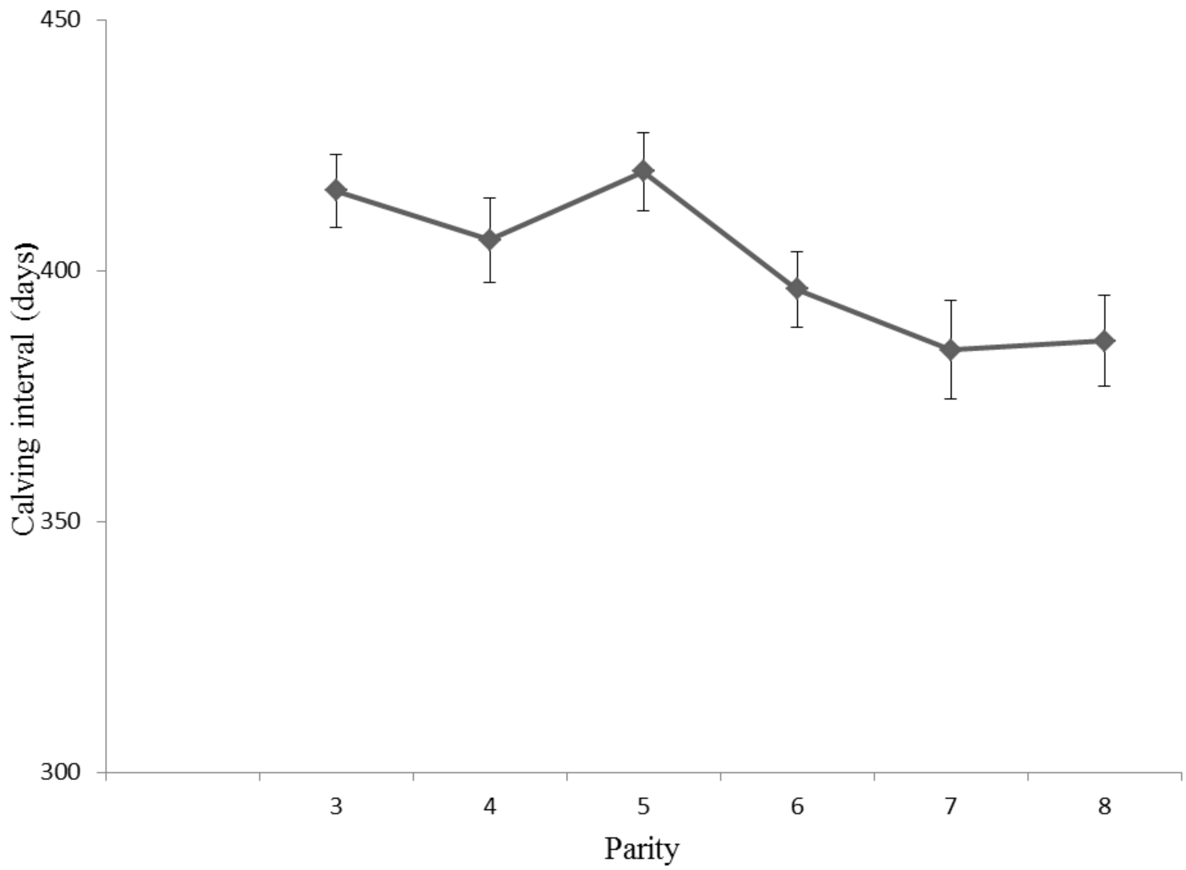

Figure 5.1: Effect of parity of cow on calving interval. Error bars represent standard errors of the mean.

Table 5.5: Pearson correlation coefficients among linear traits and fertility traits in Nguni cows

Variable	Body stature	Body length	Flank circumference	Heart girth	Navel height	Age	AFC	CI
Body depth	0.22**	0.22**	0.69**	0.53**	-0.32**	0.16**	-0.17**	-0.27**
Body stature		0.24**	0.32**	0.37**	0.39**	0.01	-0.13	-0.13
Body length			0.26**	0.20**	0.01	0.15**	0.17*	-0.14*
Flank circumference				0.72**	-0.26**	0.12**	-0.13	-0.22**
Heart girth					-0.19**	0.12**	-0.12	-0.11
Navel height						-0.21**	0.03	0.03
Age of cow							0.04	0.03
AFC								0.40**

Table 5.6: Regression coefficients (±SE) for fixed effects and covariates from statistical models used to determine the impact of body stature, body depth, heart girth, flank circumference, navel height and body length on calving interval (CI) and age at first calving (AFC) in Nguni cows

	Linear		Quadratic	
Variable	CI±SE	AFC±SE	CI±SE	AFC±SE
Body depth	-2.1 ± 0.63**	-0.2 ± 0.08**	0.04 ± 0.043	-0.007 ± 0.005
Body stature	-1.1 ± 0.78	-0.1 ± 0.10	-0.02 ± 0.10	0.01 ± 0.011
Body length	0.8 ± 0.40*	0.1 ± 0.04**	0.02 ± 0.014	-0.002 ± 0.0013
Flank circumference	-0.4 ± 0.41	0.01 ± 0.05	-0.02 ± 0.010*	-0.002 ± 0.0011*
Heart girth	0.02 ± 0.43	0.03 ± 0.07	-0.03 ± 0.016*	-0.004 ± 0.0021*
Navel height	0.9 ± 1.01	-0.002 ± 0.12	0.1 ± 0.152	-0.006 ± 0.020
Age of cow	0.1 ± 0.05**	-	-	-
Parity of cow	-6.5 ± 1.13**	-	0.4 ± 0.93	-

$^{**}P < 0.01$.

$^{*}P < 0.05$.

5.4 Discussion

Under extensive Nguni cattle production, the CI and AFC are the most easily measured fertility traits compared to other direct measures of fertility such as conception rate, birth and weaning weight (Schoeman, 1989). Pregnancy diagnosis is a vital tool of reproductive management of beef herds. Determining pregnancy status of cows is expensive and time consuming. Considering the fact that Nguni cows have a high re-calving rate of over 80% on natural pastures (Schoeman, 1989), the DLC is a good indicator of the reproductive status of Nguni cows.

Cows on succulent karoo rangelands were observed to have the shortest CI, and calved at the youngest age, and this was attributed to the fact that they had deep bodies, wide flanks and chests. The finding that cows on succulent karoo had the shortest CI and calved at the youngest age is unexpected. The succulent karoo has exceptional diversity of plants dominated by species unpalatable to domestic livestock (Bosing *et al*., 2014). Thus, reproductive performance is expected to suffer since lack of adequate nutrients reduces ovulation rates and age at puberty. Grassvelds have higher production potential for beef cattle due to the existence of grasses and dwarf shrubs that are sweet, providing palatable forage throughout the year (Rook *et al*., 2004). Nguni cows kept under grasslands had the longest CI and highest AFC compared to cows on succulent karoo, thornveld and bushveld. Cows on the succulent karoo had the deepest bodies compared to those on other vegetation types. There is a positive correlation between body depth and gut capacity in cows (Hansen *et al*., 1999).

Large body capacity in cows is associated with plenty of space for the rumen and respiratory organs, which, in turn, affects the food ingestion, digestion and assimilation capacity (Dubey *et* *al*., 2012). Deep wide bodies with wide open ribbing provide lots of room for the rumen to expand and digest large amounts of high-fibre; lower protein feeds along with plenty of water. Cows with deeper bodies, hence large body capacity, are capable of using low quality forage efficiently due to potentially longer passage rates and consequently more thorough digestion compared to those with shallow bodies. This suggests that deeper bodies may account for shorter intervals in cows bred under succulent karoo ranges, implying that body depth may have very important biological advantages for adaptation to poor nutrition.

Among the linear traits, body depth and body length had linear relationships with AFC and CI. In a comparable study in dairy cows, Forabosco et al. (2004) found that body depth was a strong indicator of fertility traits such as longevity. This finding is in agreement with our finding, which is that as body depth increases CI and AFC decreases, in the sense that the cows would stay in the herd for a long period probably because they had desirable reproductive traits such as early calving and short CI. However, Forabosco et al. (2004) did not report on the relationship between fertility traits and body length. The relationship between body depth and AFC and CI could be because of the interactions between body depth, rumen capacity, rumen fill and nutritional demands of the cow. The same reasons could be attributed to the relationship between flank circumference and CI. Thus, there could be a combined effect of body depth and flank circumference on reproductive efficiency in cows. It has been suggested that body depth of a cow is an indicator of its body and rumen capacity (Nutt *et al*., 1980).

The observation that CI and AFC decreased at a decreasing rate as heart girth and flank circumference increased indicates that wide flanks and chests are required for optimum fertility.

Pryce *et al.* (1998) suggested cows which are wide at the flanks and chests tend to have shorter inter calving periods. Cows which are wide at the flanks with deep bodies in addition to wide, well-sprung ribs are said to have a large body capacity (Hansen *et al*., 1999). Cows with little body capacity are more likely to struggle to meet nutritional requirements during pregnancy when fed on natural pastures of poor nutritional value. This is because the gut size is limited by the abdominal capacity. During pregnancy, as the fetus is growing in the uterus it fills a large portion of the cow's body cavity, thus displacing rumen capacity. Thus reduced forage intake during late gestation could be partly a result of restricted rumen capacity caused by space limitations in the abdominal cavity due to the presence of the foetus, placenta, and associated fluids.

Under-nutrition due to limited feed intake during late gestation (prepartum) has detrimental effects on subsequent reproductive efficiency. Reproductive performance is closely linked to the amount of available energy reserves a cow has especially during gestation (Olson, 2005). Reduced forage intake during pregnancy impairs energy balance hence fetal growth and body condition score of the cow at calving will be affected. Nutritional status of the cow at the time of calving determines when it will return to estrus hence calving interval (Drennan and Berry, 2006). Thus, cows which are wide at the flank and chest with deeper bodies tend to have sufficient body cavity capacity for forage intake to meet nutritional requirements during pregnancy. This shortens the lactation anoestrous period hence CI is reduced.

The possible reason for the favourable negative relationship between body depth, heart girth and flank circumference and AFC is that, under rangelands with poor nutrition, heifers with deeper bodies, wider chests and flanks hence large rumen capacities may be more willing and able to consume their forage more rapidly than those with shallow bodies, narrow chests and flanks. Moreover large body capacity is associated with plenty space for the rumen and digestive system, and this, in turn, affects the food ingestion, digestion and assimilation capacity of animal (Dubey *et al*., 2012). Thus, heifers with deeper bodies are more likely to meet their nutritional requirements whilst those with shallow bodies are more likely to struggle to meet nutritional requirements. Considering that poor nutrition prolongs pubertal development and reduces conception rate in heifers (Diskin *et al*., 2003), shallow bodied heifers are likely to take more time to calve than deep bodied heifers.

The positive relationship between body length and both CI and AFC reflects the importance of frame size under extensive rangeland conditions. Frame scores in cattle are usually based on body stature and/or body length (Owens *et al*., 1993). As the body length, hence frame size increases, the AFC and CI increases. This implies that shorter small-framed animals are more fertile compared to their longer counterparts. This can be attributed to small-framed animals having lesser maintenance requirements than large-framed animals hence they can easily meet their nutritional requirements. Though exact comparisons are not possible because of different fertility traits and breeds used, our finding that body stature does not influence fertility traits in cows is in line with that of Larroque and Ducrocq (2001) who found no significant relationships between body stature and longevity in Holstein cows. Correlations show that cows with deep bodies are associated with wide flanks, wide heart girths and the bottom of the belly is near the ground. Such cows tend to have short CI and AFC as revealed by the negative correlations between body depth, flank circumference, heart girth and CI and AFC.

Unexpectedly, linear regression showed that as age of cows increased the CI increased. Due to the fact that young cows are still growing during gestation and the fetus is also competing for nutrients, the cow is stressed nutritionally and its energy stores can be depleted. Moreover, after calving, young cows must satisfy their own growth, maintenance, and lactation requirements, as well as replenish their own depleted energy stores before initiation of estrous cycles can occur. Older cows gain body condition and weight quickly after calving hence the calving interval is expected to be shorter than young cows (Werth *et al.*, 1996). Thus, CI is expected to decrease with age as reported by Werth *et al.* (1996) and Strauch *et al.* (2001). The unexpected negative relationship between CI and age found in this study could be because of the age classes used. Renquist *et al*. (2006) reported that the association between age and reproductive performance varies with age classes with reproductive performance decreasing in later ages. However, in this case, the magnitude of the decrease in the CI with increase in age is small as indicated by the regression coefficient and is likely to be insignificant to the Nguni producers.

The finding that CI decreased with increasing parity of cow confirmed the work of Hammoud *et al*. (2010) and Werth *et al*. (1996) who argued that since first calvers will still be growing, they compete with their foetuses for available nutrients for their growth and maintenance during pregnancy. This could, adversely, influence foetal growth and development during gestation, thus extending the calving interval. However, our findings here reflect that parity also affects CI irrespective of age. This is likely to be related to the fact the cows in later parities will have experienced the process of giving birth several times so they are able to withstand and cope with stresses at calving more than first calvers hence they recalve earlier. Incidences of silent oestrus and prolonged post-partum anoestrous periods, which are usually responsible for extended CI, have been reported to decrease with advance in parity (Obese *et al*., 2013).

5.5 Conclusions

Vegetation type affected linear traits, CI and AFC. Cows raised on the succulent karoo rangelands had shortest CI, calved earliest, deepest bodies, widest chests and flanks. Body depth, body length, heart girth circumference and flank circumference were significant predictors of fertility in Nguni cows under extensive conditions. As body depth and body length increased, AFC and CI decreased linearly. As heart girth circumference and flank circumference increased, there was a quadratic decrease in AFC and CI. Due to differences in management practices, relationships between linear type traits and fertility of the Nguni cows are expected to differ with production system. It is, therefore, necessary to also determine the relationship between linear type traits and fertility of Nguni cows under communal rangelands. The high number of linear traits that are involved and considering all of them in selection programmes could be a challenge. Combining these linear traits into a smaller number of variables that describe fertility is valuable.

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Chapter 6: Relationship of linear type and fertility traits in Nguni cows kept under semi-arid and sub-humid communal rangelands

Abstract

The relationship between six linear type traits (body stature, body length, heart girth, navel height, body depth and flank circumference) and calving interval, still births and abortions was investigated in Nguni cow herds in semi-arid and sub-humid communal areas. Data were collected from a total of 200 Nguni cows from two sites experiencing sub-humid and semi-arid environments (100 each) between May and June 2013. Cows in semi-arid areas had deeper bodies, wider chests and flanks than those in sub-humid environments ($P < 0.05$). There was no significance difference in the odds of aborting and still births among cows in semi-arid regions and odds of aborting and still birth among cows in sub-humid areas. As body depth increased, the number of calves lost by a cow decreased linearly ($P<0.05$). The rate of decrease in total number of calves lost before weaning for each cow (TCL) with increase in body depth decreased ($P<0.05$) with an increase in parity up to Parity 5, then increased in Parity 6. The rate of decrease in TCL with increase in body depth was highest in Parity 2 ($b = -0.06$). Cows in semi-arid regions were 2.13 times more likely to loose a calf from calving to weaning than cows in sub-humid areas. Young (7 years and below) cows were more likely to experience calving intervals greater than a year (odds ratio 1.02), still births (odds ratio 1.03) and abortions (odds ratio 1.28). For each unit increase in body depth, the odds of a cow aborting decreased by 1.12 and the odds of a cow having still birth decreased by 1.15. It was, therefore, concluded that body depth influences the incidence of still births and abortions in Nguni cows. Production environment

influenced the likelihood of a cow to lose a calf from calving to weaning but not the likelihood of a cow to abort or have a still birth.

Keywords: Body depth, calving interval, flank circumference, heart girth.

6.1 Introduction

Low fertility, a challenge in communal cattle production, has always been attributed to low levels of management and nutritional problems (Chapter 3). Low calving percentage and high calf mortality rates are the main constraints to cattle production in communal areas (Mokantla *et al*., 2004). High calf mortality rates of about 60 % per annum were estimated in the communal production systems and most of these were reported during drought periods (Moyo, 1996). Low calving percentage can be a result of cows failing to conceive and/or embryonic losses (abortions and stillbirths). Still births and abortions are attributed to various factors including poor bull fertility, high disease prevalence and poor nutrition (Chapter 3). Calving percentages vary yearly due to environmental stresses such as droughts and fluctuation of environmental temperatures (Gusha *et al*., 2013); suggesting nutrition and environmental stress play critical roles.

In South Africa, the recent quest for viable breeds in communal production systems has resulted in the re-introduction of the Nguni breed, a low maintenance breed suitable for low-input systems based on extensive grazing (Bester *et al*., 2003). The Nguni, a small to medium-framed breed, is extremely hardy and well adapted to harsh environmental conditions of the southern Sahara. Nguni cattle are resistant to diseases and gastrointestinal parasites which are among the major causes of low fertility in communal cattle production. Due to their adaptation to low quality feeds, Nguni cows have the potential to exhibit high fertility characteristics such as high conception rates, early maturing, ease of calving and short calving intervals. Despite their huge production potential, offtake of Nguni in communal production systems has not yet reached acceptable levels (Musemwa *et al*., 2010). Low off-take for communal Nguni farmers has been largely attributed to low fertility as a result of poor breeding practices such as poor selection and uncontrolled mating systems (Mapiye *et al*., 2009). Calving intervals of nearly two years have been reported (Nqeno *et al*., 2011). While calving rates around 90 % have been reported in commercial Nguni production (Maciel *et al*., 2013), abortions and stillbirths are common among Nguni herds in communal production systems (Nqeno, 2008).

Under communal farming systems, calving occur throughout the year. Records are hardly kept and selection of the best individuals is difficult to perform. Communal Nguni farmers rely mostly on memory when selecting breeding cows and/or heifers. They have indigenous knowledge to memorize and acknowledge individual animal and ancestors' performance (Mgongo *et al*., 2014). Information on livestock can, however, only be memorised up to a point and can often be forgotten overtime especially when herd composition drastically changes in cases such as drought, disease epidemics and other natural disasters. Considering that written records in communal cattle production are rare and, that memory based selection is not reliable, there is need to come up with complementary strategies to select for cow fertility. Communal farmers use linear traits to complement memory based selection during selective breeding of cows (Mapiye *et al*., 2009). There is a relationship between linear traits and fertility in Nguni cows (Chapter 5). There is no evidence on the relationship between linear traits and fertility in Nguni cows under communal rangelands. If the relationship between linear and fertility is ascertained, farmers can select breeding cows with ease through visual appraisal. Visual appraisal using linear traits will be cheaper for the poor resource farmers. The objective of the study was to determine the relationship between linear type traits and fertility traits in multiparous communal Nguni cows. It was hypothesised that there is a negative relationship between linear type traits and fertility traits in Nguni cows.

6.2 Materials and methods

6.2.1 Study site

The study was conducted in Jozini local municipality, representing sub-humid production environment and Msinga local municipality representing semi-arid production environment. Both sites are in KwaZulu-Natal province of South Africa. Jozini is located at 27° 25' 60S and 32° 4' 0E and lies at an altitude between 150 and 600 m above sea level. The climate is characterised by hot-dry and cool-wet seasons. Annual rainfall averages 600 mm. Most rains are received between January and March, with the months of June and July being dry and cool. Highest mean monthly temperature is recorded in January (30°C) and lowest in July (11°C). The vegetation type of the area is mainly coastal sand veld, bush veld and foothill wooded grasslands (Morgenthal *et al*., 2006). Msinga is located at 28° 74' 61 S, 30° 45' 25 E. It receives erratic rainfall and has large daily temperature ranges. The area experiences extremely hot summers with highest mean monthly maximum temperature of 37°C in January. The area experiences severe cold with frost, with mean monthly minimum temperatures ranging between 4-8°C between May and July. The vegetation type is semi-arid savanna with steep and stony mountains predominated by aloes, thorn bush and some hardwood (Whelan, 2001).

6.2.2 Data collection

A total of 250 multiparous cows (125 from each region) were used. The cows were selected on the basis of the owners' willingness to participate in the study. The cattle grazed on communal rangelands. Measurements were taken during dipping days between May and June 2013. Just before dipping, cattle were held in a race for measurement. Trained personnel identified Nguni cows to be measured then estimated the age of each cow using dentition, breed score and body condition score (BCS). Cows were divided into two age groups, young (7 years and below) - with visible incisors and old (8 years and above) – with broken or gummy mouth (Raines *et al*., 2008). Visual assessment of the body condition was made using the five-point European system, in which a score of 1 was emaciated, and a score of 5 was very fat (Edmonson *et al*., 1989). Before taking the measurements, the farmer was interviewed on number of calvings (parity of cow), average calving frequency (CI), number of still births, when the cow had its last still birth, number of abortions, when the cow had its last abortion, number of calves that died before weaning and number of calves weaned. Interviews were conducted in Zulu vernacular by a trained enumerator and responses recorded on a recording sheet (see Appendix 5). Still births, abortions and calves lost from birth to weaning were coded as categorical traits (1= had still birth, 0= did not have still birth; 1= had an abortion, 0 = did not have an abortion; 1 lost a calf from birth to weaning; 0 = no calf died before weaning).

Measurements were taken between 0700 and 1000 hours before cows had started grazing. The measurements taken were body stature, body depth, heart girth, flank circumference, navel height and body length. The body stature was measured from top of the spine in between hips to ground. Body depth was measured as distance between the top of spine and bottom of barrel at last rib (the deepest point) measured from the left side of the cow. Heart girth was defined as circumference of the body taken just behind the shoulders. Flank circumference was defined as circumference of the body taken just in front of the hook bones. Navel height was measured from the ground to the navel of the cow. Body length was measured from the hindmost part of the animal to the valley in front of the second thoracic vertebrae just ahead of the center of the shoulders (Alphonsus *et al*., 2012).

Breed scores were assessed visually by the same assessor throughout the experimental period. Each animal was scored using a 1-9 scale based on nine physical characteristics of Nguni cows as described by Nguni breeders association. Each cow was given a score corresponding to the number of descriptive characteristics it possessed. Physical characteristics considered were: 1: general size of small to medium (stature less than 130 cm), 2: less developed dewlap and umbilical fold, 3: hardly noticeable cervico-thoracic hump, 4: rump drooping towards tail, 5: moderately dipped forehead constricted just below the horns, 6: wide and slightly convex face, 7: small ears with a sharp apex, 8: small udders and teats, 9: noticeably lyre shaped horns. A cow was considered for this study only if it met at least 5 of the 9 physical characteristics. A score of 1 means the cow met only one of the 9 physical characteristics and a score of 9 means that the cow met all the 9 characteristics. The measurements were recorded on a recording sheet (see Appendix 5).

6.2.3 Statistical analyses

The effects of production environment and parity of cow on linear traits and total number of calves lost before weaning for each cow (TCL) were analysed using the General Linear Model procedures (SAS, 2008). The body depth, flank circumference, heart girth, body length, navel height and body stature were fitted as covariates, where relevant. The following models were used:

Model 1: Total number of calves lost before weaning for each cow

$Y_{ijk} = \mu + P_i + E_j + \beta_1(D) + \beta_2 (A) + \beta_3(ST) + \beta_4(BD) + \beta_5(HG)+ \beta_6(FC) + \beta_7(BL) + \beta_8(SH) + E_{ijk}$

Model 2: Body stature, body depth, heart girth, flank circumference, navel height and body length

$Y_{ijklm} = \mu + P_i + E_j + RS_k + BCS_l + \beta_1(D) + \beta_2 (A) + \beta_3(ST) + \beta_4(BD) + \beta_5(HG)+ \beta_6(FC) + \beta_7(BL) + \beta_8(SH) + E_{ijklm}$

Where:

Y_{ijklm} = response variable (WP, TCL, body stature, body depth, heart girth, flank circumference, navel height and body length);

μ = population mean common to all observations;

P_i = effect of the i^{th} parity of cow;

E_j = effect of the j^{th} production environment (sub-humid and semi-arid);

RS_k = effect of the k^{th} reproductive status;

BCS_l = effect of the l^{th} body condition score;

$\beta_1 - \beta_8$ = partial linear regression coefficients of the dependent variables on covariates body stature, body depth, heart girth, flank circumference, body length, sheath height respectively;

E_{ijklm} = residual error ~ N (0; Iσ^2).

An ordinal logistic regression (PROC LOGISTIC) was used to estimate the probability of a cow experiencing a still birth, having an abortion and losing a calf from calving to weaning (SAS, 2008). The logit model fitted predictors, production environment (sub-humid; semi-arid), age of cow (young cows; old cows) body depth, body stature, body length, flank circumference, heart girth and navel height. The logit model used was:

In [P/1−P] = $\beta_0 + \beta_1X_1 + \beta_2X_2\ldots + \beta_tX_t + \varepsilon$

Where:

P = probability of a cow (aborting; experiencing a still birth; losing a calf from calving to weaning);

[P/1−P] = odds ratio (the odds of a cow aborting; the odds of a cow having a still birth; the odds of a cow losing a calf from calving to weaning);

β_0 = intercept;

$\beta_1X_1...\beta tXt$ = regression coefficients of predictors;

ε = random residual error.

When computed for each predictor (β_1... βt), the odds ratio was interpreted as the proportion of cows that abort versus those that did not abort, the proportion of cows that had still births versus those that did not have any still births and the proportion of cows that lost calves from calving to weaning versus those that did not lose any calf from calving to weaning.

6.3 Results

6.3.1 Summary statistics and levels of significance

Summary statistics for the traits analysed are shown in Table 6.1. The average body depth was 102.9 cm, with stature, body length, flank circumference and heart girth recording average values of 127.1, 127.2, 177.1 and 167.2 cm, respectively. Amongst the linear measurements, flank circumference had the largest variation (SD = 10.87 cm) while the smallest SD was for Navel height (4.36). Body depth had a standard deviation of 6.06. A mean calving interval of 1.5 years was recorded. The mean total number of calves lost before weaning per cow (TCL) was one. Table 6.2 shows the levels of significance for fixed effects and relevant covariates on, body depth, body stature, body length, flank circumference heart girth, navel height and TCL

Table 6.1: Summary statistics for linear measurements, calving interval, weaning percentage, age of cow and body condition score (BCS) for animals used in the study

Variable	N	Mean	SD	Minimum	Maximum
Body depth (cm)	250	102.9	6.06	89	121
Body Stature (cm)	244	127.1	4.94	108	143
Body length (cm)	250	127.2	6.52	111	177
Flank circumference (cm)	250	177.1	10.87	148	209
Hearth girth (cm)	250	167.2	8.33	144	193
Navel height (cm)	247	51.7	4.36	36	63
Calving interval (years)	239	1.5	0.70	1	3
TCL	246	1	1.06	0	5
BCS	250	3.5	0.52	2.5	4.5
Breed score	250	8	1.01	5	9

NB: TCL = Total number of calves lost before weaning for each cow.

Table 6.2: Significance levels for fixed effects and covariates tested for statistical models used to estimate the impact of body stature (BS), body depth, heart girth (HG), flank circumference (FC), navel height (NH) and body length (BL) on fertility of Nguni cows

	TCL	BD	BS	BL	FC	HG	NH
Body depth (BD)	**	-	-	-	-	-	-
Age of cow	**	NS	NS	NS	NS	NS	NS
Production environment	NS	**	NS	NS	**	**	**
Breed score	NS	*	**	**	**	**	NS
Body condition score	-	**	NS	NS	**	**	NS
Reproductive status	-	*	NS	NS	NS	NS	NS
Parity of cow	*	*	NS	NS	NS	NS	NS
Parity x BD	**	-	-	-	-	-	-

$**P < 0.01$; $*P < 0.05$; NS – not significant ($P > 0.05$)

NB: TCL = Total number of calves lost before weaning for each cow

6.3.2 Effects of production environment, breed score, body condition and reproductive status of cow on linear traits

The effects of production environment, breed score and reproductive status of cow on linear traits are shown in Table 6.3. The cows in semi-arid areas had deeper bodies, wider chests and flanks than those in sub-humid environments ($P < 0.05$). Cows in semi-arid areas had navels nearer to the ground than cows in sub-humid areas ($P < 0.05$). Cows with a breed score of 9 were the shortest, with shallowest bodies, narrowest chests and flanks ($P < 0.05$). Pregnant cows had deeper bodies than lactating cows ($P < 0.05$). Body depth did not differ with pregnancy stage. The body depth increased ($P < 0.05$) with increase in BCS (Figure 6.1).

6.3.3 Relationship between linear traits and cow fertility

Significance levels, estimates and standard errors of the estimates for effects included in the regression models for relationship between body depth and TCL across parities are shown in Table 6.4. The TCL generally decreased with increase in body depth in all parities. The rate of decrease in TCL with increase in body depth decreased ($P<0.05$) with an increase in parity up to Parity 5, then increased in Parity 6. The rate of decrease in TCL with increase in body depth was highest in Parity 2 ($b = -0.06$). There was no relationship between TCL and body depth in cows in Parity 4 ($P>0.05$) (Table 6.5). The odds of a calving interval of one year among cows in sub-humid areas were 2.57 times higher than the odds of calving interval of one year among cows in semi-arid areas. Cows in semi-arid regions were 2.13 times more likely to lose a calf from calving to weaning than cows in sub-humid areas. There was no significance difference in the odds of aborting and still births among cows in semi-arid regions and odds of aborting and still

Table 6.3: Effect of production environment, breed score, body condition score (BCS) and reproductive status on body depth (BD), body stature (BS), body length (BL), flank circumference (FC), heart girth (HG) and navel height (NH) in Nguni cows

	BD	BS	BL	FC	HG	NH
Production environment						
Semi-arid	104.8 ± 1.34[a]	128.1 ± 1.21	129.1 ± 1.36	179.2 ± 2.33[a]	171.6 ± 1.84[a]	50.7 ± 1.17[a]
Sub-humid	100.7 ± 1.25[b]	127.6 ± 1.13	129.3 ± 1.27	175.3 ± 2.18[b]	168.1 ± 1.73[b]	52.3 ± 1.09[b]
Breed score						
5	103.8 ± 1.57[b]	127.4 ± 2.33[a]	131.6 ± 2.61[b]	174.0 ± 4.48[ab]	167.5 ± 3.55	52.3 ± 2.25
6	102.3 ± 1.76[ab]	127.8 ± 1.60[ab]	130.8 ± 1.79[b]	184.0 ± 3.07[c]	172.0 ± 2.43	50.8 ± 1.55
7	104.5 ± 1.66[b]	129.0 ± 1.50[ab]	127.7 ± 1.68[ab]	176.6 ± 2.88[ab]	172.1 ± 2.28	51.1 ± 1.45
8	102.5 ± 1.28[b]	129.7 ± 1.16[b]	130.4 ± 1.30[b]	178.1 ± 2.22[b]	170.7 ± 1.76	52.1 ± 1.12
9	100.6 ± 1.15[a]	125.6 ± 1.04[b]	125.6 ± 1.16[a]	173.4 ± 2.00[a]	166.8 ± 1.58	51.2 ± 1.01
Reproductive status						
Early lactation	105.0 ± 1.35[b]	128.9 ± 1.22	129.1 ± 1.37	180.7 ± 2.35	171.9 ± 1.86	51.3 ± 1.18
Mid lactation	102.1 ± 1.59[a]	128.8 ± 1.44	130.5 ± 1.61	177.6 ± 2.76	168.4 ± 2.19	50.7 ± 1.39
Late lactation	102.4 ± 1.39[a]	128.2 ± 1.26	128.7 ± 1.41	177.7 ± 2.42	168.4 ± 1.92	52.0 ± 1.22
Early pregnancy	104.3 ± 1.45[ab]	127.3 ± 1.32	129.4 ± 1.48	176.4 ± 2.53	169.9 ± 2.00	51.2 ± 1.27
Mid pregnancy	103.2 ± 1.63[ab]	127.1 ± 1.48	126.1 ± 1.62	175.8 ± 2.76	167.8 ± 2.25	50.9 ± 1.45
Late pregnancy	106.1 ± 1.40[b]	127.5 ± 2.27	129.9 ± 1.42	180.6 ± 2.43	171.8 ± 1.93	49.9 ± 1.23

Values of the same parameter with different superscripts, within a column, are statistically different (P<0.05).

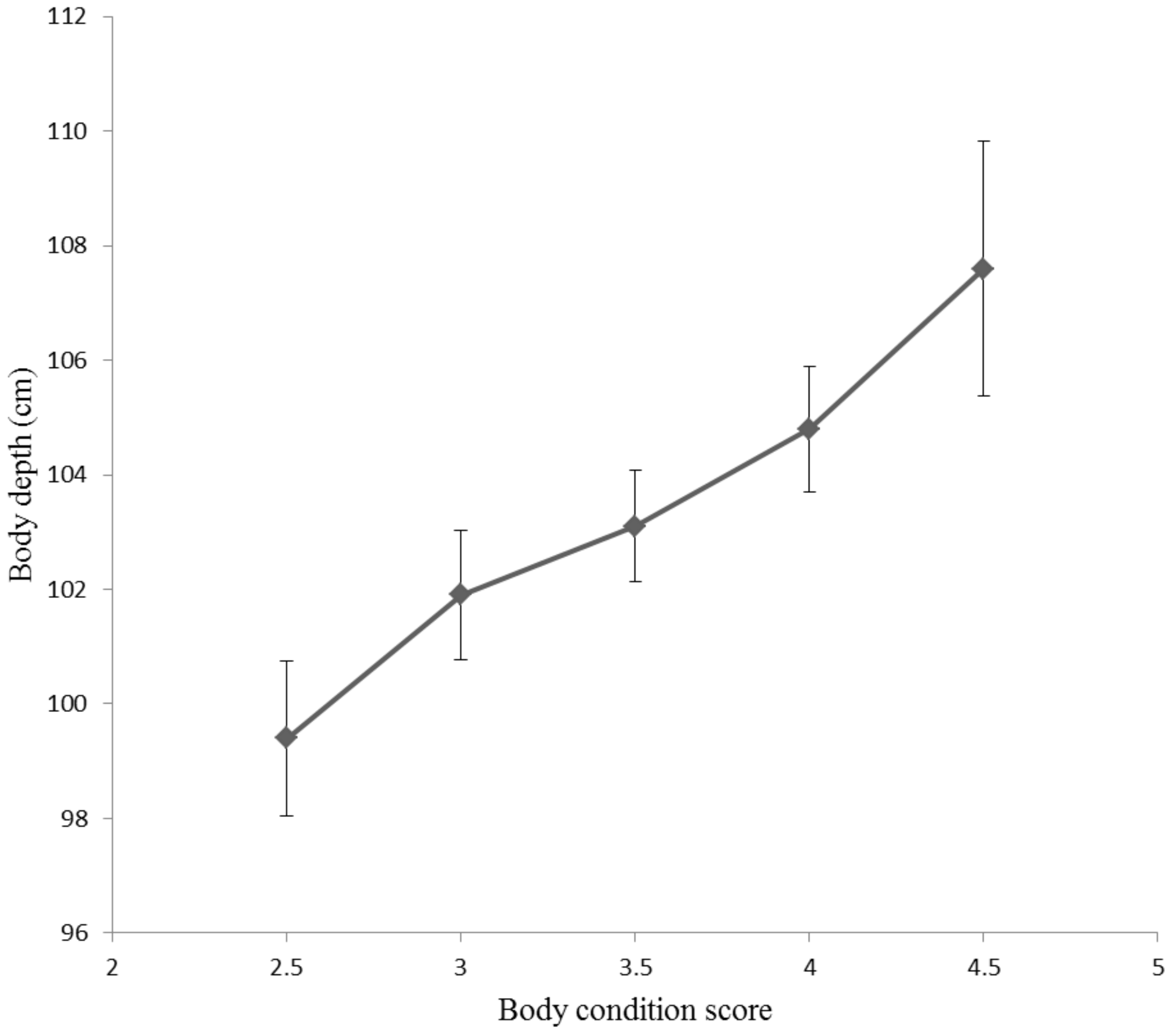

Figure 6.1: Effect of body condition score on body depth in Nguni cows. Error bars represent standard errors of the mean.

Table 6.4: Estimates (± SE) for the impact of body depth on total number of calves lost before weaning for each cow (TCL) in each parity

Parity	Intercept	TCL	P-value
2	6.4 ± 1.63	- 0.06 ± 0.016	**
3	4.9 ± 2.11	- 0.04 ± 0.021	*
4	1.83 ± 2.37	-0.01 ± 0.023	NS
5	1.15 ± 3.58	-0.01 ± 0.035	**
6	3.2 ± 3.39	-0.03 ± 0.033	*

Table 6.5: Odds ratio estimates, lower (LCI) and upper confidence (UCI) interval of ranking linear traits first in Nguni breeding cows

	#Calving interval			Abortion			Still birth			Mortality from birth to weaning		
Predictor	Odds	LCI	UCI	Odds	LCI	UCI	Odds	LCI	UCI	Odds	LCI	UCI
Production environment (Sub-humid vs. semi-arid)	2.57	2.40	4.72	0.93	0.41	2.07	1.02	0.52	2.00	0.47	0.24	0.90
Age (young cows vs. old cows)	0.98	0.77	0.98	0.78	0.83	0.99	0.97	0.55	0.91	1.17	0.64	2.15
Breed score	0.73	0.55	0.97	1.37	1.02	2.03	1.10	1.01	1.48	0.84	0.63	1.10
Body depth	1.07	0.99	1.15	0.89	0.81	0.98	0.87	0.80	0.95	0.94	0.87	1.02
Body stature	1.02	0.95	1.11	0.98	0.88	1.08	1.04	0.96	1.14	0.95	0.87	1.03
Body length	1.01	0.95	1.07	1.03	0.97	1.09	1.00	0.95	1.05	1.05	0.99	1.11
Flank circumference	1.01	0.97	1.06	1.03	0.97	1.09	1.02	0.97	1.07	1.02	0.97	1.07
Heart girth	0.98	0.93	1.03	0.96	0.89	1.03	1.00	0.95	1.07	1.02	0.96	1.08
Sheath height	0.98	0.91	1.06	0.99	0.89	1.10	0.94	0.86	1.03	1.02	0.93	1.11

#Probability modelled is calving interval = 1 year birth among cows in sub-humid areas (confidence interval 0.41 to 2.07 and 0.52 to 2.00, respectively).

Young cows were more likely to experience calving intervals greater than one year, still births and abortions. For each unit increase in body depth, the odds of a cow aborting decreased by 1.12 and the odds of a cow having still birth decreased by 1.15. A unit change in body depth did not significantly influenced the odds of a cow having a calving interval of one year and the odds of a cow losing a calf from calving to weaning (confidence interval 0.99 to 1.15 and 0.94 to 1.02, respectively). A unit change in body depth, flank circumference, heart girth and sheath height did not significantly influenced the odds of a cow having a calving interval of one year, aborting, having still births or losing a calf from calving to weaning. A unit change in breed score resulted in odds of a cow aborting and having still births increasing by 1.37 and 1.10, respectively.

6.4 Discussion

In communal beef production, fetal loss (abortion and stillbirths) is one of the major causes of poor calving percentage (Mokantla *et al*., 2004). Weaning percentage in communal Nguni production is still low despite the fact that the breed is deemed to thrive well under extensive production systems (Bester *et al*., 2003). Along with fetal loss, pre-weaning mortality is the main cause of low market off-take in communal cattle production (Musemwa *et al*., 2010). Under communal beef production conditions, where the level of management is low, mothering ability of the cow is important. Thus, traits such as stillbirths, mothering ability and abortions should be considered in communal beef breeding and management programs. Pre-weaning mortality was used as an indicator of mothering ability in this study. The calving interval range of 1 to 3 years agrees with Nqeno *et al*. (2011). The high odds ratio estimate for the effect of production environment on calving interval can be attributed to nutritional differences between the study areas. Poor nutrition and heat stress in semi-arid areas could be the major cause of long calving interval. The semi-arid areas are subjected to frequent droughts as compared to sub-humid areas.

The finding that cows in semi-arid region had deeper bodies than those in sub-humid areas as a direct result of differences in rainfall patterns, temperature, veld type and mineral status of the soil. This is in line with arguments put forward by Maciel *et al*. (2013) that Nguni cattle kept under different environments will evolve into different ecotypes in the long run as a result of the interaction between the environmental factors and their individual genetic capacities. Semi-arid regions are characterised by scanty rainfall and scrubby vegetation. Deep bodies provide large body capacity hence lots of room to consume and digest large amounts of high-fiber; lower protein feeds along with plenty of water to meet the cows' nutritional requirements. Cows from semi-arid areas had broader chests, hence better glandular function, to counter heat stress. The results that increase in breed score resulted in increase in chances of a cow aborting or having still births can be due to the decrease in body depth as breed score increased. Shallow body depth has been reported to be associated with poor fertility in cows (Forabosco et al., 2004).

The high and significant odds ratio estimates for the effect of body depth on abortion and still births can be attributed to the relationship between body depth and nutrition of the cow. Body depth is a component trait of body capacity hence it affects nutrition of the cow (Wu *et al.*, 2013). Metabolic energy deficiency during gestation is one of the nutritional reasons for stillbirths and abortions (Amin, 2014). Nguni cattle owned by resource-poor farmers are kept on communal rangelands which are of low-energy, high-fiber and poor digestibility (Nqeno *et al*., 2011). To meet their energy requirements, cows on less-digestible, low-energy, high-fiber pastures needs to consume large amounts of dry matter. Consumption of less-digestible, low-energy, high-fiber diets is controlled by rumen fill and the feed passage rate through the gastrointestinal tract (Hill, 2012). As the body depth increases, the body and gut capacity also increases hence passage rates are longer (Hansen *et al*., 1999). As result of increased body and gut capacity, dry matter intake and rate of nutrient absorption potentially increases. Thus, under less-digestible, low-energy, high-fiber pastures, cows with deeper bodies are more likely to meet their nutritional requirements compared to those with shallow bodies. Pregnant cows with shallow bodies, hence low rumen fill, may struggle to ingest adequate amounts of dietary energy, vitamins and other nutrients to meet the requirements of the rapidly growing foetuses resulting in abortions or still births. Still births and abortions in beef have also been attributed to nutritional diseases such as pregnancy toxaemia which are a result of failure by cows to meet nutritional requirements during pregnancy. Considering that most communal Nguni farmers are resource poor and cannot afford to supplement nutritional requirements to cows during pregnancy (Mapiye *et al*., 2009), it can be recommended that they resort to selecting cows with deeper bodies to overcome abortions and still births in their herds.

The observed decrease in the rate of decrease in total number of calves lost before weaning with increase in body depth across parities can be explained by variations in nutrient requirements of cows in different parities. Cows have biological priority for nutrients with maintenance coming first, followed by own growth, lactation, fetal growth, reserves then breeding (Short *et al*., 1990). Since first calvers will still be growing, they compete with their foetuses for available nutrients for their growth and maintenance during pregnancy. Pregnant young cows with deeper bodies, hence long passage rates, large body and gut capacity, are capable of consuming large amounts of dry matter and digest thoroughly. That is, they can meet their nutritional requirements as well as for the foetus. Pregnant young cows with shallow bodies, hence short passage rates, small body and gut capacity, may struggle to consume amounts of dry matter enough to meet their high nutritional requirements resulting in still births or abortions. Younger cows have more critical nutritional needs (Morley, 1978), which could explain why the effect of body depth on incidence of still births and abortions is more pronounced in early parities.

The finding that body depth influence the incidence of abortion and still births but not mortality of calves from birth to weaning shows that nutritional requirements of Nguni cows during pregnancy are more critical than during lactation. The finding that production environment did not influence the incidence of lost pregnancy and still birth in cows was unexpected. Semi-arid areas are characterised by erratic rainfall, predominated by aloes, thorn bush, some hardwood and the areas are prone to droughts (Whelan, 2001). Cows in semi-arid areas expected to be more likely to abort or have still births due to lack of adequate nutrients. Semi-arid areas are characterised by bushes, woodlands and grasslands (Morgenthal *et al.*, 2006). Nguni cows kept in sub-humid areas are expected to be less likely to abort or have still births due to relatively adequate nutrients. Since cows with deeper bodies are capable of consuming large amounts of dry matter and digest thoroughly, the finding that cows in the semi-arid regions had deeper bodies than those in sub-humid areas could be the reason why production environment did not influence the incidence of lost pregnancy and still birth in cows. Survival of Nguni calves from birth to weaning is influenced by the production environment as shown by the observed significant odds ratio estimates for the effect of production environment on death of calves from birth to weaning. The finding that cows in semi-arid areas were more likely to lose calves from birth to weaning than those in sub-humid areas could be because of large temperature fluctuations. Although there is limited, if any, scientific knowledge on the effect of climatic conditions on mortality in Nguni calves in communal production, extremely high temperatures have been associated with an increased risk of beef calf mortality in general (Moyo, 1996; Mapekula, 2009).

6.5 Conclusions

Production environment affected body depth, flank circumference, heart girth and navel height, calving interval and mortality of calves from birth to weaning. Cows raised in semi-arid areas were likely to have longer calving intervals (more than one year) and lose calves during the period between calving and weaning. Body depth had a significant influence on incidence of still births and abortions but not mortality of calves from birth to weaning. As body depth increased, total number of calves lost by a cow decreased linearly. The rate of decrease in number of calves lost by a cow as body depth increased decreased with increase in parity.

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Chapter 7: Factor analysis of linear traits and their relationship with fertility traits in Nguni cows

Abstract

The objective of the study was to assess the dimensionality of six linear traits (body stature, body length, heart girth, navel height, body depth and flank circumference) in Nguni cows using factor analysis and indicate the relationship between the extracted latent variables and calving interval and age at first calving. The traits were measured between December 2012 and November 2013 on 1559 Nguni cows kept under thornveld, succulent karoo, grassland and bushveld vegetation types. Low partial correlations (-0.04 to 0.51), high Kaiser statistic for sampling adequacy (MSA) scores and significance of the Bartlett sphericity test ($p<0.01$) showed that there were correlations between the linear traits and the data were suitable for factor analysis. Two factors had eigenvalues greater than one. Factor 1 included body depth, flank circumference and heart girth. Factor 2 included body length, body stature and navel height. Calving interval and age at first calving decreased linearly with increase of factor 1. There was a quadratic increase in age at first calving as factor 2 increased ($P<0.05$). It was concluded that the linear type traits under study can be grouped into two distinct factors, one linked to body capacity and the other to the frame size of the cow.

Keywords: Factor analysis, linear traits, body capacity, frame size

7.1 Introduction

Linear type traits are rapidly becoming popular in both beef and dairy production due to their correlations with production and fertility traits. Focus has been put on exploration on the sources of variation of individual linear traits and their relationship with production and fertility traits. Production environment has been the major source of morphological differences within breeds (Mohammed-Saleem, 1995). Traits such as body depth, heart girth circumference and body stature influence culling decisions in dairy and beef herds (Larroque and Ducrocq, 2001; Toghiani, 2011). Linear traits are also widely used for early indirect selection of heifers (Forabosco *et al*., 2004).

The Nguni cattle are recognized in Southern Africa and is the largest population in the South African beef industry totalling 35 % of the beef cattle (Scholtz *et al.,* 2008). The breed is becoming popular because of its adaptation to the local harsh environmental conditions and its multiple colours. One of the most recognised adaptive traits of Nguni cattle is the small frame size beneficing small maintenance requirements. Presently, frame size is one of the most important traits for cows kept on rangelands. Small-framed animals have low nutrient requirements (Strydom *et al*., 2001). Nguni cattle are also highly fertile, are adapted to utilizing highly fibrous feeds and are tolerant to heavy nematode and tick loads (Mapiye *et al.*, 2009). The Nguni Society of South Africa, for example, encourages farmers to put emphasis on fertility which is the major determinant of the profitability of any cow-calf beef enterprise. Linear type traits such body depth, flank circumference, heart girth , body stature, navel height and body length are significant predictors of fertility in Nguni cows under extensive conditions (Chapter 5 and 6). Nguni farmers are trained to select fertile heifers and cows through visual appraisal for conformation traits.

One of the main challenges of using linear type traits in selection programmes is the high number of linear traits that are involved and the high correlations among them. Large correlations ranging from 0.40 to 0.81 have been reported among body linear traits such as depth, body stature, body length and flank circumference in beef and dairy cows (Mantovani *et al*., 2010; Toghiani, 2011; Mazza *et al*., 2013). The strong correlations between most of the linear type traits suggest that there is redundancy and, thus some of these traits can be removed from possible linear type traits classification schemes. Given the apparent redundancy between the linear type traits, it is likely that all the linear traits which are considered during selection of cows do not really measure different constructs. There is, therefore, need to combine these linear traits into a smaller number of variables that describe fertility.

Identifying dependencies between linear type traits using factor analysis helps reduce possible redundancy and/or reduce chances of overestimation of target traits during indirect selection using linear type traits. After grouping them into factors, association between the linear traits and other traits of economic importance can be easily analysed without redundancy and collinearity. Factor analysis reduces the number of traits to be considered in a selection programme, thereby lowering costs, labour and time needed for data collection and analyses. Little, if any, scientific research has been conducted to reduce the observed linear type traits in small-framed Nguni cows. The objective of the current study was to assess the reduction in dimensionality of six linear traits and determine the relationships between the extracted factors and fertility of Nguni cows. The hypothesis tested was that a relationship between the linear traits and their underlying latent construct(s) exists.

7.2 Materials and methods

7.2.1 Study site

The study site was described in section 5.2.1.

7.2.2 Data collection

Data from section 5.2.2 was used. Since scales of measurements of the linear traits were different, each trait was scored on a scale of 1 to 9, inclusive, according to extremes of the direct measurements for analysis purposes. For example, for body depth, a score of 1 meant the cow was among those with shallowest bodies and a score of 9 meant the cow was among those with deepest bodies in the sample.

7.2.3 Statistical analyses

Six linear type traits were included using the correlation matrix between the traits to ensure that all traits were standardized in the analysis (Vucasinovick *et al.*, 1997). The matrix of partial correlations, Kaiser statistic for sampling adequacy (MSA) and Bartlett's sphericity test were used to determine the degree of interrelations between variables and adequacy for use in factor analysis. Factors were chosen based on Kaiser's eigenvalue rule which states than only factors with eigenvalues greater than one are considered and Scree test (Cattell, 1966). The point where the graph begins to become horizontal was considered indicative of the maximum number of factors to be extracted (Hair, 2009). Factors were rotated using varimax rotation. The factor weights of greater than 0.58 were considered to indicate a significant correlation between traits and factors. The statistical analyses were carried out using PROC FACTOR (SAS, 2008) using the Maximum Likelihood method to reduce the dimensionality and reduce the information in a group of p original variables Z1, Z2, ...Zp, to a new group of variables Y1 (*F1*), Y2 (*F2*), ... , Yp (*Fp*). The effects of vegetation type and parity of cow on extracted factors was analysed using the General Linear Model procedures (SAS, 2008). Days from last calving and age of cow at classification were fitted as covariates. The DLC, a good indicator of the reproductive status in Nguni cows, was used to adjust for the reproductive status of the cows at classification. The model used was:

$$[(X- \bar{X})_{n1} + (X- \bar{X})_{n2} + \ldots (X- \bar{X})_{np})]_{ijkl} = \mu + P_i + V_j + \beta_1 (D) + \beta_2 (A) + E_{ijk}$$

Where:

n = observations of the p common factor scores;

p = common factor scores;

μ = population mean common to all observations;

P_i = effect of the i^{th} parity of cow;

V_j = effect of the j^{th} vegetation type;

A = age of cow at classification;

D = Days from last calving;

β_1 = partial linear regression coefficients of the dependent variables on covariate Days from last calving;

β_2 = partial linear regression coefficients of the dependent variables on covariate age of cow at classification;

E_{ijk} = residual error ~ N $(0; I\sigma^2)$.

The PROC REG (SAS, 2008) was used to test whether the relationships between AFC and CI and extracted factors were linear, quadratic or exponential.

7.3 Results

The mean values and descriptions of the ranges for each trait are shown in Table 7.1. The means of linear type scores varied between 6.6 for body depth and 4.9 for body stature and navel height. All traits had a Kaiser statistic for sampling adequacy (MSA) score greater than 0.50. Most of the partial correlation estimates were low to relatively low (Table 7.2).

The Bartlett sphericity test showed that there were correlations between the linear traits ($P < 0.01$). The eigenvalues had estimates between 0.22 and 2.71, but only two had estimates above one. The two factors with eigenvalues above one had common variance for linear type traits of 45 % and 24 % (Table 7.3). Figure 7.1 shows the relationship between number of factors and their respective eigenvalues from the Scree test. The Scree test indicated the extraction of three factors, one more than those indicated with a critical eigenvalue greater than one.

The factor weights varied from 0.40 to 0.89 for Factor 1 for body stature and flank circumference respectively (Table 7.4). Most communality estimates were high, especially for navel height, flank circumference and body stature. Navel height had the highest communality (0.72). High and significant (> 0.55) factor weights in factor 1 were for traits related to body capacity of the cows. Consequently, the factor was called body capacity (Table 7.5). The traits with higher and significant weights (> 0.55) in Factor 2 were related to the frame size of the cow. In general, two well defined factors were formed (Figure 7.2). Factor 1 had a

Table 7.1: Description and mean values (± SD) of linear type traits in Nguni cows

Trait	Abbreviation	*Score		Mean ± SD
		1	9	
Body depth (cm)	BD	55	130	6.6 ± 1.05
Body stature (cm)	BS	112	142	4.9 ± 1.41
Body length (cm)	BL	89	200	5.3 ± 1.00
Flank circumference (cm)	FC	116	212	6.4 ± 1.10
Heart girth (cm)	HG	117	199	5.6 ± 1.03
Navel height (cm)	NH	40	61	4.9 ± 1.46

*Each trait was scored on a scale of 1 to 9, inclusive, according to extremes of the direct measurements.

Table 7.2: Measurement of sample adequacy (MSA) and partial correlations# between linear type traits

	BD	BS	BL	FC	HG	NH
BD	0.70					
BS	0.01	0.56				
BL	0.49*	0.13	0.62			
FC	0.48*	0.15	-0.09	0.70		
HG	0.06	0.25	-0.04	0.50*	0.75	
NH	-0.23	0.51*	0.10	-0.11	-0.12	0.51

#Measure of sample adequacy (MSA) on the diagonal and partial correlations off diagonal; BD = body depth; BS = body stature; BL = body length; FC = flank circumference; HG = heart girth; NH = navel height.

Significant partial correlations (> 0.47) are flagged by an *.

Table 7.3: Eigenvalues, common variance and accumulated proportion of factors

Factor	Eigenvalue	Common proportion (%)	Accumulated proportion (%)
1	2.71	45.15	45.15
2	1.44	23.96	69.10
3	0.90	15.00	84.11
4	0.37	6.23	90.34
5	0.36	5.92	96.26
6	0.22	3.74	100.00

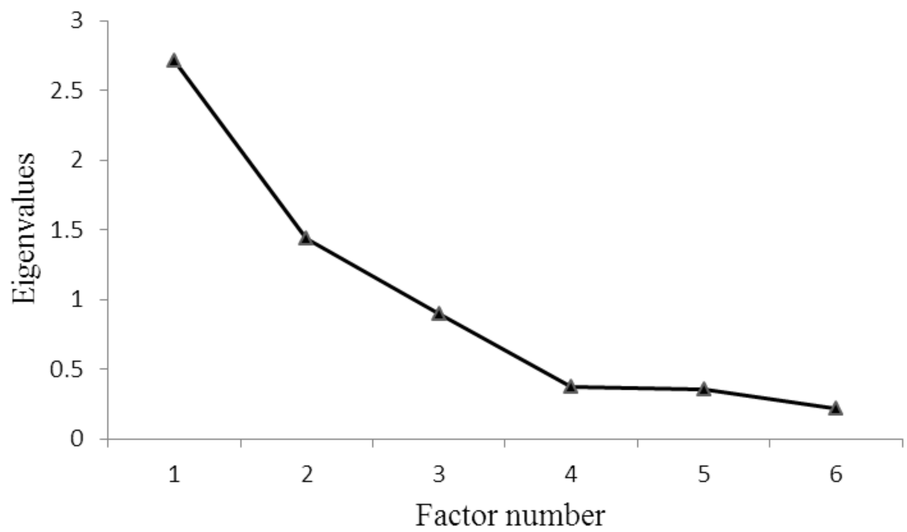

Figure 7.1: Relationship between number of factors and their respective eigenvalues from the Scree test

Table 7.4: Estimates of factor weights for linear type traits using varimax rotation

Trait	Factor 1	Factor 2	Communality
BD	0.86*	-0.14	0.75
BS	0.40	0.79*	0.79
BL	0.51	0.84*	0.32
FC	0.89*	-0.05	0.79
HG	0.81*	0.05	0.66
NH	-0.32	0.85*	0.83

BD = body depth; BS = body stature; BL = body length; FC = flank circumference; HG = heart girth; NH = navel height.

*Factor weights equal to or greater than 0.58 were significant.

Table 7.5: Effect of vegetation type on extracted factors in Nguni cows

Parameter	Factor 1	Factor 2
Name	Body capacity (BD; FC; HG)	Frame size (BL; BS; NH)
Characterisation of the factor	Cows with deep bodies, wide flanks and heart girths	Short cows with navels near the ground
Vegetation type		
Grassland	6.1 ± 0.05^{a}	5.1 ± 0.06^{b}
Succulent karoo	6.5 ± 0.08^{b}	4.7 ± 0.09^{a}
Thornveld	6.1 ± 0.06^{a}	4.7 ± 0.07^{a}
Bushveld	6.5 ± 0.05^{b}	5.1 ± 0.07^{b}

Values of each parameter in a column with different superscript differ significantly (P<0.05).

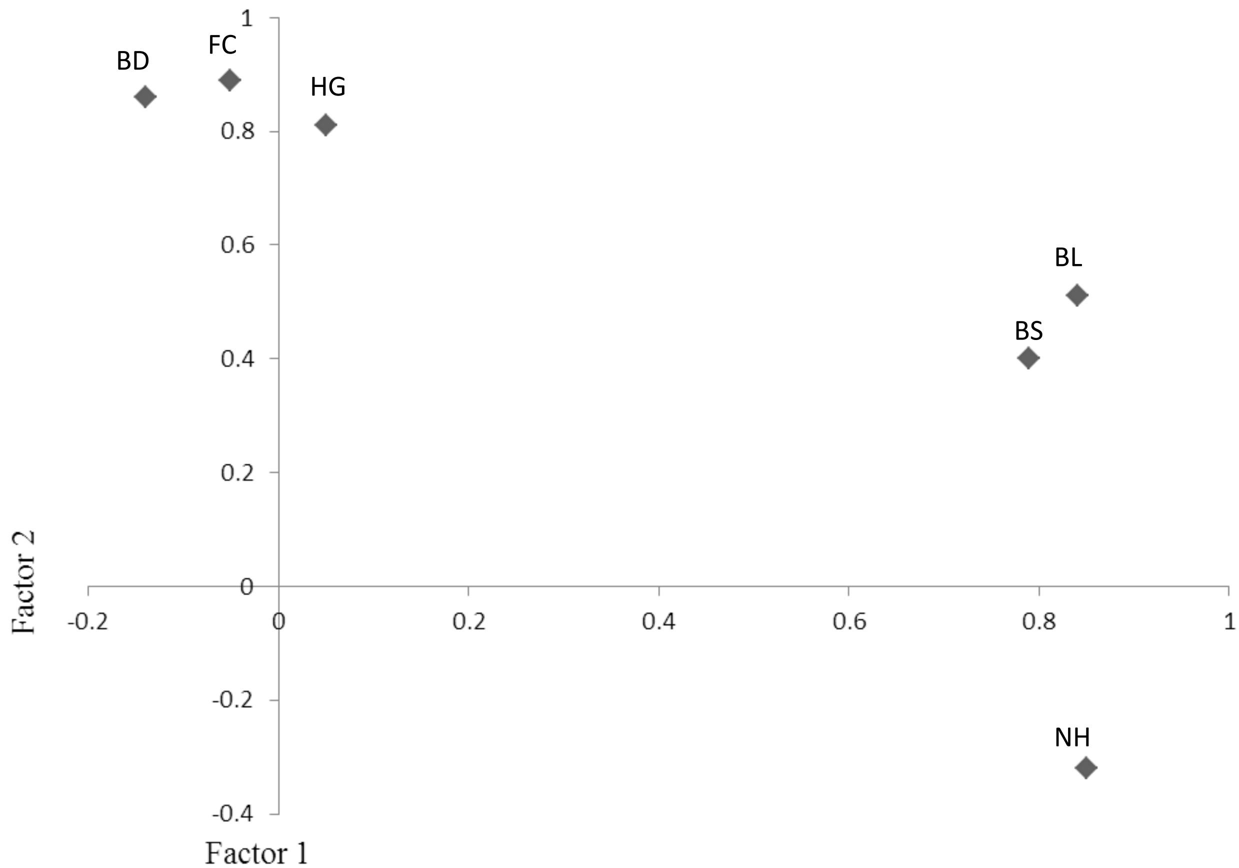

Figure 7.2: Extracted factors after varimax rotation. BD = body depth; FC = flank circumference; HG = heart girth; BL = body length; BS = body stature; NH = navel height.

common variance of 2.7 and Factor 2 had a common variance of 1.4, totalling 4.1 common variance between the traits. Cows kept under succulent karoo had the highest values for factor 1 and smallest values for factor 2 ($P < 0.01$) (Table 7.5). Factor 1 increased with increase in parity of cow (Table 7.6). Relationships between extracted factors and fertility traits are shown in Table 7.7. The CI and AFC decreased linearly with increase in factor 1 ($P < 0.05$). Cows with deep bodies, wide flanks and heart girths were associated with short CI and early age at first calving. Factor 2 had no significant relationship with CI. There was a quadratic increase in AFC as Factor 2 increased ($P < 0.05$). Long and tall cows with navels near the ground had late age at first calving.

7.4 Discussion

Standard deviations for linear traits agree with those found for linear type traits in beef cattle in Chianina beef cattle (Forabosco *et al*., 2004). Linear type classification can be an important tool in beef breeding as it can complement use of records which can be complicated and requires expensive labour and equipment. Reproductive potential of heifers can also be determined at early stages of life basing on their morphologic traits. Making selection and culling decisions basing on visual appraisal can be easier, faster and cheaper for farmers compared to use of records. There is a high number of linear traits which can be used to determine the morphology of cows and there is high degree of correlations between these traits (Brotherstone, 1994). Reducing dimensionality of linear traits through factor analysis can reduce chances of over and/or underestimation of the reproductive potential of cows during indirect selection. The finding that all the linear traits had Kaiser statistic for sampling adequacy (MSA) scores higher

Table 7.6: Effect of parity of cow on extracted factors in Nguni cows

Parity	Factor 1	Factor 2
3	6.2 ± 0.07^{a}	4.9 ± 0.08
4	6.2 ± 0.08^{a}	5.0 ± 0.01
5	6.5 ± 0.07^{b}	5.0 ± 0.09
6	6.7 ± 0.08^{c}	4.9 ± 0.09
7	7.0 ± 0.10^{d}	5.0 ± 0.12
≥8	6.7 ± 0.08^{c}	5.1 ± 0.10

^{abc}*Values of each parameter in a column with different superscript differ significantly (P<0.05).*

Table 7.7: Regression coefficients (±SE) of extracted factors on calving interval (CI) and age at first calving (AFC) in Nguni cows

Parameter	Factor 1	Factor 2
Name	Body capacity (BD; FC; HG)	Frame size (BL; BS; NH)
Linear		
CI ± SE	-13.8 ± 2.44**	-1.6 ± 2.17^{ns}
AFC ± SE	-0.8 ± 0.23**	0.1 ± 0.20^{ns}
Quadratic		
CI ± SE	-4.1 ± 1.16**	1.2 ± 1.14^{ns}
AFC ± SE	-0.35 ± 0.11**	0.24 ± 0.11*

BD = body depth; BS = body stature; BL = body length; FC = flank circumference; HG = heart girth; NH = navel height.

**P < 0.01; *P < 0.05.; ^{ns}P> 0.05.

than 0.50 and communality values greater than 0.05 show that there were correlations in the data set that were appropriate for factor analysis. Traits with MSA scores equal or lower than 0.50 and/or communality values below 0.05 are not acceptable for factor analysis (Hair, 2009). The suitability of the data for factor analysis and existence of true factors was further supported by the existence of relatively low estimates of partial correlations between linear traits and significant Bartlett sphericity test. Similar values of partial correlations and MSA were reported between linear traits in Holstein cows (Kern *et al*., 2014).

The observed contradiction that the Scree test pointed to the extraction of three factors, whilst only two factors had eigenvalues greater than one which is critical value according to Cattell (1966) was unexpected, though not strange. A similar situation was observed during factor analysis of linear traits in Kankrej cows (Pundir *et al*., 2011). It is common to have situations where the Scree test designates two to three factors more than factors designated by the Kaiser's eigenvalue greater than one rule (Hair, 2009). The Scree test is subjective, due to lack of objectivity in defining the cutoff point between the important and trivial factors (Cattell, 1966). Thus two factors were retained based on the rule that the Kaiser's eigenvalue was greater than one. The Scree test is not affected by number of variables, whilst Kaiser's eigenvalue rule can be affected by number of variables (Ledesma and Valero-Mora, 2007). A few variables were available for the current study. As such, both the Scree test and Kaiser's eigenvalue greater than one rule were used to complement each other.

Our findings that two factors were extracted agree with Parés-Casanova and Mwaanga (2013) who extracted two factors describing the conformation in Tonga cows in Zambia. Pundir *et al*.

(2011) identified three factors with eigenvalues greater than one in Kankrej cows. Differences in the number of extracted factors could be due to differences in number of variables, structure of populations and animal age groups used. Factor 1 was comprised of body depth, flank circumference and heart girth which represent body capacity of the cow. Factor 2 was comprised of navel height, body stature and body length which represent frame size of the cow. The finding that factor weights of flank circumference, body depth and heart girth did not differ shows that they equally represent body capacity of the cows (Factor 1). Nutt *et al*. (1980) reported that body depth and flank circumference of a cow are strong indicators of its body and rumen capacity. The body stature, navel height and body length factor weight values were close to each other, showing that all the three traits had a high correlation with Factor 2. As shown by high communality estimates for all traits except body length, it can be inferred that shared variation between the linear traits could be effectively explained.

The variation of Factors 1 and 2 with vegetation type might be due to natural selection favouring a particular shape and size for better adaptability to specific environments. The Succulent karoo is characterised by low vegetation index and pastures of poor nutritional value (Bosing *et al*., 2014). Cows in succulent karoo may have developed deep bodies, wide chests and flanks hence large rumen capacities to be able to consume forage rapidly to meet their nutrient requirements. Large body capacities facilitate efficient use of low quality forage due to potentially longer passage rates and consequently more thorough digestion. They might also have developed small body frames so as to lower their maintenance requirements since, in the succulent karoo, pastures are of poor nutritional value.

The observation that CI and AFC decreased as Factor 1 increased indicates that large body capacities are required for optimum fertility for cows raised under natural. When including the traits of Factor 1 in selection decisions, cows are expected to have deep bodies, wide flanks and heart girths so as to optimise body capacity. Cows with large body capacities are more likely to meet their nutritional requirements during pregnancy when fed on natural pastures and, thus have shortened lactation anoestrous periods and consequently short calving intervals. In heifers, large body capacities results to inadequate feed consumption which expedites pubertal development and increases conception rate (Diskin *et al*., 2003). The observation that AFC increased as Factor 1 increased indicates that small body frames are required for optimum fertility for cows raised under natural pastures of poor nutrition. When Factor 2 is used in selection, the cows should be small-framed. Small-framed cows have lower maintenance requirements than large-framed cows hence they can easily meet their nutrient requirements for optimal reproductive efficiency under rangeland conditions.

7.5 Conclusions

The dimensionality of the group of linear type traits studied was reduced, forming two distinct factors, one linked to body capacity and the other to the frame size of the cow. Factor 1, which is linked to body capacity, had a negative relationship with calving interval and AFC. Factor 2, which is linked to frame size, had a positive relationship with AFC but not calving interval. Selection of factor 1, which included the traits body depth, flank circumference and heart girth, could contribute to the improvement of calving interval and AFC in Nguni cows.

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Chapter 8: General discussion, Conclusions and Recommendations

6.1 General discussion

The broad objective of the study was to determine the relationship between linear type and fertility traits in Nguni cows. The main hypothesis tested was that linear type traits are closely related to fertility of Nguni cows. The hypothesis was formulated based on the previous findings in dairy cows where linear traits have been successfully used for indirect selection for fertility (Berry *et al*., 2004; Larroque and Ducrocq, 2001). Although Nguni farmers use linear traits when selecting breeding cows, there has been no scientific evidence on the relationship between the linear traits and fertility in small-framed beef cows. Selection of replacement heifers is key to success of any beef enterprise as they are the source of new genetics for the herd. Accurate selection for expressed fertility in heifers is a challenge due the lengthy time interval required to determine fertility traits such as calving interval, age at first calving and longevity. Determination of the relationships between linear traits and fertility in heifers and cows can help guide selection of heifers towards early puberty, short calving intervals and longer reproductive life among other fertility traits. In addition to pedigree information, linear traits can be measured and scored from yearling age heifers prior to breeding as part of the heifer selection program. To come up with an adoptable breeding goal for Nguni cattle producers, it is important to consider their perceptions because they have unique insight into what traits are important for the cows in their herds.

The hypothesis tested in Chapter 3 was that trait preferences of Nguni cattle owners located in semi-arid and sub-humid production environments were different. Traditionally, breeding goals for Nguni cattle producers have been targeting broadly defined group of Nguni farmers in sub-Saharan Africa without considering sub groups of producers such as Nguni cattle owners from different environments within the sub-Saharan Africa. The results confirmed the hypothesis, production environment, i.e. sub-humid or semi-arid, had most influence on Nguni farmers' traits preferences when selecting breeding cows. The difference in trait preferences could be because different production environments differ in exhibiting various stress factors, such as water shortages and temperature extremes and, thus, farmers select for different traits to counter the constraints. Farmers in semi-arid areas mostly preferred traits such as body condition score and mothering ability, which reflect adaption to harsh conditions is most likely because they will be trying to counter for frequent draughts and heat stress experienced in semi-arid areas. Despite the finding that fertility traits (calving interval and age at first calving) were found to be highly ranked, fertility problems such as extended calving intervals (2 years in sub-humid areas and 3 years semi-arid), abortions and weak calves were reported by farmers. This could reflect the difficulty in direct selection for fertility and, thus showing the need to introduce easier and effective selection strategies. The odds of farmers preferring linear traits were generally low in both semi-arid and sub-humid production environments, perhaps because farmers are not well informed of the ease and benefits of selecting for such traits. Having realized that, despite their potential usefulness, linear traits were lowly preferred by farmers during selection of breeding cows, it was necessary to investigate the relationship between the linear traits and fertility of cows under different production systems before encouraging farmers to indirectly select for fertility using linear traits.

Chapter 4 was an assessment of the sources of variation of linear traits in Nguni cows across different ecotypes. The hypothesis tested was that ecotype of cow, parity of cow, season of measurement affects body depth, body stature, body length, flank circumference, heart girth and navel height in Nguni cows. The tested hypothesis was true for the effect of ecotype of the cow, season of measurement and parity of cow on body depth, flank circumference and heart girth. Cows of the Venda ecotype were found to have the deepest bodies, widest chests and flanks which could be an adaption to their habitat bioregion. The Venda ecotype is concentrated in areas predominated by semi-arid basins characterised by species unpalatable to domestic livestock, extremely high temperatures and erratic rainfall (Bester *et al*., 2003). Deep bodies and wider flanks, which are positively correlated to gut capacity in cows (Hansen *et al*., 1999), allow the cows to use low quality forage efficiently due to potentially longer passage rates and consequently more thorough digestion. This helps the cows maintain their body condition during times of low pasture quality and quantity. This could be the reason why flank circumference and heart girth of cows of the Venda ecotype did not vary with season.

In Chapter 5 the hypothesis tested was that there was a negative linear relationship between linear type traits and fertility (calving interval and age at first calving) of Nguni cows. The linear traits can be used as early predictors of calving interval and age at first calving once their relationship has been ascertained. It was observed that flank circumference, body depth, stature, body length and navel height are all fertility indicators in Nguni cows. Small-frame, wide flanks, wide heart girths, deep and long bodies were indicators of short calving interval and age at first calving. The relationship between body depth and fertility concurred with the hypothesis. Calving interval and age at first calving decreased linearly as body depth increased (b = -2.1 and

-0.2, respectively). The relationship between flank circumference and heart girth and fertility did not concur with the hypothesis. There was a quadratic decrease in calving interval as flank circumference and heart girth increased (b = -0.02 and -0.03; respectively). Age at first calving also decreased quadratically with increase in flank circumference and heart girth (b = -0.002 and -0.004; respectively) Thus, selection for body depth, stature, flank circumference and body length leads to increased fertility as measured by calving interval and age at first calving. For this reason the Nguni breeders association should encourage Nguni cattle producers to continue collecting type traits information from all the cows registered at the National Herd Book. Chapter 5 concentrated on fertility traits commonly used in commercial Nguni production. Nguni cattle are also becoming popular among communal farmers and, thus, there is need to explore on the relationship between the linear traits and fertility traits vital in communal beef production such as mothering ability and fetal loss through still births and abortions.

In Chapter 6, the relationship between linear traits and fertility traits of Nguni cows kept under communal rangelands was determined. The hypothesis tested was that there was a negative relationship between linear type traits and fertility (incidence of abortion; incidence of still births; mothering ability) in Nguni cows kept under communal rangelands. The hypothesis was true for the relationship between body depth and incidence of abortion and incidence of still births. The findings in Chapter 6 complement findings of Chapter 5 that linear traits affect fertility in Nguni cows. In chapter 6, it was body depth, however, that influenced fertility traits such as the incidence of still births and abortions in cows but not mothering ability as measured by mortality of calves from birth to weaning. For each unit increase in body depth, the odds of a cow aborting decreased by 1.12 and the odds of a cow having still birth decreased by 1.15. Body depth, indicating body capacity, is vital for fetal development and growth (Wu *et al*., 2013). During pregnancy, as the foetus is growing in the uterus it fills a large portion of the cow's body cavity, thus displacing rumen capacity. This results in reduced forage intake due to restricted rumen capacity. Reduced forage intake during pregnancy impairs energy balance which results in poor embryonic growth, impaired immune function hence susceptibility to uterine infections and, consequently, increased early embryonic mortality. Cows with deeper bodies tend to have sufficient body cavity capacity for forage intake to meet nutritional requirements during pregnancy and, thus, are less likely to abort or have still births. Farmers should select on linear traits to improve fertility of Nguni cows. One of challenges that could be faced by Nguni cattle producers in using linear type traits in selection programs is redundancy due to the high number of linear traits involved and high correlations between them. It is likely that all the linear traits which are considered during selection of cows do not really measure different constructs. For simplicity, there is need to determine a small number of factors, based on the inter-related linear traits, which describe more general aspects of the cow conformation (artificial variables).

In Chapter 7, the dimensionality of the six linear traits in Nguni cows was reduced using factor analysis. The hypothesis tested was that a relationship between the linear traits and their underlying latent construct(s) exists. The results confirmed the hypothesis. Two factors were extracted from the six linear traits. Factor 1 was comprised of body depth, flank circumference and heart girth, which are representative of body capacity of the cow and thus, one of the three can be used to select for increased body capacity in cows. Of the three linear traits representative of body capacity (body depth, flank circumference and heart girth), flank circumference had the highest factor weight reflecting that it is more representative of Factor 1. That implies that flack circumference should be given first preference as a trait representative of body capacity. Factor 2, which encompassed navel height, body stature and body length, was representative of frame size of the cow.

6.2 Conclusions

Famers' preferences for cow traits differed with production environment. Famers in sub-humid areas perceived calving interval and age at first calving as the most important traits to consider when selecting Nguni cows whilst farmers in semi-arid areas preferred age of the cow and BCS. Calving interval and age at first calving of Nguni cows varied with vegetation type and climatic conditions. Farmers perceived that long calving intervals and late calving of Nguni cows in semi-arid areas are caused by high prevalence of diseases, low bull to cow ratio and poor nutrition. Linear traits of Nguni cows vary with vegetation type, season and parity. Cows raised on the succulent karoo rangelands had shortest CI, calved earliest, deepest bodies, widest chests and flanks. The body depth had negative linear relationship with both CI and AFC. Flank circumference and heart girth circumference had negative quadratic relationships with CI and AFC. Small framed cows with deep bodies had short calving intervals, calved early and were less likely to abort or have still births. Linear traits under study can be grouped into two distinct factors, one linked to body capacity (body depth, flank circumference and heart girth) and the other to the frame size (navel height, body stature and body length) of the cow. It was concluded that body depth, navel height, body stature, flank circumference, heart girth and body length were all significant predictors of fertility in Nguni cows under extensive conditions.

6.3 Recommendations and further research

To maximise reproductive efficiency, it is recommended that body capacity and frame size be considered as traits of economic importance and be included, in addition to the use of records to directly select for reproductive traits such as calving interval and age at first calving, in Nguni cow fertility improvement programmes. Limited information on the use of linear trait as predictors of fertility in Nguni cows could be the reason why farmers barely keep records of the traits. Now that the relationship between linear traits and fertility traits in Nguni cows have been ascertained, Nguni cattle farmers and breeders should keep records on linear type traits such as body depth, body stature, body length, heart girth, navel height and flank circumference and use them for estimating breeding values of Nguni cows. When selecting replacement heifers, farmers should select for small framed heifers as indicated by stature and large body capacities as indicated by deep bodies, wide flanks or heart girths. When selecting for linear measurements, parity, season of measurement and ecotype should be given serious consideration and adjusted for. This work is a decent starting point to set up a genetic model aimed at estimating genetic parameters for linear traits of Nguni cattle. This could be a starting point to incorporating linear traits and/or visual appraisal for fertility improvement programs for beef cattle under extensive production. There is need to investigate on the modeling approach for predicting calving interval and age at first calving in heifers using linear traits.

Further research should focus on relationship between linear and fertility traits in Nguni cows at gene level. This requires further understanding. Possible study areas include:

1. Determination of genetic parameters for linear type traits in Nguni cows. Determining heritability and repeatability of type traits in Nguni cows can help determine the emphasis to

give on linear traits in predicting breeding values of cows and predict genetic progress from selection to improve the linear traits.

2. Determination of the genetic relationships between the linear traits and fertility in Nguni cows. Determining genetic correlations between linear traits and fertility traits should be done to ascertain if selection for linear traits does not result in decreased fertility.
3. Identify genes associated with linear type traits in Nguni cattle to facilitate the use of biotechnologies such as marker assisted selection (MAS) and gene assisted selection (GAS) in linear trait selection programmes
4. Determining the relationship between these linear traits and other important component traits of fertility such as longevity and stayability. Because some longevity and stayability of a cow can only be recorded after the cows have been culled, using linear traits as early predictors of such fertility traits is important for breeders.

6.4 References

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Appendix 1: Trait preferences of Nguni farmers with Nguni herds in KwaZulu-Natal Province, South Africa

Discipline of Animal and Poultry Science

College of Agriculture, Engineering and Science

School of Agricultural, Earth and Environmental Science

University of KwaZulu-Natal, Pietermaritzburg

2013

Survey questionnaire on trait preferences of Nguni farmers with Nguni herds in KwaZulu-Natal Province, South Africa.

This study aims to compare trait preferences of Nguni cattle owners located in semi-arid and sub-humid environments. It is a research project under the Discipline of Animal and Poultry Science, University of KwaZulu-Natal, Pietermaritzburg. We would like to obtain some personal and cattle breeding data from you to document your cattle breeding practices. Your input is highly valued and the information that you provide will help to improve Nguni cattle production. We request that as the principal decision-maker in your farm business please answer the questions in the survey. All information provided by you in this questionnaire will be treated as strictly confidential, and no individual farmer or farm will be identified in the study results. Your participation is voluntary and you may withdraw from the survey at any time without consequence. Your participation in this survey is highly appreciated. Thank you!

Interviewer…………………………….. Community name …………….

Respondent name……………………..

Date...…………………………………...

A. HOUSEHOLD DEMOGRAPHIC ASPECTS

1. Head of house hold

a. Sex M□ F□ b. Marital status Married□ Single□ Divorced□ Widowed□

c. Age <30□ 31-45□ 46-60□ >60□

d. Highest education level No formal education□ Grade1-7□ Grade8-12□ Tertiary□

2. Principal occupation? ....

3. Religion? Christianity□ Traditional□ Moslem□ Other (specify)…….

4. Is the head of the household resident on the farm? Yes □ No □

5. What is the size of the household?

Role	Males	Females
Adults (13+ years)		
Children (<13 years)		

6. What type of livestock species do you keep (Rank 1 as the most important species)

Class	Cattle	Goats	Sheep	Chickens	Other
Number					
Rank					

7. Is grazing communal? Yes□ No□

8. If not, what is your land tenure system? ....

B. CATTLE HERD COMPOSITION AND PERFORMANCE

1. What is the composition of your cattle herd?

Calves (less than 7 months) □…. Heifers ….□ …Steers…□ Cows □…. Oxen□…. Bulls□

2. If you have lactating cows, how many are they? ……………………………..

3. Do you milk your cows? ....

4. If yes, how many times per day? ....

5. On average, how many litres of milk do you get per cow per day? …………….

6. How did you acquire your cattle? Inherited□ Exchanged□ Bought□ Others (specify)…….

C. CATTLE FEEDING AND MANAGEMENT

1. What type of feeding system do you use?

Feeding system	Tick
Herding	
Paddock	
stalling	
Free grazing	
Other (specify)	

2. What feed do you use to supplement your cattle

Source of feed	Tick
Veld	
Pasture	
Crop residues	
Conserved feed	
Bought-in feed	
Other (specify)	

3. How do you describe the condition of your grazing lands?

Condition	Tick
Very poor, little grass (Extremely deteriorating)	
Poor, but some grass (Deteriorating)	
Fair – Reasonable amount of grass	
Good – plenty grass	
I don’t Know	

4. What is the current general body condition of your animals? Very poor□..Poor□..Good□.. Excellent□

5. How has the body conditions changed over the past 12 months? Deteriorated□.. Improved□..No change□

6. If the condition has deteriorated, what are the causes? Poor grazing□... Diseases□...Other (specify)…….

7. Do you provide supplementary feed to your cattle? Yes □... No □...

8. If yes, when do you provide supplements for you cattle?

Rainy season □ Winter □ All year round □ in times of emergency □ Other (specify) …………………..

9. How often do you provide supplementary feeding?

More than twice a day □ Once a day □ Every 2 – 4 days □ Weekly □ Forty-nightly□ Other (specify) …………………..

10. Which class of cattle do you supplement and why?

Class	Tick	Reason
Calves		
Heifers		
Steers		
Cows		
Oxen		
Bulls		

D. BREEDING AND MANAGEMENT

1. What breeds do you have?

Breed	Nguni	Bonsmara	Mixed Breed	Other………..
Number				

2. What factors do you consider when selecting cows for breeding stock? (Rank 1 as the most common factor)

Factor	tick	rank
Chest size (flank circumference		
Height (stature)		
Length		
Rumen size (depth)		
Height from the ground to the navel (navel height)		
Calving interval		
Age at first calving		
Incidence of abortion		
Incidence of still births		
Body condition		
healthy		
colour		
Good mothering ability		
Age		
Growth rate of calves		
Birth weight of calves		
Milk yield		
Other (specify)		

3. Do you have any problems with cow fertility?

Yes □… No □

4. If yes, what are they? (Tick one or more)

Abortion □ Still births □ Dystocia □ Other (specify) □

....

....

9. What are the causes of the problems, if any? (Rank 1 as the major cause)

Causes	Tick	Rank
Nutrition		
Age		
Diseases		
Other (specify)		

10. Do you have a problem of late calving? Yes □… No □

11. If yes to question 9, what are the reasons for late calving? (Rank 1 as the most important)

Reason	Rank
Disease	
Inadequate bulls	
Breed line	
Other (specify)	

12. On average, what is the calving interval of your cows?

Calving interval	Tick
One year	
Two years	
Three years	
Other (specify)	

13. When do most of your cows calve down?

Season	Tick
Rainy season	
Dry season	
Summer	
Winter	
Throughout the year	

14. Do you experience calving problems? Yes □… No □

15. If yes, what are they?

....

....

....

16. What are the causes of the problems, if any? (Rank 1 as the major cause)

Causes	Tick	Rank
Nutrition		
Age		
Diseases		
Other (specify)		

17. What is the average length of lactation period for your cows?

Lactation period	Tick
Less than six months	
Between six and 12 months	
Between 12 and 18 months	
More than 18 months	

18. How do you identify your cattle? Give names □… tag □… brand □… Other (specify)…………

Thank you very much for your valuable participation. Your contribution is greatly appreciated. If you have any further questions about this survey, please contact:

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Prof M Chimonyo (Professor, *Discipline of Livestock and Poultry Science, University of KwaZulu-Natal, Pietermaritzburg)*

Telephone: (033)260 5477; Email: chimonyo@ukzn.ac.za

DECLARATION BY THE PARTICIPANT

RESEARCH SURVEY ON TRAIT PREFERENCES OF NGUNI FARMERS WITH NGUNI HERDS IN KWAZULU-NATAL PROVINCE, SOUTH AFRICA

I……………………………………………………………………… (Full names of participant) hereby confirm that I understand the contents of this document and the nature of the research project, and I consent to participating in the research project.

I understand that I am at liberty to withdraw from the project at any time, should I so desire.

SIGNATURE OF PARTICIPANT DATE

……………………………………………………………………………………………………

END

Appendix 2 : Ethical approval

UNIVERSITY OF KWAZULU-NATAL™
INYUVESI YAKWAZULU-NATALI

POST GRADUATE OFFICE
COLLEGE OF AGRICULTURE, ENGINEERING AND SCIENCE
2013 -04- 25
PIETERMARITZBURG CAMPUS

9 April 2013

Mr Titus Jairus Zindove 211557884
School of Agriculture, Earth and Enviromental Sciences
Pietermaritzburg Campus

Dear Mr Zindove

Protocol reference number: HSS/0164/013D
Project title: Genetic improvement of fertility and linear type traits in Nguni cows

EXPEDITED APPROVAL

I wish to inform you that your application has been granted Full Approval through an expedited review process.

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number. Please note: Research data should be securely stored in the school/department for a period of 5 years.

I take this opportunity of wishing you everything of the best with your study.

Yours faithfully

....

Professor Steven Collings (Chair)

/pm

cc Supervisor: Prof Michael Chimonyo
cc Academic Leader: Professor D Jaganyi
cc School Admin.: Mrs Sibongile Ntuli

Humanities & Social Sc Research Ethics Committee
Professor S Collings (Chair)
Westville Campus, Govan Mbeki Building
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Founding Campuses: Edgewood Howard College Medical School Pietermaritzburg Westville

INSPIRING GREATNESS

Appendix 3: Recording sheet for linear traits on commercial Nguni cows

Farm name…………………………………… Location………………………………………….

Date…………………………

Animal Identification	Ecotype	BCS	Breed score	Body Depth (cm)	Height (stature) (cm)	Body length (cm)	Flank circum (cm)	Heart girth (cm)	Sheath (cm)

Appendix 4: Ethical approval

UNIVERSITY OF
KWAZULU-NATAL
INYUVESI
YAKWAZULU-NATALI
Research Office
Animal Ethics Research Committee
Govan Mbeki Centre, Westville Campus,
University Road, Chiltern Hills, Westville, 3629, South Africa
Telephone 27 (031) 260-2273/35 Fax (031) 260-2384
Email: animalethics@ukzn.ac.za

27 February 2013

Reference: 078/13/Animal

Mr T Zindove
School of Agricultural, Earth and
Environmental Sciences
University of KwaZulu-Natal
PIETERMARITZBURG Campus

Dear Mr Zindove

Ethical Approval of Research Projects on Animals

I have pleasure in informing you that the Animal Ethics Sub-committee of the University Ethics Committee has granted ethical approval for **2013** on the following project:

"Genetic improvement of fertility and linear type traits in Nguni cows."

Yours sincerely

THT Coetzer

Professor Theresa HT Coetzer
Chairperson: Animal Ethics Sub-committee

Cc Registrar – Prof. J Meyerowitz
Research Office – Dr N Singh
Supervisor – Prof. M Chimonyo
Head of School – Prof. A Modi
SAEES – Mrs M Manjoo

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Founding Campuses:
- Edgewood
- Howard College
- Medical School
- Pietermaritzburg
- Westville

Appendix 5: Recording sheet for linear traits on communal Nguni cows

Municipality……………………………………

Animal Identification											
Breed score											
Body Depth											
height											
Body length											
Flank circum											
Heart girth											
Sheath											
Age											
Number of calvings											
AFC (Yrs)											
DOB of current calf											
DOB of preceding calf											
Still births											
Lost pregnancies											
Calves dead before weaning											
Number of calves weaned											
Current BCS											