Phenotypic characterization of Zulu sheep: Implications for conservation and improvement

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Phenotypic characterization of Zulu sheep: Implications for conservation and improvement

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DEDICATION

To Mr and Mrs Nkosana Mavule,

Butholezwe Sibanda Mavule, Baneka Sibanda and Bongiwe Sibanda

DECLARATION

I declare that the work contained in this dissertation is my own, unless otherwise specified. It is being submitted for the degree of Master of Science in the University of Zululand. The work herein has not been submitted before for any degree or examination in any other university.

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Signed on the ________ day of __________________, 2012

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ABSTRACT

Understanding the characteristics of the Zulu sheep breed in its home tract is an essential step towards the development of a sustainable conservation and improvement programme. A survey was conducted in 11 rural areas of KwaZulu-Natal in the quest to (i) describe traditional Zulu sheep production systems, (ii) describe the morphological structure of the breed, and (iii) to quantify morphological variation among sheep populations.

Most farmers began sheep production with an initial stock size of less than four, either bought from other farmers or inherited. Sheep were mainly used as a source of food and income. Flock sizes were 39.8±7.5 on average, with each flock constituting of 3.12±0.31 rams, 21.8±5.61 ewes, 5.0±0.87 yearlings and 9.9±2.05 lambs. About 28.0% of the flocks occurred in isolation while 43.7% interacted with two or fewer neighbouring flocks. There was about 7.4% decrease in sheep numbers in the past 5 years. Drought and diseases were the major causes of sheep loss.

Principal component analysis of morphometric traits extracted two components with a total variance of 66.9% in young sheep and four components in adult sheep with a total variance of 62.1%. The first factor (PC1) in each case had high loadings for variables relating to body size, while PC2 had high association with traits reflecting body shape. PC3 had high factor loadings for head length and head width, representing head size. The use of principal components was more appropriate than the use of original correlated variables in predicting body weight of Zulu sheep.

Dark brown was the most prevalent coat colour. It occurred as either solid or mixed with white. Sheep from Nqutu measured highest in most morphometric variables whilst sheep from Empangeni measured lowest. Discriminant analysis identified rump width (RW), head width

(HW), heart girth (HG), thorax depth (TD) and tail length (TL) as the most discriminative variables in differentiating Zulu sheep populations. Two major groups were identified by cluster analysis, one formed by Empangeni, Mtubatuba and Nongoma and the other by Jozini Msinga and Eshowe populations. Estcourt and Nqutu joined these major groups as individual entities at distance with the latter being furthest. Discriminant function analysis was able to correctly classify 62.2% of individual sheep into their original populations. The high morphological variation among Zulu sheep populations, infer considerable genetic variability. Maintaining this genetic variation is important if the goal is to continue and improve the productive performance of the animals and respond to change in climate, disease or consumer preference while improving the livelihoods and food security of livestock keepers.

Key words: Production systems; Animal genetic resources; Morphological variation

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

GENERAL INTRODUCTION

1.1 Background

Domestic animals have been part of the living world since the beginning of human history (Epstein, 1971). Over the years they have developed unique combinations of traits through adaptation to best respond to specific pressures presented by different ecological and cultural environments (Köhler-Rollefson, 2000; Hall, 2004). This has brought about a great genetic diversity which has given birth to many different breeds of domestic animals. These breeds contribute greatly to the world's genetic diversity, and are particularly well adapted to specific local conditions where exotic breeds would not survive. Unfortunately, the natural variability, procured over thousands of years, is becoming increasingly endangered (Rege and Lipner, 1992; Hall, 2004; Kunene and Fossey, 2006; FAO, 2007; Kosgey *et al.*, 2008).

Rege and Lipner (1992) highlighted that high human population growth rate and the desire for higher living standards, combined, are pressuring local livestock keepers to increase production. Hence the need to concentrate on specialised, narrow ranged genotypes, suitable for current production and market conditions (Rege and Lipner, 1992; FAO, 2007). Farmers have thus indiscriminately crossbred their flocks with, and/or replaced them with less adapted exotic breeds. This is seriously threatening the existence of indigenous populations. In addition, crossbreeding among indigenous breeds due to increased intermingling, through social exchanges of previously isolated populations and trade, and effects of drought and famine in some regions, exert additional pressures on indigenous African animal genetic resources (AnGR) (Rege and Lipner, 1992).

The FAO's Global Databank for Animal Genetic Resources has information on a total of 7616 livestock breeds (FAO, 2007), of which 20.0% are classified as at risk. Already, 14.0% of sheep breeds globally are extinct (FAO, 2007). Sixty-two breeds have become extinct during the last six years– the loss amounting to almost one breed per month. The DAD-IS (2012) indicates that these figures give a partial picture of genetic erosion. Breed inventories, and particularly surveys of population size and structure at breed level, are not complete in many parts of the world. Population data are unavailable for 36.0% of all breeds (DAD-IS, 2012). Unrecorded genetic resources are being lost before their characteristics can be studied and their potential evaluated (Rege and Lipner, 1992; FAO, 2007). This lack of data is a serious constraint to effective prioritisation and planning of breed conservation measures (FAO, 2007).

Rodero and Herrera (2000) indicated that studies are necessary to characterize, identify and differentiate breed populations. Carneiro *et al.* (2010) have put emphasis on identifying the origin and history of breeds, as well as their geographical distribution, qualities and aptitudes, phenotypic description and morphological traits. The need to characterise livestock breeds has led to the formulation of 'The Global Plan of Action for Animal Genetic Resources' by FAO which recognizes that "a good understanding of breed characteristics is necessary to guide decision-making in livestock development and breeding programmes" at local, national, regional and global levels (FAO, 2011). Research, training programmes and monitoring of trends in distribution and loss of biodiversity in the regions covered will also make use of the compiled database (Rege and Lipner, 1992). Once their potential is known, the indigenous breeds can be better utilised as part of sustainable farming systems (Kunene *et al.*, 2009)

The Zulu sheep breed, is kept mainly in the rural communities of KwaZulu-Natal. It belongs to the Nguni type of breeds together with the Pedi and Swazi sheep (Kunene *et al.*, 2009) and is one of the 17 sheep breeds known to exist in South Africa (DAGRIS, 2007). The ancestors of this breed are thought to have been brought to the east coast of South Africa between 200 and 400 AD by the Nguni people (ARC, 2001, Kruger, 2001; du Toit, 2008). The breed is small bodied with variable coat colour, but dark brown and black variations are most common (DAGRIS, 2007). Males can be horned or polled (Kunene *et al.*, 2007). Ears can be long, very short (elf) or almost non-existent (gopher) (DAGRIS, 2007; Kunene *et al.*, 2007). The breed serves as a source of meat and income to the poor rural farmers of KwaZulu-Natal (Kunene and Fossey, 2006). Ramsey *et al.* (2000) reported the excellent mothering abilities and good walking and foraging ability of Zulu sheep. Adaptation to their hot humid environment and resistance to prevalent external and gastro-intestinal parasites, tick-borne diseases is the most likely explanation for their economic importance (Ramsey *et al.*, 2000). Nevertheless, their numbers are decreasing and the breed may become extinct if no stringent measures are put in place to check its erosion (Kunene and Fossey, 2006). To allow this breed to be lost through inaction would be disrespectful to both history and posterity.

Characterization of Zulu sheep is the first essential step in formulating strategies to conserve and better utilise it. According to FAO (2007), a global strategy involves "all activities associated with identification, quantitative and qualitative description, documentation of breed populations and the natural habitats and production systems to which the breed is adapted, the aim being to obtain better knowledge of the breed, its present and potential uses for food and agriculture in defined environments, and its current state as a distinct breed".

Kunene and Fossey (2006) and Kunene *et al.* (2007) have laid the foundation for further studies on characterization of the production system and morphological structure of Zulu sheep, respectively. The authors documented body weight, heart girth, wither height, scrotal circumference, coat colour, presence of horns and ear types of Zulu sheep. Their study, however, covered few geographic locations and animals used were mainly from research institutions (i.e. University of Zululand and Makhathini Research Station), with the exception of those from KwaMthethwa, a rural production system. Thus, inherent variation among and within the existing communal sheep populations might not have been fully captured. A wide coverage of geographic area would give better representation of the situation on the ground, as far as the production environment of this breed is concerned. Head length, head width, rump length, rump width, rump height, thorax depth, shin circumference, shape of horns, orientation of horns, face profile, back profile, orientation of ears, presence or absence of wool/hair, wool hair distribution, colour of hoof and tail type which are commonly used in morphological characterization of small ruminants have not been characterised (Nsoso *et al.*, 2004; Traoré *et al.*, 2008). The incorporation of these traits gives a detailed description of the breed, and hence identify its distinctiveness (FAO, 2007). Such information is used as standard benchmarks for controlling entry and continued membership in a breeding scheme. An estimate of genetic variability within and among breed populations, a prerequisite for breed conservation programmes, can also be extrapolated from such morphological studies.

The study of Kunene *et al.* (2007) to measure variation in morphological characteristics of Zulu sheep was restricted to the use of univariate analysis, whereas the current trend in livestock classification involves the use of multivariate statistical tools (Yakubu *et al.*, 2010). Univariate analysis considers one variable at a time, separately, thus allowing substantial overlapping of results to occur. Such a technique may, therefore, not sufficiently explain how individual animals and populations differ when all measurements are considered simultaneously. With multivariate statistical techniques such as principal component analysis and canonical discriminant analysis, all variables are considered simultaneously. This approach provides better resolution in comparison of populations and in quantifying contribution of individual traits towards total variance in a population. This cannot be achieved with univariate analysis, especially if variables are correlated. Canonical discriminant analysis can separate ‘between population effect’ from ‘within population effect’ by maximizing discrimination among populations when tested against the variation within populations (Riggs, 1973). After determining the intra-population variability, the Mahalanobis distance (D^2) can be used as an indication of the difference between populations (Loos, 1993). Principal component analysis can be employed to extract factors contributing towards variation amongst individual animals based on body measurements (Shahin *et al.*, 1993; Yakubu and Ayoade, 2009; Yakubu *et al.*, 2009; Ogah, 2011). These techniques have been used to quantify genetic variability of Zulu sheep through analysis of morphometric traits.

1.2 Objectives

The objectives of this study were:

(i) to describe traditional Zulu sheep production systems, evaluate their sustainability and identify some constraints limiting their productivity;

(ii) to describe the morphological structure of the Zulu sheep breed, giving a detailed outline of contributions made by specific morphological traits towards total morphological variance of the breed;

(iii) to evaluate the use of principal components in estimating body weight of Zulu sheep; and

(iv) to quantify morphological variation among Zulu sheep populations, exploring the possibility of distinguishing sub-breeds among the Zulu sheep populations.

1.3 Outline of Thesis

Chapter 1 presents the general introduction and the objectives of this dissertation. Chapter 2 gives a comprehensive review of the relevant literature. The topics covered were the origin of sheep in South Africa; biodiversity and why it has to be conserved; phenotypic characterization of breeds; the use of multivariate techniques in morphological characterization of breeds and phenotypic characteristics of Zulu sheep. Chapter 3 is devoted to presenting a report on a field survey undertaken to describe the Zulu sheep production system and the socio-economic and cultural values of communal farmers in KwaZulu-Natal. Management practices, indigenous knowledge and constraints faced by farmers which have an impact on sheep production are also discussed. Chapter 4 is a report on the morphological structure of Zulu sheep based on principal component analysis of body measurements. Correlation coefficients among morphometric traits and the effects of sex, age and location on linear body measurements are also presented. The same chapter also gives regression formulas that were obtained to estimate body weight of Zulu sheep from linear body measurements. These are compared to those obtained using principal components. (The chapter has been accepted at Small Ruminant Research for publication). Chapter 5 presents the differentiation of Zulu populations using discriminant analysis. Frequencies of qualitative traits within studied areas are also given. (This chapter has been submitted to the South African Journal of Animal Science). Chapter 6 is a general discussion on findings of this study.

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The Global Databank for Animal Genetic Resources (AnGR) documents more than 14 017 breeds of livestock belonging to 37 domesticated species in over 181 countries (DAD-IS, 2012). This however is an underestimation as large proportions of indigenous livestock populations in developing countries are yet to be documented (FAO, 2011). Moreover, where figures on populations exist, they may not be recent updates, and may lead to erroneous inferences on current livestock biodiversity status.

Hall (2004) highlights a two-stage process which has led to the development of the enormous livestock biodiversity. “First”, he says, “there was domestication, and then there was breed differentiation”. Both stages involved genetic constitutional change and are thus both evolutionary and cultural. Through these stages, livestock populations have acquired unique adaptations in response to diverse production systems and agro-ecological environments in which they are raised. The genetic diversity that the environmentally adapted breeds embody provides the building blocks for the very successful breeding improvement programmes for specialised breeds. Moreover it presents an opportunity to respond to the present and future needs of livestock production in both developed and developing countries (FAO, 2007).

The valuable AnGRs are being lost, either to crossbreeding or breed substitution. There is urgent need for conservation measures to keep the genetic decay in check. The FAO global strategy for the management of AnGRs involves characterization and documentation of domestic animals. This has been designated as The Global Plan of Action’s Strategic Priority Area 1 and is devoted to “Characterization, Inventory and Monitoring of Trends and Associated Risks” (FAO, 2011).

In addition, FAO has developed an information system called the Domestic Animal Diversity Information System (DAD-IS), to provide countries with extensive searchable databases and guidelines for better characterization, conservation and utilization of animal genetic resources.

This chapter reviews the origin of Zulu sheep in South Africa and the importance of genetic diversity in AnGRs. A general framework on the need and methods used to conserve AnGRs is discussed. In addition, methods used in phenotypic characterization of livestock breeds and brief description of the Zulu sheep breed based on previous studies are reviewed.

2.2 The origin of Zulu sheep in South Africa

According to Kruger (2001), South Africa was occupied solely by San hunter-gatherers before the time of Christ. Epstein (1971) suggests that the domestication of animals began in the Middle East, where sheep and goats probably were the first animals to be domesticated. Early archaeological evidence suggests two centres of domestication- the north of Africa in the Sahara region and perhaps the Indus valley which had a considerably wetter climate at that time (ARC, 2001). The processes of warfare, barter and migration led to a southward movement of the animals down the length of Africa. The nomads and their animals afterwards settled in the central lake area of Africa. Kruger (2001) suggests a mixing of breeds at this stage. There was a further southward migration which may have arrived in South Africa as early as 400BC. By 200 AD the Khoi-khoi pastoralists arrived at the northern borders with early sheep breeds (Ramsey *et al.*, 2000; Kruger, 2001). The Nguni type of sheep, to which the Zulu breed belongs (ARC, 2001), migrated with the Nguni people down the east coast of Africa southwards to the areas where they are presently located (Ramsay *et al.*, 2000; Kunene *et al.*, 2007).

2.3 Genetic diversity and its importance in sheep breeds

Genetic diversity of livestock species is the result of a combination of various processes. These include domestication, migration, genetic isolation, environmental adaptation, selective breeding, introgression and admixture of subpopulations. Lacy (1997) identifies genetic diversity as both a trait of individuals and a trait of populations. Small populations lose genetic variability because of genetic drift, and inbreeding within populations can further decrease individual variability. Lower variability suppress individual fitness (Rege, 1999), resistance to disease and parasites, and flexibility in coping with environmental challenges (Rege and Lipner, 1992). Moreover, lower variation decreases mean fitness of populations, resilience, and long term adaptability (Lacy, 1997).

Sheep breeds are far from uniform (Kruger, 2001). Their differences are a result of the fact that in the thousands of years since animals were first domesticated, they have been introduced to different environments and subjected to the breeding practices of different communities and social groups (Köhler-Rollefson, 2001; Hall, 2004). A large variety of breeds have developed through adaptation to various ecological niches and the differing preferences and needs of their keepers (Hall and Ruane, 1993). Hall (2004) reports that, as breeds differentiate, divergence of phenotype can come about through natural artificial selection, genetic drift and non-genetic processes. The breeds are shaped to carry genes that enable them to cope with difficult environments, walk long distances, thrive on thorny vegetation in drought-affected areas, and resist parasites and disease attacks (Köhler-Rollefson, 2001).

However, modern livestock production relies on a few specialised breeds (Rege and Lipner, 1992; FAO, 2007). These breeds grow quickly, produce tonnes of meat, wool and milk, but rely on high quality feed and need intensive veterinary care to produce and survive (Ramsey *et al.*, 2000; FAO, 2007; Kunene *et al.*, 2009). The gene pool of improved breeds is becoming ever shallower (Köhler-Rollefson, 2001). This is due to intensive selection, artificial insemination and other breeding techniques designed to maximise production (Köhler-Rollefson, 2001; Mendelsohn, 2003; FAO, 2007). In the process, most of the diversity from these breeds has been squeezed out, and as such, herds are becoming more and more uniform (Rege and Lipner, 1992). On the other hand, indigenous livestock breeds are under threat. Breeding programmes, brought forth by both non-government organizations and governments, have fuelled the use of exotic breeds for upgrading, crossbreeding, or replacement of indigenous breeds (Köhler-Rollefson, 2001; Martyniuk, 2003; FAO, 2007). In the event of a disease outbreak, entire national herds could be wiped out suddenly, ruining the country's economy, weighing down rural communities with poverty, and leaving consumers hungry (Köhler-Rollefson, 2001). Local breeds are a source of genetic diversity needed by modern livestock production to ensure stability and continuity (Rege, 1999).

2.4 The need to conserve indigenous animal genetic resources

Many traditional sheep breeds are in danger of extinction (FAO, 2007). Several studies recognise different threats to livestock biodiversity, yet few systemically quantify these threats. The decay of livestock biodiversity is as a result of crossbreeding of local breeds with improved breeds, expansion of wildlife reserves and intensive agriculture, changes in the economy, and other factors (Henson, 1992; Rege, 1999; Köhler-Rollefson, 2001; Kruger, 2001). Already, 14.0% of sheep breeds globally are extinct (FAO, 2007), and 29.0% are thought to be endangered (FAO, 2007).

Indigenous sheep breeds may produce less meat, wool or milk than exotic breeds, however they usually fulfil multifaceted roles they are allocated to by their owners, and require lower input to produce (Kunene and Fossey, 2006). Indigenous breeds provide material that can be useful for the development of new breeds. The genetic diversity they embody enables breeders to respond to changes in production, marketing and the natural environment (Abegaz *et al.*, 2005).

Advance in functional genomics, has allowed scientists to begin to systematically screen indigenous livestock breeds for genetic traits that confer disease resistance (Baker and Gray, 2003), influence the processing of animal products, or provide special production characteristics. Disease-causing agents such as gastro-interstinal parasites and bacteria are becoming increasingly resistant to medicines such as anthelmintics and antibiotics (Köhler-Rollefson, 2001). Breeding for disease resistance has become a common trend in control of diseases (Baker and Gray, 2003). Indigenous breeds exhibit disease-resistance traits, though typically they have not been subjected to strong selection for productivity (Baker and Gray, 2003). Hence they are of importance to the livestock industries and scientists.

Marginal areas can be better utilised by minority species or locally adapted breeds. Köhler-Rollefson (2001) has indicated that, even where conditions are not extreme, extensive animal husbandry with specifically adapted breeds is more ecologically sustainable than irrigated agriculture. The death of these breeds will make it difficult to produce food in marginal areas.

Conservation of indigenous AnGRs is important, not only for the communities that keep them, but also for the future of modern agriculture. Livestock breeds can possibly be conserved only if the AnGRs are first identified and adequately documented, and if the communities which keep the animals participate fully in conservation efforts (Köhler-Rollefson, 2000).

2.5 Methods of conserving indigenous animal genetic resources

Conventional approaches to conserving indigenous animal breeds include *in-situ* and *ex-situ* conservation (Köhler-Rollefson, 2000). *In-situ* conservation is whereby breeding populations of live animals are maintained in their adaptive environment, along with appropriate management practices (Brem *et al.*, 1989; Henson, 1992).

In recent years, it has been agreed that breeds can be best conserved if maintained as part of functional production systems and in the social and ecological contexts in which they were developed and continue to develop (Köhler-Rollefson, 2001; Mendelsohn, 2003). Therefore, community-based conservation of livestock breeds is advocated.

Ex-situ conservation can either be *ex situ in vivo* or *ex situ in vitro*. The latter is when living animals are conserved outside their adaptive environment or where the breed is now normally found, whereas the former is when genetic material is conserved in an artificial environment outside the living animal. *Ex situ in vitro* usually is conservation of animal genetic material in the form of living ova, embryos or semen stored cryogenically in liquid nitrogen (Brem *et al.*, 1989; Köhler-Rollefson, 2001).

2.6 Characterization of livestock production environment

A comprehensive description of the production environment enables the use of performance data and special adaptations of breeds/populations to be rationally understood. Adaptive fitness of a breed is difficult and complex to measure directly, but can be indirectly measured by describing the factors which have affected an animal gene pool over time, and have probably maximized its adaptive fitness for that environment (FAO, 2007). Thus, a description of production environments would be crucial, where comparative adaptive fitness of specific AnGR needs to be understood.

Description of livestock production environments has abounded the literature on livestock studies in developing regions. FAO (2011) considers the characterization of the production environment to be an integral part of phenotypic characterization. The term “phenotypic characterization of AnGR” refers to the process of identifying distinct breed populations and describing their characteristics and those of their production environments. In this context, the term “production environment” is taken to include not only the “natural” environment but also management practices and the common uses to which the animals are put, as well as social and economic factors such as market orientation, niche marketing opportunities and gender issues (FAO, 2011). It is important to assess the whole range of production systems and environments where a particular breed is raised to give an indication of its range of productive and adaptive potential (FAO, 2007)

2.7 Phenotypic variability: a reflector of genetic variability

Ogah *et al.* (2011) defines phenotypic variability as the observable variation in a population, this includes both genotypic and environmental components. Genetic variability is the proportion of variation that is due to the genetic differences among individuals in a population (Pakzadeh, 2007). Humphrey (1991) asserts that if phenotypic observations are based on adequately large sample size and the physical traits measured show significant difference among population they can provide a reasonable reflection of overall genetic performance. Morphological characters have been used to detect genetic relationships of breeds in different domestic species (Jordana *et al.*, 1993; Herrera *et al.*, 1996). Genetic diversity and similarity among or within breeds has also been studied using morphostructural differences (Herrera *et al.*, 1996; Traoré *et al.*, 2008).

2.8 Application of multivariate analysis tools in phenotypic characterization of breeds

Although, univariate analysis is used in many studies, its use is most appropriate when one variable is considered at a time for several objects (Manley, 2004). To better understand the whole physical structure of the animal and spatial variation inter/ intra-populations, various morphometric traits can be recorded systematically and multivariate analytical methods employed. This allows analysis of multiple variables simultaneously (Manley, 2004). Multivariate methods are commonly applied in morphological description of animal genetic resources. For example, principal component analysis (PCA) has been used in quantifying size and shape of domestic rabbits (Yakubu and Ayoade, 2009), sheep (Salako, 2006; Traoré *et al.*, 2008) and goats and cattle (Yakubu *et al.*, 2010). Application of canonical discriminant analysis has also been reported for sheep (Traoré *et al.*, 2008; Yakubu and Akinyemi, 2010), goats (Jordana *et al.*, 1993; Capote *et al.*, 1998; Yakubu *et al.*, 2010) and poultry (Ogah *et al.*, 2011).

2.9 Phenotypic characteristics of the Zulu sheep

The Zulu sheep travelled between 200 and 400 AD with the Nguni people, their cattle and dogs from North and Central Africa to the eastern coast of South Africa (ARC, 2001). The breed, being isolated from other sheep breeds, have developed certain distinctive characteristics, portraying great phenotypic diversity. The variation is ascribed to a broad ancestral gene pool, which supplies the genes necessary for the animals' adaptation to different and sometimes challenging conditions (Ramsey *et al.*, 2000). Zulu sheep can survive and flourish where other sheep breeds fail (ARC, 2001). Kunene *et al.* (2009) reported that, the Zulu Sheep present opportunities to produce without the intensive veterinary inputs that most other sheep breeds need and has the added advantage that they have co-evolved locally.

Zulu sheep are multi-coloured breed, with colours ranging from tan, brown, dark brown, to black coat, some with white patches. The highest live weight and heart girth for mature Zulu rams are 38 kg and 80 cm, respectively, while ewes are 32 kg and 76 cm, respectively. A large percentage (44.0%) of sheep had large ears and only 7.0% had ear buds (gopher ears). Rams had larger scrotal circumference in autumn and summer (25 and 26 cm) than in winter and spring (23 cm). Kunene *et al.* (2009) highlighted the need for more traits to be measured or scored to come up with a detailed description of the breed and hence explore all the possible avenues to its exploitation. The main objective of the present study was therefore to describe the production system and morphological variations of Zulu sheep of KwaZulu-Natal, South Africa.

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CHAPTER 3

ZULU SHEEP PRODUCTION SYSTEM IN THE COMMUNAL FARMING SECTOR OF KWAZULU-NATAL, SOUTH AFRICA

(This chapter was submitted to Scientific Research and Essays)

Abstract

Understanding the production environment under which Zulu sheep are raised is an essential step towards the development of a sustainable breed conservation and improvement programme. Ninty-six farmers across 11 rural areas of KwaZulu-Natal were interviewed, through a set of structured questionnaires, to describe traditional Zulu sheep production system, evaluate its sustainability and identify some constraints limiting production. The study revealed that sheep were the least owned livestock species amongst interviewed farmers after cattle and goats. Farmers began sheep production with an initial stock of fewer than four animals, either bought from other farmers or inherited through patrilineality. Sheep flock sizes were 39.8±7.5 on average, with each flock constituting of 3.12±0.31 rams, 21.81±5.61 ewes, 4.98±0.87 yearlings and 9.92±2.05 lambs. About 28.0% of the flocks occurred in soletery while 43.7% interacted with 2 or fewer neighbouring flocks. Breeding rams were selected mainly for body size and conformation. Mating was uncontrolled in all the surveyed areas. The study revealed an estimate of 7.4% decrease in sheep flock sizes in the past 5 years. Drought and diseases were identified to be the major causes of sheep loss. Farmers accessed drugs through private drug suppliers. Animals were only sprayed and drenched when they showed a need, to control external and gastro-intestinal parasites, respectively. Sheep were used primarily as a source of meat for household consumption. Use as source of income and manure ranked second and third, respectively. Most farmers sold their sheep to other farmers. It was concluded that interventions could contribute to more effective farming and increased income if prior knowledge is obtained through collaboration with the farmers and suitable assistance is provided according to the needs of the different communities. There is a necessity to explore the possibilities of organized marketing of animals so that farmers can reap maximum benefit from their investments. The study indicated that the information obtained would assist in planning suitable conservation, improvement and extension programs for the breed.

***Key words**:* Production environment; Animal genetic resources; Socio-economic; Production systems

3.1 Introduction

The existence of the Zulu sheep breed is threatened (Kunene *et al.*, 2009). Its place is being taken up by less adapted exotic breeds, either by replacement or crossbreeding (Kunene *et al.*, 2009). The perception that indigenous livestock are less performing compared to their exotic counterparts held by most farmers might be a driving force in this change. Scholtz *et al.* (2008) points out that such a line of thinking has been receiving political backing over the years in many African countries. Thus breeding programmes put in place in Africa h been geared towards improving this presumed low productivity through crossbreeding (Köhler-Rollefson, 2001).

Many researchers have however urged that such upgrading efforts are futile due to farmers' inability to meet management requirements for crossbred offspring or their exotic parents since the imported breeds have high feed maintenance requirements (Rege and Lipner, 1992; Köhler-Rollefson, 2001). The predicament makes raising indigenous livestock, by the resource poor rural farmers, advantageous over the exotic ones in that the livestock are adapted to local conditions and will give some level of production even under adverse conditions (FAO, 2007).

Lately farmers and government have begun to realise that high productivity is not necessarily more important than the ability of livestock to survive natural calamities (Köhler-Rollefson, 2001). This enlightenment has attracted the attention of many researchers to conduct studies on characterization of indigenous animal genetic resources (Kunene and Fossey, 2006; Kosgey *et al.*, 2008; Taye *et al.*, 2010). However, appalling to note is that many rural farmers today no longer possess this valuable heritage, procured over hundreds of years through adaptation, in pure form. Moreover, production systems are being altered to suit the new upcoming types of breed that require intense care to produce and survive. Consequently knowledge and skills gained over years on the management of indigenous genetic resources is being lost to posterity without characterization and documentation.

FAO (2007) have indicated that a comprehensive description of the production environment is essential to make use of performance data and to understand the special adaptations of breeds/populations. Knowledge about characteristics of Zulu sheep is still scanty, particularly about their production environment. This would enable a better comparative understanding of the adaptive fitness and performance of the breed. Adaptive fitness of the breed can thus be characterized indirectly by describing the primary variables (criteria) which have affected an animal gene pool (breed) over time, and have probably maximized its adaptive fitness for that environment.

The current study provides a better understanding of traditional Zulu sheep production systems, to evaluate their sustainability, to identify some constraints limiting their productivity. This can be useful for policy makers and extension services to improve the productivity and sustainability of these farming systems. More importantly it provides information needed in strategizing conservation and improvement programmes of the breed.

3.2 Methods and material

3.2.1 Study area

An on-farm survey was conducted in rural communities of Empangeni and Eshowe in uThungulu District, Hlabisa, Jozini, Ingwavuma and Mtubatuba in uMkhanyakude District, Nongoma and Ulundi in Zululand Districts, Msinga and Nqutu in uMzinyathi District and a commercial farm at Estcourt in uThukela District of KwaZulu-Natal, South Africa. Fig 3.1 shows locations sampled during the survey. These areas are located between latitudes 27°7' to

29°0' S and longitudes 29°52' to 31° 59' E, with the altitude ranging from 80 to 1900 m above sea level. Annual rainfall in these areas ranges from 600 mm in the drier valley to over 1 400 mm near the coast.

3.2.2 Selection of farmers and data collection

Selection of respondents was based on farmers' possession of Zulu sheep and willingness to participate in the study. The Department of Agriculture officials in the selected areas, assisted in identifying farmers who were still in possession of Zulu sheep. Data were collected from 96 households from either the household head or the main caretaker of the sheep. During the data collection process, the participants were told the objectives of the study and how its outcomes would be of benefit to both them and their sheep breed. Interviews were done at farmers' homesteads. Farmers were interviewed individually. The interview used a set of structured questionnaires which were a slight modification of questionnaires designed by the Department of Agriculture, Forestry and Fisheries (DAFF) for livestock breed survey in South Africa (See Appendix 1). The questions were in structured form, covering various aspects of the general household characteristics and sheep rearing, breeding, feeding, housing and marketing. Data about the major crops and cropping, numbers and main uses of Zulu sheep was also recorded. Data about the constraints faced by farmers in such aspects as animal health was also gathered. In order to quantify the magnitude of mortalities on the farms, retrospective information on the number of sheep owned and died in each age and sex category (rams, ewes and lambs) within 12 months before the study was collected. Mortality rate was calculated as the percentage of deaths (regardless of cause) of all animals that were on farms studied during the reference period. The distribution of households per district is presented in Table 3.1.

3.2.3 Statistical analysis

All data were analysed using SPSS (SPSS, 2010). Frequencies and means of household characteristics flock sizes and management practices were calculated using descriptive statistics. Statistical differences in prices of mature male and female sheep between studied areas were carried out using univariate analysis of the general linear model. Indices were calculated to provide ranking of selection criteria of rams and the reasons for keeping sheep, and calculated as: Index= Sum of (3 for rank 1 + 2 for rank 2 + 1 for rank 3) given for an individual reason divided by the sum of (3 for rank 1 +2 for rank 2 + 1 for rank 2 + 1 for rank 3) for all reasons.

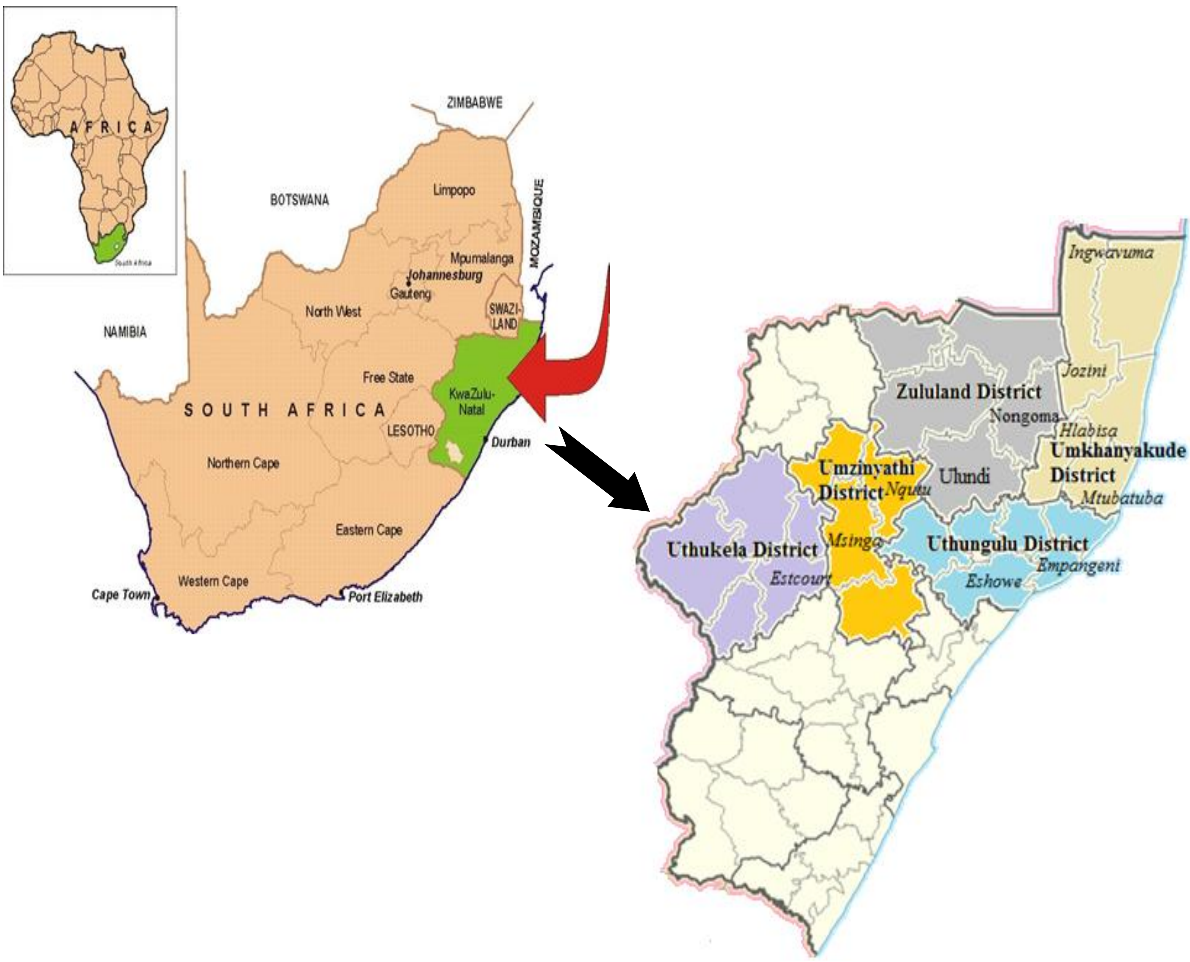

Fig 3.1 Map illustrating municipal boundaries and rural areas from which sampling was done.

Table 3.1 Number of selected households in each studied area

Districts	Area	Number of Farmers Sampled per Area
Uthungulu	Empangeni	4
	Eshowe	1
Mkhanyakude	Hlabisa	8
	Jozini	14
	Ingwavuma	2
	Mtubatuba	6
Zululand	Ulundi	10
	Nongoma	14
Umzinyathi	Nqutu	15
	Msinga	21
Uthugela	Estcourt	1
Total		96

3.3 Results

3.3.1 Household characteristics

Characteristics of respondents and their households are presented in Table 3.2. The proportion of male respondents was higher than the proportion of female respondents. Male: female ratio (71.4%) was lowest in Jozini and highest in Eshowe, Estcourt and Mtubatuba (each had 100%). Of the 93 respondents who gave valid age records, predominant (53.8%) were those between ages 55 and 80, and very few were younger than 30 years. Household size was recorded for 95 families. Twenty-three percent of these had fewer than five members and only 1.1% had more than 16 members. The majority (67.4%) of the respondents had a household size range of 5-10.

Table 3.3 shows proportions of different sources of income and respective responses by farmers in areas surveyed in KwaZulu-Natal on consideration of livestock as their major source of income. A large percentage (60.6%) of farmers indicated that livestock was their major source of income. Results also show that farmers had other sources of income, which supplemented livestock production. Analysis of the weighted data indicated that a greater proportion of farmers

(39.8%) were self-employed while others were formally employed and received grants and pension.

Table 3.2 Gender, age groups and household sizes of interviewed sheep farmers in KwaZulu-Natal

Area	Male	Female	Men %	Age Groups			Household Size			
				20-35	35-55	55-80	<5	5-10	11-15	>15
Jozini	10	4	71.4	1	3	8	4	9	1	0
Msinga	19	2	95.0	1	6	14	5	13	2	1
Eshowe	1	0	100.0	0	1	0	1	0	0	0
Estcourt	1	0	100.0	1	0	0	1	0	0	0
Nongoma	12	2	92.3	1	4	9	4	7	3	0
Empangeni	4	0	100.0	0	1	3	0	4	0	0
Nqutu	13	2	86.7	5	2	7	3	12	0	0
Mtubatuba	6	0	100.0	0	6	0	2	4	0	0
Ingwavuma	2	0	100.0	0	1	1	0	1	1	0
Hlabisa	6	2	75.0	2	3	2	0	8	0	0
Ulundi	8	2	80.0	1	3	6	2	6	1	0
Total N	82	14	86.3	13	30	50	22	64	8	1
Overall %	86.3	13.7	86.3	14.0	32.3	53.8	23.2	67.4	8.4	1.1

Table 3.3 Sources of income for Zulu sheep farmers in KwaZulu-Natal

	Livestock as major of source income		Source of Income (%)			
Area	Yes	No	Formal Employment	Grant	Pension	Self-Employment
Jozini	35.7	64.3	14.3	21.4	42.9	21.4
Msinga	61.9	38.1	35.0	40.0	20.0	5.0
Eshowe	100.0	0.0	0.0	0.0	0.0	100.0
Estcourt	100	0.0	0.0	0.0	0.0	100.0
Nongoma	53.8	46.2	14.3	14.3	35.7	35.7
Empangeni	50.0	50.0	0.0	25.0	0.0	75.0
Nqutu	86.7	13.3	7.1	42.9	0.0	50.0
Mtubatuba	50.0	50.0	33.3	0.0	0.0	66.7
Ingwavuma	100.0	0.0	50.0	0.0	0.0	50.0
Hlabisa	25.0	75.0	37.5	12.5	25.5	25.0
Ulundi	90.0	10.0	0.0	0.0	0.0	100.0
Overall	60.6	39.4	19.4	22.6	18.3	39.8

3.3.2 Livestock ownership patterns

Table 3.4 is a presentation of weighted herd sizes of livestock species. A large proportion (45.3%) of respondents owned less than 10 cattle. Farmers owning between 41-50 sheep were 7.4% of the total number of interviewees. Very few (8.4%) owned more than 50 sheep.

Table 3.4 Weighted herd sizes of livestock species kept by interviewed Zulu sheep farmers in KwaZulu-Natal

Livestock	Flock sizes	Number of farmers	Percentage of farmers
Cattle	<10	39	45.3
	11-20	20	23.3
	21-30	11	12.8
	31-40	10	11.6
	41-50	1	1.2
	>50	5	5.8
Goats	<10	37	43.0
	11-20	20	23.3
	21-30	16	18.6
	31-40	5	5.8
	41-50	4	4.7
	>50	4	4.7
Sheep	<10	24	25.3
	11-20	22	23.2
	21-30	20	21.1
	31-40	14	14.7
	41-50	7	7.4
	>50	8	8.4

The overall proportion of farmers that owned sheep as their major livestock species was lower (21.9%) than that of farmers owning cattle (54.2%) or goats (24.0%) as major livestock species (Table 3.5). Nqutu was the only area, amongst studied areas, where sheep were identified as the major livestock species.

Table 3.6 shows estimated livestock trends in the past five years. There has been a 25% increase (25.1%) in cattle flock sizes in the past five years. However goats and sheep have decreased by estimates of 3.4 and 7.4%, respectively. Most respondents reported a decrease in sheep numbers.

Table 3.5 Farmer's response on major livestock species in the rural areas of KwaZulu-Natal

	Major Livestock Species (%)		
Area	**Cattle**	**Goats**	**Sheep**
Empangeni	25.0	75.0	0.0
Hlabisa	62.5	12.5	25.0
Jozini	71.4	7.1	21.4
Msinga	33.3	57.1	9.5
Mtubatuba	66.7	33.3	0.0
Ingwavuma	100.0	0.0	0.0
Nongoma	64.3	21.4	14.3
Nqutu	40.0	0.0	60.0
Ulundi	70.0	0.0	30.0
Overall	54.2	24.0	21.9

Table 3.6 Estimated livestock trends in the past five years in KwaZulu-Natal

Trend	Number of Farmers	Percentage of total farmers	Overall percentage increase
Cattle			
decrease	22	25.9	
increase	63	74.1	
			25.1
Goat			
Decrease	91	95.8	
Increase	4	4.2	
			-3.4
Sheep			
Decrease	93	96.9	
Increase	3	3.1	
			-7.4

3.3.3 Sheep flock size and composition

Average flock sizes and structures of sheep owned by farmers in each area are shown in Table 3.7. Ewes constituted the greatest percentage of the flocks. Nqutu had the largest average flocks while Mtubatuba had the smallest. Ram to flock ratio was highest in Eshowe (20%) and lowest in Mtubatuba (2.9%). The percentage of mature ewes per flock was highest in Nqutu (79.8%), and the lowest in Mtubatuba (26.1%). In total the percentage of yearlings (29.2%) was lower than that of mature ewes (59.2%). Lambs constituted 15.7% of the average flock.

Table 3.7 Average flock sizes and structures of sheep owned by traditional farmers in the communal areas of KwaZulu-Natal

	Flock composition (%)								
	Flock size	Mature Rams		Mature Ewes		Yearlings		Lambs	
Area	mean±s.e	%	mean±s.e	%	mean±s.e	%	mean±s.e	%	mean±s.e
Empangeni	25.0±2.8	12.0	2.8±0.48	60.0	13.8±1.93	16.0	6.3±0.63	12.0	2.3±0.25
Hlabisa	18.5±5.0	13.4	2.2±0.48	45.1	7.3±1.67	38.0	6.2±2.12	17.4	2.8±1.49
Jozini	23.0±5.3	9.1	2.8±0.49	34.3	9.1±1.61	29.1	7.7±2.66	14.3	3.8±1.09
Msinga	18.8±2.6	15.3	10.0±0.01	57.8	10.9±1.91	25.8	4.9±0.95	18.4	3.5±0.69
Mtubatuba	8.0±2.6	6.5	1.0±0.00	26.1	4.0±0.00	13.0	2.0±0.00	6.5	1.0±0.00
Ingwavuma	39.0±3.0	12.8	2.5±0.50	46.2	20.0±1.00	23.1	9.0±1.00	15.4	7.5±0.50
Nongoma	10.6±1.6	14.5	1.8±0.40	44.3	5.4±0.60	24.4	3.0±0.72	8.1	1.0±0.24
Nqutu	110.4±18.4	8.8	6.7±1.30	79.8	60.6±18.06	35.0	26.6±11.51	21.8	16.6±4.70
Ulundi	26.2±2.7	11.1	2.9±0.46	43.9	11.5±1.23	27.9	7.3±0.88	19.1	5.0±0.83
Overall	39.8±7.5	9.6	3.1±0.31	59.2	21.8±5.61	29.2	9.9±2.05	15.7	4.97±0.83

3.3.4 Perceptions on conservation of animal genetic resources

Farmers were questioned if they were aware of the global awareness campaign going-on on conservation of AnGR. Over 60% of interviewees responded that they had minimal knowledge whilst 35.8% had no knowledge (Table 3.8). The percentage of farmers who regarded the conservation of AnGR as important was highest (72.9%), followed by 16.7% who thought it was extremely important and 10.4% thought not important. Also Zulu sheep were valued as important by most respondents (57.3%). Twenty-three percent considered them extremely important with but a few who thought they were not important (18.8%).

The most common reason given by interviewed farmers for preference of Zulu sheep over exotic breeds was that the breed is tolerant to harsh conditions (60.4%). Other reasons given were that it is a rare breed (29.2%) and that it has good quality/tasty meat (9.4%).

Table 3.8 Average number and proportions of farmers on perception of conservation and importance of Animal Genetic Resources and utilisation of Zulu sheep

	Number of Farmers	Percentage
Awareness Regarding conservation of AnGR		
No knowledge	37	38.5
Minimal	30	31.3
Average	26	27.1
well informed	3	3.1
The value of Conservation of AnGR		
Not important	10	10.4
Important	70	72.9
Extremely important	16	16.7
The value of Zulu sheep to farmers		
Not important	18	18.8
Important	55	57.3
Extremely important	23	24.0
Why do farmers prefer Zulu sheep?		
Tolerant to harsh conditions	58	60.4
Rare breed	28	29.2
Tasty meat	9	9.4

3.3.5 Uses of Zulu sheep

Table 3.9 shows the ranking of sheep production objectives given by farmers. Keeping sheep for meat obtained the highest ranking followed by 'sale' and then 'manure'. Skin and rituals received the lowest ranking.

Table 3.9 Rankings of uses of sheep by rural farmers of KwaZulu-Natal

Production objectives	Rank 1	Rank 2	Rank 3	Index
Meat	85	8	0	0.537
Sale	11	55	0	0.283
Manure	0	18	50	0.170
Skin	0	0	3	0.006
Rituals	0	0	2	0.005

3.3.6 Feeding, housing and watering of Zulu sheep

Most respondents were classified under the extensive sheep production system and a few were semi-intensive (Table 3.10). Sheep grazed on communal grazing land during the day and were enclosed in kraals in the evening (Fig 3.2). Ninety-eight percent of the flocks were housed in separate open kraals adjacent to or within the owner's homestead while 2% were kept in sheds. The majority (82.3%) of farmers interviewed released their flocks for grazing between 0730 and 0830h while 17.7% were released between 0900 and 1100h. The percentage of farmers who released their flocks from 0900 to 1100h was high in Ulundi and Nqutu. All farmers interviewed enclosed their sheep at sunset (between 1700 and 1800h).

Fig 3.2 Zulu sheep in a kraal in Jozini communal area

From the field survey it was found that 76.0% of farmers interviewed did not offer supplementary feed to their sheep. Farmers who gave supplements to their sheep indicated to use mainly mineral concentrates. Other feed supplements used were beer residues, lucerne and maize grains (Table 3.11). The results also show that almost 70.0% of the interviewed farmers produced crops, with maize being the predominant crop produced (89.6%). Some farmers planted vegetables (9.0%) and rye grass (1.5%). Most flocks owned by households producing crops had access to crop residues (65.7%).

Table 3.10 Proportions of production systems, housing and feeding practices amongst farmers in communal areas of KwaZulu-Natal

	System of Production		Housing		Time of Release		Time of Enclosure	Supplementary feeding	
Area	**Extensive**	**Semi-intensive**	**Kraal**	**Shed**	**9:00-11am**	**7:30-8:30am**	**5-6pm**	**No**	**Yes**
Empangeni	100	-	100	-	-	100.0	100	100	-
Estcourt	-	100	100	-	-	100.0	100	-	100.0
Hlabisa	100	-	100	-	12.5	87.5	100	100	-
Jozini	100	-	100	-	21.4	78.6	100	78.6	21.4
Msinga	90.5	9.6	90.5	9.5	-	100.0	100	57.1	42.9
Mtubatuba	100	-	100	-	16.7	83.3	100	66.7	33.3
Ingwavuma	100	-	100	-	-	100.0	100	100	-
Nongoma	85.7	14.2	100	-	7.1	92.9	100	64.3	35.7
Nqutu	100	-	100	-	33.3	66.7	100	80.0	20.0
Eshowe	100	-	100	-	-	100.0	100	100	-
Ulundi	100	-	100	-	60.0	40.0	100	90.0	10.0
Total	94.8	5.2	97.9	2.1	17.7	82.3	100	76.0	24.0

Table 3.11 Feed supplementation and use of crop as stock feed amongst sheep farmers in northern-KwaZulu-Natal

Response	Frequency	Percent
Type of feed Supplements		
Beer residue	3	14.3
Mineral Concentrates	15	71.5
Lucerne	2	9.5
Maize grain	1	4.8
Any form of crop production		
No	29	30.2
Yes	67	69.8
Type of crops produced		
Maize	60	89.6
Ryegrass	1	1.5
Vegetables	6	9.0
Sheep feeding from crop residues		
No	23	34.3
Yes	44	65.7

3.3.7 Watering of sheep

Table 3.12 shows distributions of water sources and ways in which sheep access water in KwaZulu-Natal. The majority of farmers in this study sourced water from rivers. Dams provided water to 24.0% of the farmers. Tap water and boreholes were less common sources of water for sheep (6.2 and 1.0 %, respectively).

Some flocks had water fetched and brought home while others would be driven to or would find their way to the water source. The proportion of flocks which travelled to water sources was higher (91.7%) in summer than in winter (81.3%). Some farmers (18.8%) in winter fetched water and brought it home for their sheep to drink. Incidences of this practice were less frequent in summer (8.3%). Areas in Ulundi, Mtubatuba and Msinga had higher proportions of farmers who fetched water for their sheep in winter (40, 33.3 and 33.3%, respectively). The proportion of farmers who fetched water for their flocks in summer was highest in Msinga (19.0%). Fetching water in summer was not as common as in winter (Table 3.12).

Table 3.12 Percentages of ways in which sheep were watered and sources of water used by farmers in KwaZulu-Natal

	Source of Water				Watering in Winter		Watering in Summer	
	Bore hole	Dam	Tape water	River	Animals travel to water	Water fetched	Animals travel to water	Water fetched
Empangeni	-	-	-	100.0	100	-	100	-
Estcourt	-	100	-	-	100	-	100	-
Hlabisa	-	37.5	-	62.5	75.0	25.0	87.5	12.5
Jozini	-	14.3	-	85.7	92.9	7.1	92.9	7.1
Msinga	4.8	23.8	14.0	57.1	66.7	33.3	81.0	19.0
Mtubatuba	-	66.7	-	33.3	66.7	33.3	100	-
Ingwavuma	-	50.0	-	50.0	100	-	100	-
Nongoma	-	7.1	7.1	85.7	92.9	7.1	92.9	7.1
Nqutu	-	40.0	-	60.0	100	-	100	-
Eshowe	-	-	100	-	-	100.0	-	100
Ulundi	-	-	10.0	90.0	60.0	40.0	100	-
Total	1.0	24.0	6.2	68.8	81.3	18.8	91.7	8.3

Fig 3.3 presents percentages of respondents in different distances travelled by flocks to the water source in winter and summer. The proportion of farmers who reported that their sheep travelled shorter distances (<1km) in summer was higher (72.9%) than in winter (45.8%). More flocks travelled longer distances (>1km) to the water source in winter (45.8%) than in summer (25.0%). Low percentages of flocks drank water that was fetched and provided at home in winter (8.3%) and in summer (2.1%).

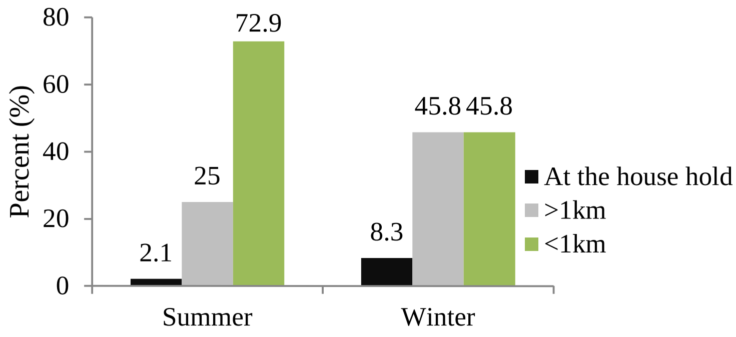

Fig 3.3 Percentage response by farmers on distance travelled to the water sources by sheep in winter and summer.

3.3.8 Establishment of flocks and breeding management practices

The analysis of flocks' origin indicated that most (61.9%) respondents started rearing sheep with initial stock purchased from other farmers (Table 3.13). Thirty two percent were obtained through inheritance and 6.2% as gifts. The possibility of relationships within initial stock was estimated by asking farmers to indicate if their stock were; 'bought from the same flock', 'bought from different flocks in the same community' or 'bought from different communities'. The results obtained are also presented in Table 3.13.

Some farmers were able to recall the number of sheep that was used to establish their flocks. More than seventy percent of the respondents started off with fewer than 3 animals while 19.4%, 6.0% and 3.0% started with ranges of 4 to 6, 7 to 9 and more than 10 sheep, respectively. The overall mean size of the founder flock was 3.5±3.8 (±SD). In Table 3.13 it is also shown that 58.3% of the sheep flocks had not been crossbred with exotic breeds. Twenty-eight percent of the flocks did not interact with other flocks; i.e. they existed in isolation from neighbouring flocks. More than 70.0% interacted with at least one flock. Flocks interacting with 2 flocks were modal amongst the flocks surveyed; followed by those interacting with 1 flock. Farmers were also questioned on their knowledge on inbreeding, its deleterious effects on livestock productivity and the methods used to control inbreeding. The results obtained are presented in Table 3.13

Table 3.13 Flock establishment, interaction with other flocks, inbreeding awareness and methods employed to control inbreeding by communal farmers in KwaZulu-Natal

	Number of Respondents	Percentage
Ways of establishing foundation stock		
Bought	59	61.9
Gift	6	6.2
Inherited	31	32.0
Relatedness of the foundation stock		
Obtained from the same flock	42	65.6
Obtained from different flocks, but the same community	10	15.6
Obtained from different communities	12	18.8
Number of founders		
<4	48	71.6
4-6	13	19.4
7-9	4	6.0
10>	2	3.0
	N=67	Mean=3.52±3.8
History of cross breeding		
No	55	58.3
Yes	41	42.7
Interaction with other flocks		
Yes	68	71.6
No	27	28.4
Number of neighbouring flocks with which the flock interact		
0	27	28.4
1	12	12.8
2	29	30.9
3	10	10.4
4	5	5.2
5	6	6.3
6	7	7.3
Inbreeding Awareness		
No knowledge	12	14.1
Minimal	24	28.2
Average	42	49.4
Well informed	7	8.2
Methods used to control Inbreeding		
Borrow Rams	15	15.6
Buy Rams	6	7.2
None	63	65.6

Table 3.14 shows proportions of sources of rams, reasons for keeping rams and methods of mating by Zulu sheep farmers in KwaZulu-Natal. Rams were used for breeding purposes by all farmers interviewed. No socio-cultural use was mentioned in the entire survey. Mating was uncontrolled in all flocks surveyed.

Table 3.14 Proportions of sources of rams, reasons for keeping rams and methods of mating by Zulu sheep farmers in KwaZulu-Natal

	Number of farmers	Percentage
Source of Ram		
Borrowed	1	1.2
Communal area ram	6	5.9
Donated	1	1.2
Bought	8	8.2
Own bred	80	83.5
Total	96	100.0
Reason for ram		
Breeding	96	100
Socio-cultural	0	0
Mating		
Uncontrolled	96	100
Hand mating	0	0

The questionnaire was complemented by the interviewee's preference for traits he/she considered important in selecting rams. Free answers were possible, however, each farmer had to rank his/her preferences with the trait ranked first as the most important. Indices were then calculated to estimate the relative importance of traits in selecting rams. The indices obtained are presented in Table 3.15.

Table 3.15 Ranking of selection criteria for breeding rams

Selection criteria	Rank 1	Rank 2	Rank 3	Index
Colour	8	5	51	0.195
Conformation	17	51	6	0.226
Size	68	40	0	0.525
Horns	2	1	39	0.051
Tail Type	1	0	0	0.003

3.3.9 Access to veterinary services and control of gastrointestinal and external parasites

The access to veterinary services and veterinary methods adopted by owners of sheep are presented in Table 3.16. More than eighty percent (81.3%) of farmers obtained medication for their animals through private drug suppliers. Only 3.1% each indicated that they sourced help from extension services and government veterinary, with 12.5% stating that they had no access to veterinary help. Most farmers did not follow routine systems in controlling internal and external parasites. Animals received treatment for external (58.3%) and internal (60.4%) parasites when showing ill health. Ten percent and 17.7% did not use any medication to control external and gastro-intestinal parasites respectively. Most interviewed farmers used a spray (53.1%) in controlling external parasites. Gastro-intestinal parasites were predominantly controlled by drenching (70.8%).

Table 3.16 Access to veterinary services and veterinary methods adopted by owners of sheep in surveyed areas of KwaZulu-Natal

	Number of farmers	Percent
Access to veterinary services		
Extension service	3	3.1
Government vet	3	3.1
None	12	12.5
Veterinary drug supplier	78	81.3
External parasite control		
Done routinely	30	31.3
Done when need arises	56	58.3
None	10	10.4
Internal parasite control		
Done routinely	21	21.9
Done when need arises	58	60.4
None	17	17.7
Method of external parasite Control		
Dip	9	9.4
Hand dressing	9	9.4
Injection	17	17.7
Spray	51	53.1
None	10	10.4
Methods of gastro-intestinal parasites control		
Drench	68	70.8
Injection	11	11.4
None	17	17.7

3.3.10 Causes of mortalities

To determine mortality rates, farmers were asked to give estimates of the number of sheep, within different groupings (mature males, mature females and lambs), that had died within the year 2010/2011. Farmers were not keeping any written records, thus numbers of these mortalities were recalled from memory. It should therefore be acknowledged that the assertions made from these findings can be tampered with. Results from the investigation are presented in Table 3.17. Causes of mortalities and the respective proportions of farmers reporting them are shown Table 3.18.

Table 3.17 Total number and percentage of Zulu sheep reported to have died from June 2010 to June 2011 in KwaZulu-Natal

Mortalities	Total number of mortalities	Average mortalities per flock	Std. Deviation	Percentage (%)
Mature Male	39	0.76	1.37	8.9
Mature Female	95	1.83	2.76	21.8
Lamb	302	6.29	11.16	69.4
Total Mortalities	435	8.37	11.43	100.0

Table 3.18 Causes of Zulu sheep mortalities reported by farmers in KwaZulu-Natal

Reasons for mortalities	Number of farmers reporting reason	Percent
Unfavourable weather conditions	3	4.7
Disease	18	28.2
Drought	28	43.8
Predation by dogs	3	9.4
Gastro-intestinal parasites	5	3.1
Road accidents	4	6.3
Predators	3	4.7
Theft	3	4.7
Too much rain	2	3.1
Total	64	100.0

3.3.11 Marketing of Zulu sheep in rural communities of KwaZulu-Natal

The proportion of farmers who sold their sheep (57.3%) was greater than that of farmers who did not sell sheep (42.7%). Most farmers were compelled by need to sell sheep, only a few had defined system of marketing (e.g. selling rams when their numbers have increased). The greater proportion of farmers selling sheep were not specific in the type of animals they sold (70.9%), while some farmers indicated that they sold old rams, unproductive ewes and weaners respectively (Table 3.19).

Average prices for mature male and female sheep are shown in Table 3.20. Mature males were sold at a higher ($p < 0.05$) price than mature females. Mature female prices did not vary significantly between all the areas studied. The lowest mature female was sold at an average price of R750 in Ingwavuma while Ulundi and Nongoma had the highest average price of R1025. The prices of mature males were lowest in Estcourt and highest in Ulundi.

Table 3.19 Sheep marketing in Northern KwaZulu-Natal by traditional farmers

Aspects of sheep marketing	Response	Frequency	Percent
Does the farmer sell his/her sheep	No	41	42.7
	Yes	55	57.3
	Total	n=96	
What determines your selling of sheep	Prevalence of need	49	89.1
	System of production	6	10.9
	Total	n=55	
And which animals do you sell	Mature rams	7	12.7
	Not specific	39	70.9
	Unproductive ewes	7	12.7
	Weaners	2	3.6
	Total	n=55	

Table 3.20 Average prices for mature male and female Zulu sheep amongst rural communities of KwaZulu-Natal

Area	Mature male price (R)	Mature female price (R)
Empangeni	1000.0±88.4[ab]	1000.0±81.6[a]
Estcourt	800.0±125.0[a]	800.0[a]
Hlabisa	1066.7±102.0[ab]	900.0±94.2[a]
Jozini	1100.0±88.4[ab]	875.0±81.6[a]
Msinga	950.0±51.0[ab]	779.2±47.1[a]
Mtubatuba	950.0±88.4[ab]	900.0±81.6[a]
Ingwavuma	1000.0±125.0[ab]	750.0±115.4[a]
Nongoma	1225.0±88.4[ab]	1025.0±81.6[a]
Nqutu	1030.8±49.0[ab]	823.1±45.3[a]
Ulundi	1300.0±62.5[b]	1025.0±57.7[a]
Overall*	1060.0±206.7	880.9±179.6

[a.b]Means in the same column with different super scripts are significantly different at $p<0.05$
* Means in the specified raw are significantly different at $p<0.001$

3.4 Discussion

There is an increasing interest in the characterization of African native animal genetic resources (Traoré *et al.*, 2008; Kunene *et al.*, 2009; Yakubu *et al.*, 2010) because of their valuable contribution towards livestock biodiversity and adaptive attributes to fulfil the multifaceted roles they are allocated to by the poor livestock keepers in the region (Köhler-Rollefson, 2001; Ali, 2011). Zulu sheep have become a stable part of KwaZulu-Natal ecosystem through hundreds of years of adaptation to the production environment in which they are raised (Kunene *et al.*, 2007). The current study described and documented Zulu sheep production systems in the traditional sector of KwaZulu-Natal as an essential step towards the development of a sustainable breed improvement programme.

The findings that households were predominantly headed by males and that most livestock farmers are old aged are common phenomena in most developing countries (Oladele, 2001; Bembridge, 1984). The present study confirmed findings of Kunene and Fossey (2006) who reported that the proportion of old people is dominant in rural communities of KwaZulu-Natal. Bembridge (1984), Mahanjana and Cronjé (2000) and Mapiliyao (2010) reported similar findings in the Eastern Cape. Meanwhile, Oladele (2001) in Nigeria echoed that old people are custodians of tradition. This implies that young people are less involved in livestock production in developing countries. The migration of younger people to urban areas might be a contributing factor to the high proportion of elderly people found in these areas (Sokhela and Bembridge, 1991).

Though livestock farming was identified as the major activity in most areas studied, farmers had alternative means to source income. Seemingly farm produce alone could not sustain the household upkeep. Sokhela and Bembridge (1991) attributed this to unreliable food crop yield in the province. 'Even in good years', the authors highlighted, 'maize crop yield is not enough to guarantee the respondents sufficient food and income for one year' (Sokhela and Bembridge, 1991). Hence, other sources of income (self-employment, formal employment, grant and pension) reported in the current study, seem to serve as supplements to farming income. This phenomenon presents an opportunity for sustainable utilisation of indigenous livestock; which can withstand drought and can produce under conditions of low input and low level management, thus requiring less input and availing farmers time to conduct other activities.

Kosgey *et al.* (2008) assert that flock composition in terms of sex and age classes is an indicator of the management system, because it reflects to some degree the management objectives, flock productivity and constraints on the system. Overall, the mean flock size (39.8) reported in the current study was higher than that reported by Mapiliyao (2010) in the Eastern Cape of 18.3 and 19.0 for the villages of Sompondo and Gaga, respectively. However, the fact that Nqutu and Estcourt had outstandingly high mean flock sizes is an influencing factor towards a higher figure obtained in this study. A mean (19.1) similar to that of Mapiliyao (2010) would be obtained if Nqutu and Estcourt were excluded from the calculation. The high percentage of mature breeding ewes (59.2%) in the current study was similar to that reported by Mapiliyao (2010) for Gaga and Sompondo villages in Eastern Cape. Taye *et al.* (2010) also gave a similar figure of 58.8% in Ethiopia. Kosgey *et al.* (2008) ascribed this to the fact that farmers in their study maintained breeding ewes for long periods and that the importance of culling was not fully recognized. The removal of rams for sale or family consumption is another possible factor contributing to the high proportion of ewes per flock in this study.

One aim of this study was to document information that would be useful in the future when formulating a breeding programme for Zulu sheep. The following findings were important, particularly as considerations in designing a breeding programme for Zulu sheep in KwaZulu-Natal. Firstly, individual sheep flock sizes were quite small (about 48.0% of the flocks were made up of fewer than 20 animals; see Table 3.4). Secondly a great proportion (28.4%) of these flocks existed in isolation from other neighbouring flocks or interacted with only a few flocks (about 72.0% interacted with 3 or fewer flocks, see Table 3.13). Bias (2006) highlights the fact that when a population is divided into isolated subpopulations it tends to lose more heterozygosity than it would if the population was undivided. Thirdly most breeding rams were sourced locally (either own-bred or bought from neighbouring farmers). This rendered the genetic diversity within a flock and even within a village to be potentially narrow and increased inbreeding (Gill and Harland, 1992). Also, high incidence of uncontrolled mating noted in surveyed areas predisposes flocks to loss of genetic diversity (Bias, 2006). The importance of maintenance of genetic variability in small populations and the effect of inbreeding has been discussed by several authors (Gill and Harland, 1992; Mendelsohn, 2003; Bias, 2006). Breeding between individuals sharing common ancestors tends to reduce the rate of allelic variation in the next generation which then reduces the genetic diversity of the population (FAO, 2007). The accumulation of deleterious recessive alleles may threaten the fitness of the population and negatively affect reproductive rates, thereby increasing the risk of extinction (Gandini *et al.*, 2004; Woolliams, 2004).

Furthermore, though a majority of farmers (85.9%) showed awareness of inbreeding and its deleterious effects, the effort put forth to address the implication did not seem to correspond with their knowledge. Sixty five per cent of the interviewed farmers did not put into practice any measures to control inbreeding. The few who did introduced new rams into their flocks, either by borrowing or buying rams from neighbouring farmers. Communal herding, which allows breeding females to mix with breeding males from other flocks, can minimise inbreeding (Kosgey *et al.*, 2008), but this appears to be rarely practised among the farmers in this survey.

Over 71.0% of the respondents in this study established their flocks by three or fewer breeding animals, sourced mainly from a single flock (through gifts, inheritance or purchase) or from different flocks in the same village, implying high chances of close relationships amongst foundation stock. This tends to narrow the genetic constitution of the progeny flock, because the primary constraint on the genetic profile of a breed/flock is the genetic constitutions of its founders (Gill and Harland, 1992). Founder effects acting on different demes generally lead to subpopulation with allele frequencies that are different from the larger population (Bias, 2006). Thus each subpopulation developing from different genotypic constitution from that of the larger population would develop into a unique strain. According to Gill and Harland (1992), the greater the genetic diversity the greater the potential of a breed to respond to changing environmental conditions. A good breeding programme for Zulu sheep will serve well if it adequately addresses these constraints.

Inadequate feeding and poor quality feed are often regarded to be major factors limiting sheep production (Kosgey *et al.*, 2008). The current study revealed that most (76.0%) interviewees did not offer supplementary feeding to their flocks; animals depended entirely on veld for their nutritional requirements. This finding concurs with the results of Kunene and Fossey (2006) and other studies in areas where extensive livestock production is practised (Sölkner *et al.*, 1998; Taye *et al.*, 2010). This study as did Kosgey *et al.* (2008) revealed that farmers who supplemented diets of their animals provided them with mineral concentrates. Supplementary feeding amongst famers in the present study can be ascribed to unreliability of roughage production especially during drought periods.

Most animals were released for grazing in the morning (0730-0830h) and brought back for enclosure in the evening (1700-1800h). The proportion of farmers who released their animals later (0900-1100h) was higher in Ulundi and Nqutu. Although not presented in the current study it was generally observed that these areas had good pastures when compared to the rest of the areas studied. Late release of animals by farmers therefore might be attributed to the fact that animals graze to their satiety in shorter grazing time due to high pasture availability. Late release of animals allows farmers to carry out other household chores before they lead their flocks for grazing.

The knowledge of the reasons for keeping small ruminants is a prerequisite for deriving operational breeding goals (Kosgey *et al.*, 2008). Ignorance of this aspect has been a major constraint in the lack of success in genetic improvement programmes attempted in the tropics (Sölkner *et al.*, 1998; Rewe *et al.*, 2002). The reasons for keeping sheep identified in the present study reflect multiple objectives by the farmers and are consistent with the findings of Kunene and Fossey (2006) in KwaZulu-Natal and Mapiliyao (2010) in Eastern Cape. Sheep were commonly used as a source of meat, family income and manure, in the present study. Together these uses accounted for 99.0% of the total usage. The other use mentioned by farmers was skins. Only two farmers, in Ingwavuma, were identified to be using sheep for rituals (Table 3.9). FAO (2007) mentions fibres, hides, skins and pelts as other important products used in other sheep breeds, and could be possible opportunities which farmers can exploit to better utilise their sheep. Zulu sheep were preferred over exotic breeds particularly for their adaptive traits (resistant to local prevalent diseases and drought). The reasons for breed preference should be investigated further because it may have an influence on the implementation of a breeding programme. Farmers who are not satisfied with their breed might not be willing to put effort into improving the animals.

In spite of all the socio-economic advantages mentioned by farmers, this study revealed that sheep flock sizes are declining. This confirms the finding of Kunene and Fossey (2006). This shows that more damage to this important resource has occurred over the years. Inaction might lead to total eradication of the breed. It is therefore imperative that emergent measures be put in place to hold in check the genetic decay. FAO (2007) asserted that the prospects for a breed depend to a great extent on its present and future function in livestock systems. Some breeds are lost due to the emergence of new circumstances that change the lifestyle of their keepers and thus the breeds are set aside and are faced with the danger of extinction. Several reasons have been given by Oldenbroek (1999) as to why the implementation of conservation measures for a particular breed might be considered important: genetic uniqueness; a high degree of endangerment; traits of economic or scientific importance (unique functional traits); and ecological, historical or cultural value. If identified and understood by the keepers of Zulu sheep, these will, to some extent, determine the effectiveness of the conservation measures.

Though most farmers applauded the breed for its tolerance to local prevalent harsh environmental conditions, the major cause of loss of sheep identified in this study was drought. This sounds equivocal, but drought intensity in some parts of the province can be so high that its effects override the sheep's adaptive attributes. Disease was identified as the second major cause of sheep mortality in the present study. This concurred with findings by Kosgey *et al.* (2008) who ascertained that poor health is the key limiting factor to the productivity of sheep raised by most rural farmers in developing countries. Most farmers interviewed depended on drug suppliers for veterinary help; this raises some doubts about the accurate diagnosis of diseases. Maximum productivity in a given system of production emerges when disease control is optimal (Gatenby, 1986). Thus, healthcare is an important problem to consider before genetic programmes can be seriously contemplated. Community-based animal health programmes may be one way forward and wider utilisation of indigenous breeds tolerant to disease another (Njoro, 2001). Other causes of sheep loss such as vehicle accidents and theft identified in the present study were less important (Table 3.18) - a finding similar to that of Mapiliyao (2010).

Zulu sheep were preferred over their exotic counterparts by most farmers in this study. Reasons given for this preference were that the breed is tolerant to diseases and drought and that it has good meat quality. These results confirmed the findings of Kunene and Fossey (2006) and are indicative of the fact that Zulu sheep are important to the livelihood of rural farmers and possess survival traits which enable them to live and produce under management levels of resource-poor farmers who would do well with disease resistant multipurpose animals with low-maintenance feed requirements and relatively high good mutton output. Zulu sheep, therefore, can be used as a tool to alleviate poverty, improve food security and livelihoods of the resource-poor farmers in KwaZulu-Natal.

The survey revealed that there was no formal market in which farmers sold their sheep. Sheep were sold primarily to other farmers, but hardly ever to abattoirs, suggesting the possibility of non-competitive prices. Also noted in the present study is the non-specificity in the type of animals sold by farmers and a high proportion of farmers selling to meet emergency family needs. This was a result of the fact that farmers did not have in place systems to guide them in selling their animals. This suggests a necessity to explore possibilities of organised marketing so that farmers can reap maximum benefit from their investments. Kosgey *et al.* (2008) indicated that farmers would likely not adopt improved management practices whilst proceeds from sale of animals are low. Thus the issue of sheep market would have to be addressed in order to win the hearts of farmers towards the conservation and improvement of Zulu sheep. Findings on sheep prices show that mature males sold at higher prices than females. This is in agreement with findings from other researchers who have conducted similar studies elsewhere (Dossa *et al.*, 2008; Nwafor, 2004).

3.5 Conclusions

The study revealed a number of pertinent issues that, if adequately addressed, could increase the general productivity of Zulu sheep and help in developing effective breed conservation and improvement programmes of the breed. Drought seems to be a major factor limiting productivity followed animal health. A full screening of all diseases and rehabilitation of extension services will help develop an adequate preventive health program. Though sheep flock sizes were found to be depreciating due to drought, diseases, inbreeding, poor nutrition and crossbreeding, the high regard that farmers showed for their sheep is a consolation in that there is still hope in the survival and sustenance of the breed. If stringent measures are put in place to mitigate corrosion of this valuable genetic resource, through technical support and suitable assistance according to the needs of the different communities, the breed may considerably alleviate poverty in rural communities of KwaZulu-Natal. It is necessary to look at the production system in a holistic way and involve concerned farmers in devising effective Zulu sheep breeding programmes. The possibilities of organized marketing need also to be explored in order for farmers to reap maximum benefit from their investments, as this will also motivate their involvement in fighting against genetic degradation of the breed.

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CHAPTER 4

MORPHOLOGICAL STRUCTURE OF ZULU SHEEP BASED ON PRINCIPAL COMPONENT ANALYSIS OF BODY MEASUREMENTS

(This chapter has been accepted at Small Ruminant Research)

Abstract

Morphology of indigenous sheep in South Africa is unknown, and even where data exist, they are rarely presented using standardised methodologies. Principal component analysis (PCA) was applied to 13 body measurements to provide an objective description of the body shape and size of 1665 Zulu sheep, obtained from rural communities of KwaZulu-Natal. Data were analysed separately for young (no permanent incisors) and adult sheep (≥2 pairs of permanent incisors). On average, mature males measured higher than mature ewes in most morphometric traits. The correlation coefficients between different body measurements in young sheep were all significant except for the correlation between ear length and tail length. In adult sheep, 79 out of 96 combinations showed significant correlation. Body weight and heart girth had the highest correlations in both age groups. Ear length and tail length related combinations had lower correlation coefficients in both age groups. The PCA of morphometric traits extracted two components with a total variance of 66.8% in young sheep and four components in adult sheep which explained a total variance of 62.1%. The first factor (PC1) in each case had high loadings for variables relating to body size, while PC2 had high association with traits reflecting body shape. The PC3 had high factor loadings for head length and head width, and thus defined head size. Tail length, ear length and wither height on the other hand contributed least towards total variation. The use of principal components was more appropriate than the use of original correlated variables in predicting body weight of Zulu sheep. PCA was able to identify traits with greater variability. These can be improved with greater success in breeding programmes. Also, the number of variables was reduced to give a concise picture of morphological structure (body size and shape) of a Zulu sheep. These components can be used as selection criteria for improving meatiness in Zulu sheep and moreover in predicting the live weight of Zulu sheep.

Key words: Zulu sheep; Principal component analysis; Morphological structure

4.1 Introduction

The need to characterise indigenous breeds prior to strategizing means of their conservation, improvement and sustainable utilisation, cannot be over emphasised (Rege and Lipner, 1992; Franklin, 1997; FAO, 2007). Breed standards and judging panels for morphological evaluation do not exist for Zulu sheep, since its standards have not been fully established. Moreover very little attention has been given to the breed compared to other sheep breeds. Preliminary work done by Kunene *et al.* (2007) has used a few body measurements (live weight, heart girth and wither height) to describe the breed.

Several researchers have used body measurements in describing the morphological structure of different livestock species (Ibe, 1989; Salako, 2006; Yakubu, 2009; Taye *et al.*, 2010; Ogah, 2011). Linear body measurements together with body weight describe more completely an individual or population than the conventional methods of weighing and grading (Salako, 2006). A quantitative measure of conformation will enable reliable genetic parameters for the traits to be estimated and this will make it possible for conformation to be included in breeding programmes (Ogah, 2011). Linear body measurements have also been used to predict live weight in sheep (Ibiwoye and Oyatogun, 1987; Atta and Khidir, 2004; Kunene *et al.*, 2009; Taye, 2010). However, the biological relationship existing among the linear body variates may be different if these body measurements are treated as bivariates rather than multivariates (Yakubu and Ayoade, 2009). Thus principal component analysis, a multivariate technique, can be used when morphological traits are intercorrelated, in the size and shape of a breed.

Principal component analysis (PCA) investigates relationships among several quantitative variables measured on a single object, reducing the number of variables under analysis to a small number of indices (called the principal components) that are linear combinations of the original variables (Morrison, 1976). The analytic tool, in this case, combines the morphometric variables to produce indices or components that are uncorrelated. This allows data to be viewed from different dimensions (Manley, 2004). Moreover data can be adequately described by a few variables (components). Thus simple patterns of relationships among the variables are discovered. In particular, the observed variables can now be explained largely or entirely in terms of a much smaller number of variables (components).

Several researchers have employed PCA to extract factors contributing towards variation amongst individual animals based on body measurements (Shahin, 1993; Yakubu and Ayoade, 2009; Yakubu *et al.*, 2009; Ogah, 2011). Salako (2006) employed the tool in 10 linear body measurements in an effort to elicit an objective description of body shape in 0 to 14 months old Uda sheep. Linear body measurements were reduced to two principal components that accounted for 75.0% of total variation. The first component was designated to represent body size while the second represented body shape. Okpeku *et al.* (2011) in their study used extracted principal components to predict body weight of goats in southern Nigeria. The authors concluded that the resultant factor score coefficients could be used to predict body weight with more accuracy than the original interdependent variables.

The purpose of this study was to define the morphological structure of Zulu sheep, examining changes in body measurements and their relationships in different age groups, and to examine percentage contributions of body measurements towards total dimensional variation of the breed. It tested the hypothesis that the relationships involving body weight and morphological traits when factor scores are used may be different from the relationships obtained when the inter-correlated original morphological variables are used.

4.2 Methods and Materials

4.2.1 Study Site

The distribution of the breed was identified through discussions with officers of the Department of Agriculture and Environmental Affairs (DAEA) in respective municipalities. Sheep were sampled from 11 rural communities, distributed across 5 districts of northern KwaZulu-Natal. The areas studied are as described in section 3.2.1.

4.2.2 Data Collection

In each of the locations, farmers with sheep were randomly selected and records taken on a randomly selected sample of more than 10 sheep per farmer depending on the flock size and the number of farmers owning sheep per given area. Data were collected during the period between June and November of 2010. A scale was used to determine live weight of sheep. Sheep were weighed in the morning before their release for feeding to minimise post-prandial gut variation. Pregnant ewes were excluded. Different body dimensions were measured using a tape measure (with records taken to the nearest cm) after restraining and holding the animal in an unforced position. The body parts were measured as described by Taye *et al.*, (2010) and Yakubu *et al.*, (2010). Reference points recorded are as shown in Fig 4.1 and were head length (HL), head width (HW), ear length (EL), heart girth (HG), body length (BL), wither height (WH), thorax depth (TD), rump height (RH), rump width (RW), rump length (RL), shin circumference (ShC), tail length (TL) and tail circumference (TC). Also recorded were sex and age of each animal. Age was estimated using the dentition method as well as making enquiries from the farmers.

Fig 4.1: Morphometric variables studied and their reference points. BW, body weight; HG, heart girth; WH, wither height; RH, rump height; TD, thorax depth; BL, body length; TL, tail length, TC, tail circumference; HL, head length; HW, head width; ShC, shin circumference; EL, ear length; RW, rump width; RL, rump length

4.2.4 Statistical analysis

All Statistical analyses were carried out using the SPSS/PASW statistics 19 (SPSS, 2010). Prior to this univariate analyses were carried out on all the variables included in the study to observe their individual behaviour (normality and homoscedasticity) and to detect outliers. Univariate analysis of variance of the effect of age on body measurements was then obtained first from the entire data matrix. Data were then split into two sets based on sheep age (dentition), with one set constituting trait records of sheep with no permanent incisors (young) and the other records of sheep with two or more permanent incisors (adult). Analysis of variance of fixed effects of area, sex and age on body measurements was done on the separate data matrices by the univariate analysis of the General Linear Model of SPSS. Pearson's coefficients of correlation (r) among body weight and the various morphometric traits were estimated for each age group. From the correlation matrix, data were generated for the principal component factor analysis. Bartlett's test of spherity, anti-image correlations and Kaiser's measure of sampling adequacy were conducted to determine the appropriateness of the common factor model in analysing the data sets. A measure of sampling adequacy below 0.5 could not be accepted. Principal Component

Analysis was applied separately to 13 morphometric measurements of young and adult sheep. The analytic tool combined measurements (variables) into uncorrelated components. Varimax rotation was applied to enhance the interpretability of the principal components. The Kaiser Rule criterion (Manley, 1994) was used to determine the number of factors extracted and it only retained factors that had Eigenvalues greater than 1. The stepwise multiple regression procedure was used to obtain models for predicting body weight from (i) body measurements and from (ii) principal components. Models with higher coefficients of determination (R^2) were considered better than models with lower R^2 values.

$$BW = a + b_iX_i + \ldots\ldots + b_kX_k \qquad \text{(i)}$$

$$BW = a + b_iPC_i + \ldots\ldots + b_kPC_k \qquad \text{(ii)}$$

Where BW is the body weight, *a* is the regression intercept, b_i is the *i*th partial regression coefficient of the *i*th linear body measurement, X_i or the *i*th principal component (PC).

4.3 Results

4.3.1 Descriptive analysis of bodyweight and morphological traits

Means, standard errors and coefficients of variation and significance of location, age and sex effects on each morphological trait measured are presented in Table 4.1. Body measurements of young sheep had relatively higher coefficients of variation than adult sheep. Body weights (BW), tail length (TL), tail circumference (TC) and ear length (EL) were the most variable measurements in adult sheep, as indicated by coefficients of variation (CV) between 23 and 31. While HG, WH, RH and BL showed the most homogeneity with CVs between 9.01 and 9.74. In young sheep CV was highest for BW (49.0 %) and SC (43.9%) and lowest for RH (13.1%). Age significantly affected all body measurements in younger sheep but showed no significant effects on TC, TL, ShC, EL, RW and RL in adult sheep. A detailed presentation of the effect of age on body measurements is shown in Table 4.2. Each measurement developed at a different rate in different age groups. Some morphometric parameters were early maturing and stopped growing before others. The measure of sexual dimorphism (m/f) has also been included in the same table to express differences between males and females. Males were larger for all variables except for EL, which showed no significant difference between sexes. Fig 4.2 shows significance of difference in body weight between different age groups. There is a successive significant increase in body weight with age until animals reached a dentition of two pairs, at which successive increase in age resulted in no significant change in body weight. Weight differences between sexes in different age groups are presented in Fig 4.3. Differences between sexes were similar until the animals reached an age of two pairs of incisors, where after males became larger than females of the same age group.

Table 4.1 Descriptive statistics and significance of area, age and sex effects on each of the morphological traits in young and adult Zulu sheep

	Adult (n=1149)						Young (n=516)					
	Statistics			Effects			Statistics			Effects		
Traits	Mean±S.E	SD	CV	Area	Age	Sex	Mean±S.E	SD	CV	Area	Age	Sex
BW (kg)	34.7±0.24	8.12	23.41	***	*	***	18.5±0.40	9.07	49.04	***	***	*
HG (cm)	80.1±0.23	7.81	9.74	***	**	***	62.4±0.58	13.10	21.00	***	***	ns
WH (cm)	62.6±0.17	5.64	9.01	***	*	***	52.7±0.39	8.87	16.84	***	***	*
RH (cm)	63.8±0.21	5.29	8.29	***	**	***	54.2±0.52	7.10	13.10	***	***	*
TD (cm)	32.7±0.12	4.09	12.52	***	*	***	26.0±0.27	6.18	23.74	***	***	ns
BL (cm)	64.1±0.18	5.82	9.09	***	***	***	52.1±0.45	9.89	19.00	***	***	ns
TL (cm)	27.6±0.37	7.41	26.82	***	ns	***	23.9±0.46	7.19	30.02	***	**	ns
TC (cm)	23.2±0.36	7.24	31.18	***	ns	***	15.8±0.39	6.05	38.32	***	***	**
HL (cm)	19.1±0.10	2.08	10.92	***	***	***	15.4±0.18	3.10	20.14	***	***	ns
HW (cm)	11.0±0.06	1.40	12.66	***	**	***	9.6±0.10	1.65	17.27	***	***	ns
SC (cm)	26.4±0.32	4.40	16.64	**	*	-	16.1±0.52	7.05	43.85	**	***	-
ShC (cm)	9.3±0.08	1.68	18.14	***	ns	***	8.2±0.08	1.36	16.54	***	***	ns
EL (cm)	9.3±0.11	2.46	26.30	***	ns	**	8.6±0.15	2.54	29.73	***	***	ns
RW (cm)	16.6±0.13	2.81	16.89	***	ns	**	12.7±0.20	3.50	27.59	***	***	*
RL (cm)	21.5±0.14	2.99	13.94	***	ns	***	17.2±0.24	4.06	23.61	**	***	ns

ns: non-significant; * significance level: $p < 0.05$; ** significance level: $p < 0.01$; *** significance level: $p < 0.001$. BW, body weight; HG, heart girth; WH, wither height; RH, rump height; TD, thorax depth; BL, body length; TL, tail length, TC, tail circumference; HL, head length; HW, head width; ShC, shin circumference; EL, ear length; RW, rump width; RL, rump length

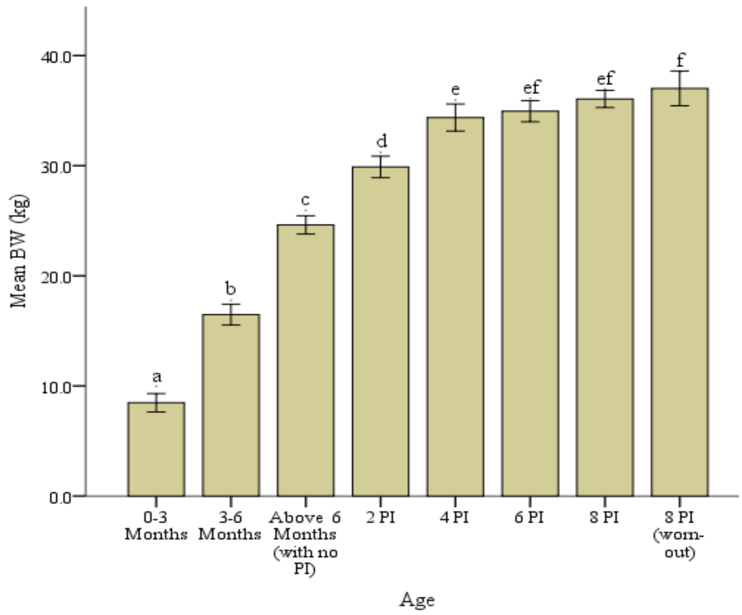

Fig 4.2 Significance of differences in body weight between different age groups in Zulu sheep. Error bars represent the standard error of the mean. Bars with different letters are significantly different ($p < 0.05$). PI – Permanent Incisors

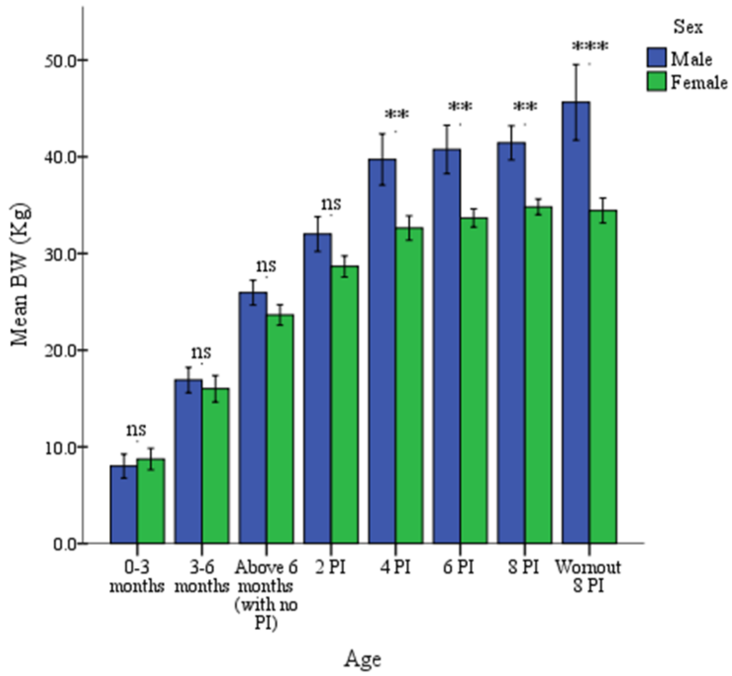

Fig 4.3 Significance of difference in body weight between sexes in different age groups in Zulu sheep. Error bars represent the standard error of the mean. ns- not significant ** $p < 0.01$ *** $p < 0.001$. PI – Permanent Incisors

Table 4.2 Marginal means with standard errors (SE) for each of the body measurements in Zulu sheep shown by age

Traits	**Age**								**Sex**		**Sexual dimorphism**
	< 3 Months	**3-6 Months**	**>6 Months**	**1 Pair**	**2 Pairs**	**3 Pairs**	**4 pairs**	**worn-out**	**Male**	**Female**	
BW	8.5±4.91[a]	16.5±5.05[b]	24.6±6.71[c]	29.9±6.60[d]	34.3±8.35[e]	34.9±7.23[ef]	36.1±8.04[ef]	37.0±8.85[g]	39.1±0.58	33.4±0.24	1.16
HG	47.5±0.79[a]	60.7±0.783[b]	71.0±0.51[c]	75.1±0.49[d]	79.9±0.54[e]	80.5±0.48[e]	81.5±0.39[e]	82.2±0.65[e]	83.1±0.57	79.3±0.24	1.05
RH	45.3±1.17[a]	52.4±0.88[b]	57.6±0.52[c]	62.4±0.42[d]	63.1±0.67d[e]	63.1±0.49d[e]	64.2±0.38[de]	65.2±0.79[de]	65.6±0.58	63.2±0.20	1.05
WH	42.8±0.58[a]	52.6±0.58[b]	57.9±0.36[c]	60.9±0.38[d]	62.6±0.42[de]	62.7±0.36[de]	62.6±0.27[de]	64.5±0.55[e]	64.9±0.43	61.9±0.17	1.04
TD	19.4±0.38[a]	26.0±0.40[b]	29.5±0.28[c]	31.0±0.24[d]	32.1±0.29[de]	32.6±0.25[ef]	33.2±0.19[ef]	33.9±0.48[f]	34.5±0.27	32.1±0.13	1.09
BL	41.0±0.67[a]	51.4±0.67[b]	58.1±0.37[c]	61.9±0.51[d]	63.9±0.42[de]	63.8±0.39[de]	64.7±0.27[ef]	65.9±0.53[f]	65.1±0.40	63.8±0.20	1.03
TL	21.3±0.55[a]	25.1±0.78[b]	25.5±0.82[b]	28.5±1.29[bc]	27.0±0.73[b]	27.7±0.68[b]	27.0±0.64[bc]	31.1±1.28[c]	30.8±0.62	26.7±0.43	1.13
TC	11.3±0.34[a]	14.4±0.61[a]	20.0±0.54[b]	21.9±0.78[bc]	23.0±0.82[bc]	24.2±0.735[c]	23.3±0.586[bc]	21.2±1.563[bc]	27.9±0.83	21.8±0.36	1.28
HL	12.2±0.22[a]	15.3±0.25[b]	17.5±0.17[c]	18.4±0.34[cd]	18.6±0.23[cd]	19.1±0.18[de]	19.2±0.14[de]	20.0±0.35[e]	20.0±0.22	18.8±0.10	1.07
HW	8.1±0.10[a]	9.7±0.23[b]	10.5±0.10b[c]	10.9±0.19[c]	10.7±0.14[c]	10.8±0.14[c]	11.1±0.08[c]	11.9±0.34[d]	11.7±0.18	10.9±0.06	1.09
SC	9.3±0.70[a]	14.1±0.90[b]	20.6±0.51[c]	25.3±0.53[d]	26.5±0.79[d]	26.6±0.75[d]	26.8±0.61[d]	27.5±1.06[d]	26.6±0.31	-	-
ShC	7.3±0.12[a]	8.2±0.16[b]	8.8±0.10b[c]	10.1±0.63[d]	9.0±0.12[c]	9.3±0.10[c]	9.1±0.08[c]	9.2±0.26[c]	10.2±0.29	9.1±0.06	1.13
EL	7.3±0.25[a]	8.7±0.30[b]	9.3±0.20[b]	9.6±0.46[b]	8.9±0.24[b]	9.2±0.24[b]	9.5±0.17[b]	9.5±0.33[b]	8.7±0.25	9.5±0.12	0.91
RW	9.7±0.27[a]	12.4±0.31[b]	14.8±0.24[c]	16.4±0.34[d]	16.5±0.29[d]	16.8±0.31[d]	16.7±0.19[d]	16.7±0.40[d]	17.3±0.34	16.5±0.13	1.06
RL	13.7±0.28[a]	17.0±0.33[b]	19.6±0.30[c]	21.7±0.49[d]	21.2±0.37[d]	21.2±0.25[d]	21.5±0.20[d]	22.0±0.50[d]	22.4±0.28	21.2±0.15	1.07

a,b,c,d,e,f row means with common superscripts do not differ ($P < 0.05$), *significance level: $p<0.05$, **significance level: $p<0.01$, ***significance level: $p<0.001$. BW, body weight; HG, heart girth; WH, wither height; RH, rump height; TD, thorax depth; BL, body length; TL, tail length, TC, tail circumference; HL, head length; HW, head width; ShC, shin circumference; SC, scrotum circumference; EL, ear length; RW, rump width; RL, rump length

4.3.2 Phenotypic correlations

Pearson's coefficients of correlation among various morphometric variables are shown in Table 4.3. A total of 96 correlations were estimated in each age group. In young sheep all body measurements were positively and significantly inter-correlated except for correlation between EL and TL ($r = 0.086$, $p > 0.05$). In adult sheep, 79 correlations were positively significant and 17 were not significant. Out of the 96 only 2 (ear related combinations) were negative. Coefficients of correlation were relatively higher for all the body measurements in young sheep than those for adult sheep. Heart girth and BW had highest correlations in both age groups. Body weight in adult sheep had also higher correlations with TC ($r = 0.530$), BL ($r = 0.509$), WH ($r = 0.479$) and TD ($r = 0.459$) while lowest with EL ($r = 0.061$). In young sheep, all body measurements were highly correlated with body weight except for ear length. Ear length and tail length related combinations had lower correlation coefficients in both age groups together with rump width in adult sheep. The correlation between TC and HG in adult sheep was high ($r = 0.551$). Ear length had negative correlations with TD ($r = -0.012$) and HW ($r = -0.006$).

4.3.3 Principal Component Matrix

The Kaiser-Meyer-Olkin Measure of Sampling Adequacy was high for both young and adult sheep (0.941 and 0.787, respectively). While additionally the significance of the correlation matrices tested with Bartlett's Test of Sphericity for body dimensions of young sheep ($\chi^2 = 2409.85$, $p < 0.001$) and for adult sheep ($\chi^2 = 1278.02$, $p < 0.001$) provided enough support for application of Principal Component Analysis on the data set.

Table 4.3 Coefficients of correlation among morphometric traits in Zulu sheep in KwaZulu-Natal

Traits	BW	HG	WH	TD	BL	TL	TC	HL	HW	ShC	EL	RW	RL
BW		0.881**	0.831**	0.739**	0.843**	0.300**	0.781**	0.855**	0.661**	0.559**	0.318**	0.760**	0.734**
HG	0.742**		0.822**	0.756**	0.859**	0.331**	0.727**	0.819**	0.584**	0.606**	0.305**	0.787**	0.745**
WH	0.479**	0.428**		0.732**	0.824**	0.315**	0.707**	0.835**	0.656**	0.611**	0.341**	0.742**	0.732**
TD	0.459**	0.440**	0.441**		0.690**	0.377**	0.661**	0.750**	0.562**	0.527**	0.222**	0.610**	0.659**
BL	0.509**	0.457**	0.427**	0.340**		0.298**	0.688**	0.818**	0.675**	0.568**	0.329**	0.720**	0.702**
TL	0.184**	0.068^{ns}	0.262**	0.155**	0.031^{ns}		0.443**	0.334**	0.340**	0.396**	0.086^{ns}	0.395**	0.385**
TC	0.530**	0.551**	0.307**	0.273**	0.312**	0.017		0.699**	0.577**	0.568**	0.213**	0.638**	0.600**
HL	0.337**	0.244**	0.407**	0.320**	0.333**	0.279**	0.182**		0.702**	0.576**	0.348**	0.722**	0.713**
HW	0.228**	0.152**	0.222**	0.248**	0.319**	0.155**	0.129**	0.454**		0.452**	0.321**	0.531**	0.591**
ShC	0.384**	0.293**	0.208**	0.109*	0.287**	0.154**	0.231**	0.186**	0.154**		0.244**	0.664**	0.620**
EL	0.061^{ns}	0.023^{ns}	0.181**	-0.012^{ns}	0.083^{ns}	0.091^{ns}	0.005^{ns}	0.134**	-0.006^{ns}	0.051^{ns}		0.362**	0.270**
RW	0.407**	0.361**	0.300**	0.010^{ns}	0.248**	0.223**	0.186**	0.269**	0.073^{ns}	0.346**	0.151**		0.696**
RL	0.338**	0.245**	0.209**	0.207**	0.299**	0.168**	0.230**	0.204**	0.263**	0.383**	0.090*	0.467**	

^{ns} Values underlined are not significant. ** Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed). Upper Matrix = sheep with no permanent incisors yet (less than 14 months). Lower Matrix= Sheep with one permanent pair of incisors onwards (greater than 14 months). BW, body weight; HG, heart girth; WH, wither height; RH, rump height; TD, thorax depth; BL, body length; TL, tail length, TC, tail circumference; HL, head length; HW, head width; ShC, shin circumference; EL, ear length; RW, rump width; RL, rump length

Table 4.4 summarises the principal component weights derived from the correlation matrix of the 13 linear body measurements after a Varimax rotation. The coefficients presented show the relative contribution of each measurement to a particular principal component (factor), while the percentage of total variance is used as an index to determine how well the total component solutions account for what the variables (measurements) together represent. In young sheep two factors (PC1 and PC2) with Eigenvalues greater than 1 accounting for a total variance of 66.9% were extracted. Of the total variance, 38.7% was accounted for by PC1, which had high positive loadings for body weight, heart girth, wither height, thorax depth and body length, while PC2 with high positive loadings for tail length, tail circumference, head length, head width, shin circumference, rump width and rump length, accounted for 28.1% of the total variance. Fig 4.4 is the diagrammatic presentation of these associations. From the graph, EL and TL are seen outlying from the major two clusters, with one cluster constituting of TD, BL, WH, HG and BW and the other of HL, HW, RW, RL, TC and ShC. In adult sheep, four principal components (PC1, PC2, PC3 and PC4) accounting for 62.1% of the total variance were extracted. The first factor (PC1) explained 23.6% of the total variance and was characterized by relatively high positive loadings for body weight, heart girth, thorax depth, body length and tail circumference. The second factor (PC2) was more closely related to rump length, rump width and shin circumference, which explained 14.9% of the total variance. The third factor (PC3) was influenced by head width and head length and accounted for 14.1% of the total variance, while the fourth factor (PC4) had high positive loadings for ear length, tail length and wither height, contributing 9.6% to the total variance. The component plot of the first three factors in rotated space for body measurements of adult sheep is shown in Fig 4.5. The clustering of variables in adult sheep was not clearly defined. Communality (the proportion of common variance present in a variable) for all the body measurements in young sheep ranged from 0.18 (EL) to 0.88 (BW, HG) and from 0.46 (BL) to 0.80 (BW) in young and adult sheep, respectively.

Table 4.4 Eigen values, share of total variance along with factor loadings after Varimax rotation and communalities of the body measurements of Zulu sheep

	Young sheep			Adult sheep				
Traits	**PC1**	**PC2**	**Communality**	**PC 1**	**PC 2**	**PC 3**	**PC 4**	**Communality**
BW	0.90	0.27	0.88	0.75	0.44	0.16	0.13	0.80
HG	0.88	0.32	0.88	0.79	0.32	0.02	0.08	0.74
WH	0.87	0.28	0.83	0.43	0.02	0.30	0.58	0.61
TD	0.79	0.27	0.70	0.56	-0.19	0.43	0.08	0.54
BL	0.87	0.29	0.83	0.47	0.33	0.36	0.01	0.46
TL	-0.04	0.70	0.49	-0.10	0.14	0.36	0.60	0.52
TC	0.42	0.63	0.57	0.78	0.12	-0.01	-0.02	0.63
HL	0.61	0.62	0.76	0.22	0.13	0.68	0.34	0.64
HW	0.43	0.62	0.56	0.04	0.14	0.83	-0.09	0.72
ShC	0.31	0.72	0.61	0.20	0.68	0.07	0.00	0.51
EL	0.18	0.39	0.18	0.03	0.09	-0.17	0.72	0.56
RW	0.48	0.70	0.72	0.17	0.73	-0.03	0.37	0.69
RL	0.49	0.67	0.68	0.11	0.76	0.18	0.04	0.63
Eigen values	5.04	3.65		3.07	1.93	1.83	1.25	
% of total Variance	38.7	28.1		23.6	14.9	14.1	9.6	

Values underlined are ≥ 0.5; Measure of sampling adequacy = 0.941 and 0.787 for young and adult sheep, respectively. BW, body weight; HG, heart girth; WH, wither height; RH, rump height; TD, thorax depth; BL, body length; TL, tail length, TC, tail circumference; HL, head length; HW, head width; ShC, shin circumference; EL, ear length; RW, rump width; RL, rump length.

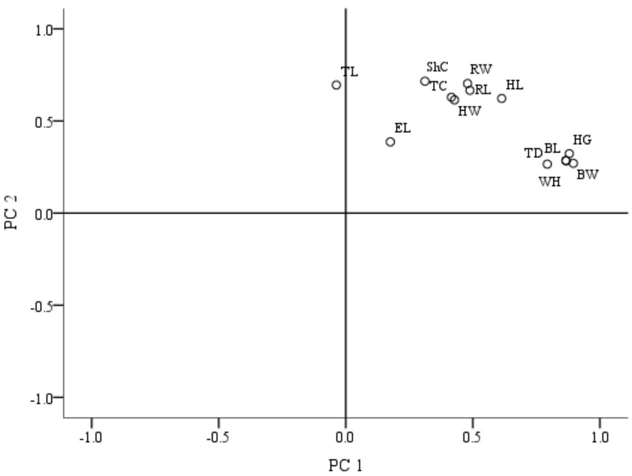

Fig 4.4 Projections on principal components (PC) of the factors and associations between body measurements after a Varimax transformation in young Zulu sheep. BW, body weight; HG, heart girth; WH, wither height; RH, rump height; TD, thorax depth; BL, body length; TL, tail length, TC, tail circumference; HL, head length; HW, head width; ShC, shin circumference; EL, ear length; RW, rump width; RL, rump length.

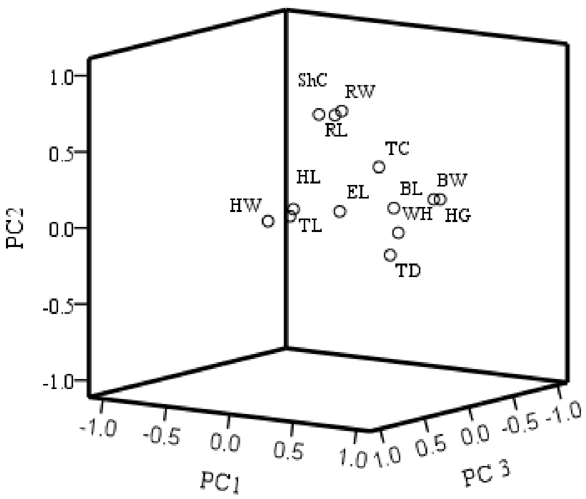

Fig 4.5 Projections on principal components (PC) of the factors and associations among body measurements after a Varimax transformation in adult Zulu sheep. BW, body weight; HG, heart girth; WH, wither height; RH, rump height; TD, thorax depth; BL, body length; TL, tail length, TC, tail circumference; HL, head length; HW, head width; ShC, shin circumference; EL, ear length; RW, rump width; RL, rump length.

4.3.4 Predictions of body weight of Zulu sheep from interdependent linear body measurements and their independent principal component scores

The inter-dependent original body dimensions and their independent principal component factor scores were used to predict body weight of Zulu sheep (Table 4.5). Results of the stepwise multiple regression analysis in young sheep revealed that heart girth alone accounted for 77.5% of the variation in body weight. Inclusion of wither height into the model increased the proportion of explained variance to 81.0%. The accuracy of the model was further improved to 82.3% when body length and thorax depth were added to the equation. The contribution of heart girth as highest single contributor (R^2 = 55.1) to the variation of body weight in adult sheep was relatively lower than that of young sheep (R^2 = 77.5%). However, the proportion of explained variance progressively increased to 60.8% when wither height, body length and thorax depth were added to the model.

Table 4.5 Stepwise multiple regression of body weight on original body measurements and their factor score in young and adult Zulu sheep

Model	Predictors	Models	R^2	S.E
Young sheep	Original body measurements as predictors			
1	HG	BW = 0.609HG - 19.48	0.775	4.2985
2	HG, WH	BW = 0.423HG + 0.333WH - 25.45	0.81	3.9597
3	HG, WH and BL	BW = 0.347HG + 0.258WH + 0.188BL - 26.459	0.819	3.8633
4	HG, WH, BL and TD	BW = 0.316HG + 0.225WH + 0.188BL + 0.140TD - 26.46	0.823	3.829
	Principal components as predictors			
1	PC1	BW = 8.11PC1 + 18.49	0.802	4.0351
2	PC1 and PC2	BW = 8.11PC1 + 2.45PC2 + 18.49	0.875	3.21
Adult sheep	Original body measurements as predictors			
1	HG	BW = 0.021HG - 27.18	0.551	5.44
2	HG and WH	BW = 0.022HG + 0.030WH-37.95	0.583	5.25
3	HG, WH and BL	BW = 0.631HG + 0.224WH + 0.224BL - 44.25	0.601	5.14
4	HG, WH, BL and TD	BW = 0.602HG + 0.184WH + 0.211BL + 0.198TD - 45.00	0.608	5.09
	Principal components as predictors			
1	PC1	BW = 6.76PC1 + 34.69	0.693	4.50
2	PC1 and PC2	BW = 6.76PC1 + 1.81PC2 + 34.69	0.743	4.12
3	PC1, PC2 and PC4	BW = 6.76PC1 + 1.81PC2 + 0.24PC4 + 34.69	0.744	4.12

BW, body weight; HG, heart girth; WH, wither height; TD, thorax depth; BL, body length;

The use of PC1 as a single predictor explained 80.2% and 69.3% of the total variability in young and adult sheep, respectively. Inclusion of PC2 to the model increased the proportion of explained variance to 87.5% and 74.3% in young and adult sheep, respectively. The best prediction equation (BW = 6.76PC1 + 1.81PC2 + 0.24PC4 + 34.69; R^2 = 74.4%) in adult sheep was obtained after PC4 inclusion into the model.

4.4 Discussion

Zulu sheep have a marked sexual dimorphism, as adult males are larger than females of the same age group for almost all measurements. Sexual dimorphism is a fundamental morphological component of angulates and has a bearing on population dynamics, ecology, behaviour and evolution (Esquivelazeta *et al.*, 2011). Moreover differences in morphological traits between male and female, sheep may reflect differences in the hormonal secretions and their activities in the two sexes (See images in Appendix 2).

The averages for BW (39.01), HG (83.06), WH (64.81) and SC (26.6) in mature males found in this study are similar to those reported by Kunene *et al.* (2007) for LW of 38 kg, HG of 80 cm, WH of 64 cm and SC of 27cm. Measurements similar to those reported in this study for mature ewes were also obtained by Kunene *et al.* (2007) (BW of 32 kg, HG of 76 cm and WH of 61 cm). Coefficients of variations (8.0% to 31.2%) were relatively higher than those obtained by Legaz *et al.* (2011) for Spanish Assaf.E sheep breed (3.7% to 15.0%), an indication of higher heterogeneity in Zulu sheep. Larger CVs for BW, TL, TC and EL concurs with the finding of Legaz *et al.* (2011). Large variation shown by higher standard deviations in some measurements is a result of absence of selection, or the fact that some body parts are affected differently by the environment than others. Heart girth, particularly, is usually affected by gut fill and is highly variable (Salako, 2006) (See young sheep in Table 4.1). Head length and width being cephalic measurements portray very little variability due to their close association with cranial bone. The wither height measurements of 52.7 and 62.6 cm were close to rump height measurement of 54.21 and 63.77 cm, in both young and old sheep, respectively, an indication that the animal is not sloping when standing (Salako, 2006).

It was expected that heart girth, wither height, thorax depth and body length would produce high correlations with body weight, as similar findings have been reported elsewhere (Salako, 2006; Kunene *et al.*, 2009; Yakubu and Ayoade, 2009; Taye *et al.*, 2010). Positive and highly significant ($p < 0.05$) correlation among body measurements indicate high predictability (Salako, 2006). Apart from using these as predictors of body weight, their selection in breeding programs can result in remarkable body weight improvement. However heart girth manifested even higher correlation coefficients with body weight in both age groups, explaining why some researchers have advocated the use of heart girth as a sole predictor of body weight (Kunene *et al.*, 2009; Yakubu and Ayode, 2009). Lower correlation coefficients existing between ear length and tail length with other body traits are also notable in the correlation matrix (Table 4.2). These traits are determined by non-additive genetic effects, and are presumably less influenced by the environment. Therefore selecting them in breeding programs will not lead to significant improvement of body weight and other measurements that are of economic importance.

The finding that young sheep had relatively higher correlation coefficients amongst body measurements than adult sheep is a reflection of predominant metamorphic growth at this stage (Salako, 2006), where a change in one measurement results in a direct change in the other. Marker and Dickman (2003) have shown that in mammals each body measurement develops at a different rate at different ages. A confirmation of this assertion can be seen in significance of morphometric differences between age groups presented in Table 4.2. Certain body parameters are early maturing and stop growing before others, which explains the lower correlation coefficients obtained in adult sheep. The fact that most adult sheep used in the current study had reached the plateau of their growth brought about lower variation in body measurements, therefore differences observed at this stage were genetic and environment related and less age related. Yakubu *et al.* (2010) ascribed the varying estimates of correlation among variables to the fact that post natal growth does not take place proportionally in all tissue categories and body regions. The author asserted that, instead, it gives preference in the different growth phases of particular tissue type or body regions within those tissue categories.

Size and body conformation are important traits to most sheep producing farmers and are presumably under strong selection in most breeds. However as has been mentioned earlier by Ramsey *et al.* (2000) and Kunene *et al.* (2009), Zulu sheep have not been subjected to intense selection, hence the within breed variation they portray is as a result of their presumed broad genetic pool.

Principal component analysis determines the variability of individual traits and how these contribute towards the total morphostructural variance of the animal, thus giving an informative outline on which traits can be improved with much success through selection. The measurements (body weight, heart girth, wither height, thorax depth and body length) associating with PC1 in both young and adult sheep in the current study are by themselves good descriptors of general body size. Their high association with PC1 signifies that they make the greatest contribution towards total variation of morphological structure of the animal. While body measurements (rump width, rump length and shin circumference) associating with PC2 were good descriptors of body shape and are grouped as second largest contributors towards morphological variance. PC3, due to high loadings for head length and head width, can be named head size and are ranked third largest contributors.

The finding that each principal component is an association of related morphometric traits defining certain body dimensions of the animal is of importance in breeding programmes. , i.e. PC1, PC2, PC3 defines body size, body shape and head size, respectively. Since principal components are uncorrelated by definition, body size is not related to body shape and head size. Thus selection to improve body shape, an important target for meat production (Salako, 2006) implies little variation in sheep size and head size. Hence, breeders could improve body shape in order to better meat production traits and maintain an animal's body size suitable for walking longer distances and survival in the harsh environmental conditions of KwaZulu-Natal.

Tail length had a negative coefficient (-0.04) for PC1 (the component that contributed most towards total variance) while ear length had coefficients less than 0.4 for either of the extracted components in young sheep; an indication that ear length had very low contribution towards total variance. Similarly in adult sheep tail length and ear length had high correlations with PC4 (the least contributing factor towards total variance). This suggests that very little improvement can be accomplished on these traits if they can be used as selection criteria in breeding programmes. Thus principal component analysis is an important tool, not only in that it reduces data, but that it identifies traits that can be selected with much success in breeding programs.

The percentages (66.9 and 62.1%) of variation explained by PCA in young and adult sheep in this study are lower than those reported by Yakubu *et al.* (2010) of 79.0 and 86.5% in young and adult Fulani cattle, respectively. This is an indication that more conformational variation was left unexplained in the present study. This could be attributed to wider geographical area from which samples were collected and the wide age ranges used for both age groups. Brooks *et al.* (2010) ascribed the remaining unexplained variation to segregation of casual alleles at contributory loci, measurement error and environmental factors. Hence higher percentages of explained variation could have been obtained if sampling for this study had been restricted to a single representative population and age group for both young and adult.

The present findings are in agreement with the observation of Salako (2006) in immature Uda Sheep of Nigeria who showed that the first factor which explained the highest percentage of total variance had high loadings for traits related to body size, while PC2 associated with traits depicting body shape. Also similar to this study are the findings of Yakubu and Ayoade (2009) in Nigerian domestic rabbits who reported that the first factor was characterised by high positive loadings of all body measurements except ear length. The variables which associated with body length had the highest loading, followed by thigh circumference and heart girth in Yakubu and Ayoade (2009) study.

The higher number of factors extracted in adult sheep compared to that obtained in young sheep is attributable to high correlation coefficients observed in the original measurements of young sheep (Table 4.2). Manly (1994) underlined that high correlations among measured variables are a precondition for carrying out principal component analysis. The extent to which a set of variables decomposes into fewer factors by principal component analysis depends on the level of redundancy (correlations) in original variables.

Body weight increase in sheep production is one of the essential goals of improvement programmes, which requires adequate knowledge of correlated traits that can be considered when selection is to be applied (Ogah, 2011). The importance of HG in weight estimation demonstrated in the present study could be as a result of the fact that muscle, and some fat along with bone structure contribute to its formation (Okpeku *et al.*, 2011). Several authors in similar studies have concluded that heart girth can be used as a sole predictor of body weight due to high associate regression coefficients obtained (Kunene *et al.*, 2009; Taye *et al.*, 2010). This however has limitations of multicollinearity that are usually found when using linear traits, rendering weight prediction unreliable. Thus the use of PCA factor scores, which are orthogonal and not correlated, is usually advocated (Ibe, 1989; Yakubu and Ayoade, 2009; Ogah, 2011). The current study was able to demonstrate that the use of principal components (PC1, PC2 and

PC4) was more appropriate than the use of original correlated variables in predicting body weight. This concurred with findings of (Keskin *et al.*, 2007; Yakubu and Ayoade, 2009).

4.5 Conclusions

The principal components extracted in both age groups determine the sources of shared variability which explain body conformation in Zulu sheep. These components represent the general body size, shape and head size of the breed. The communalities estimates indicated that ear length and tail length did not contribute effectively to explaining body size and conformation in young sheep. Traits with higher communalities in either age group could be considered in explaining body size and conformation in Zulu sheep. These may be related to environmental components, different association of each measurement with bone, or time taken to reach maturity. The use of principal components (PC1, PC2 and PC4) was more appropriate than the use of original correlated variables in predicting body weight of Zulu sheep as multicollinearity problems were eliminated which can lead to unstable regression coefficients, hence erroneous inference.

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CHAPTER 5

MORPHOLOGICAL DIFFERENTIATION OF EIGHT ZULU SHEEP POPULATIONS USING CANONICAL DISCRIMINANT ANALYSIS

(This chapter was submitted to Tropical Animal Health Production)

Abstract

The characterization of genetic variability among populations of a breed is prerequisite for its effective long-term management. Thirteen morphological variables and eleven qualitative traits were used to evaluate genetic variation among eight Zulu sheep populations obtained from rural areas of KwaZulu-Natal. Dark brown was the most prevalent coat colour, occurring in either solid or mixed with white. Univariate analysis of body measurements showed a significant morphostructural variation among populations. Sheep from Nqutu measured highest in most morphometric traits while Empangeni sheep measured lowest. Discriminant analysis identified rump-width, head-width, heart-girth, thorax-depth and tail-length as the most discriminative variables to differentiate among the studied sheep populations. Mahalanobis distance was shortest between Empangeni and Nongoma sheep populations (3.16) and largest between Nqutu and Empangeni (20.37) populations. Nqutu sheep population generally had the furthest distance to all other sheep populations. Cluster analysis revealed two major groups, one formed by Empangeni, Mtubatuba and Nongoma, the other by Jozini, Msinga and Eshowe populations. Estcourt and Nqutu joined these major groups as individual entities at distance. About 62.0% of individual sheep were correctly classified into their original populations. Nqutu had the highest percentage (88.9%) of correct assignment. Mtubatuba had the lowest (46.7%). The results revealed significant polymorphism among Zulu sheep populations, both in terms of qualitative and morphometric traits, inferring a considerable genetic variability. Maintaining this genetic variation is very important for the continuity of the breed, as it provides animals with options to respond to change in climate, disease or consumer preference.

Key words: Morphometric, Multivariate, Body measurements, Sheep morphology, Genetic variability

5.1 Introduction

The characterization of genetic variability among populations of a breed is prerequisite for its effective long-term management. (Rege and Lipner, 1992; FAO, 2007). Sheep like all other livestock species are recognised as important components of livestock biodiversity. In the rural communities of KwaZulu-Natal, South Africa, where livestock provides a livelihood for the majority of the population, indigenous livestock breeds form the backbone of livestock production because of their ability to survive and produce under hash environmental conditions (Kunene and Fossey, 2006).

Several authors have given a brief history of its establishment in KwaZulu-Natal (Ramsey *et al.*, 2000; ARC, 2001; Kunene *et al.*, 2007; du Toit, 2008). When the Nguni people migrated down the east coast of Africa between 200 and 400 AD they brought with them Nguni sheep (Kruger, 2001). The settlers dispersed to occupy different locations, leading to division of the flock into now known three groups; the Pedi sheep in Sekukunniland, the Swazi sheep in Swaziland and the Zulu sheep in KwaZulu-Natal (Kunene *et al.*, 2007). Further dispersal of the settlers (together with their sheep) into different locations of KwaZulu-Natal has led to the formation of isolated subpopulations raised in different ecological, socio-cultural and management environments. It is quite possible that these subpopulations may have developed into different “types” of Zulu sheep. As in speciation, the formation of distinct sub-breeds requires a group of animals to be reproductively isolated and to become distinct (Hall, 2004). Nevertheless the extent to which these sheep populations vary genetically has not been documented. Such information is essential for the development of appropriate breeding and conservation programme of the breed. Moreover, information obtained from the characterization process would contribute significantly in defining the morphological standard of Zulu sheep from both variability and the mean point of view.

Earlier studies conducted by Kunene *et al.* (2007) on the morphological characterization of Zulu sheep have been restricted to the use of analysis of variance, whereas the current trend in livestock classification involves the use of multivariate statistical tools (Yakubu *et al.*, 2010). Canonical discriminant analysis of morphometric traits has been used in evaluating variation within and between breeds. It discriminates different population types when all measured morphometric variables are considered simultaneously (Traoré *et al.*, 2008). Its use has been extensively applied in goats (Jordana *et al.*, 1993; Herrera *et al.*, 1996; Capote *et al.*, 1998; Zaitoun *et al.*, 2005; Dossa *et al.*, 2007; Traoré *et al.*, 2008). However, few such studies exist in sheep (Riva *et al.*, 2004; Carneiro *et al.*, 2010; Legaz *et al.*, 2011), and have not been particularly conducted in Zulu sheep.

The aim of this study was therefore to quantify genetic variability among Zulu sheep populations in different geographical locations of KwaZulu-Natal based on morphostructural characteristics. The objective being to determine if these populations have disintegrated into distinct groups.

5.2 Methods and Materials

5.2.1 Data collection

Quantitative data used in the study was collected as described in chapter 4. Thirteen body measurements were used; these were; body weight (BW), heart girth (HG), thorax depth (TD), body length (BL), wither height (WH), rump length (RL), rump width (RW), tail length (TL), tail circumference (TC), shin circumference (ShC), head length (HL), head width (HW) and ear length (EL). All measurements were obtained from 777 adult sheep. To avoid age effects, only sheep with two pairs incisors and above were considered.

Records were also taken on coat colour, face colour, presence or absence of horns, shape of horns, orientation of horns, type of ears, orientation of ears, coat colour, presence or absence of wool/hair, wool hair distribution, colour of hoof, face profile, rump profile, back profile, and tail type.

5.2.2 Statistical analysis

The SPSS statistical package version 19 (SPSS, 2010) was used for all the data analysis. Mean comparison for each biometric characteristic for different populations was done using univariate analysis of variance of the General linear model of SPSS. Pair wise comparison of means was done using the Turkey’s method. Frequencies for each level of the qualitative traits were calculated using crosstabs of descriptive statistics of SPSS.

Multivariate technique involved the use of canonical discriminant analysis on body weight and the original 12 primary linear body measurements of Zulu sheep. The standardized discriminant function was used to screen for the most discriminating variables among areas. Wilks` lambda was used to test the significance of the discriminant function while the Bartlett`s V transformation of lambda (chi-square statistic) was later used to compute the significance of lambda. For area identification, the unstandardised discriminant function procedure was employed. Means were computed for each variable per area. The means obtained were then used to group Zulu sheep in clusters, using SPSS hierarchical cluster analysis. The ability of this function to identify group membership is indicated as the percentage of individuals correctly classified from the sample that generated the function. The robustness of the function was validated using split-sample validation of the SPSS package (SPSS, 2010).

5.3 Results

5.3.1 Qualitative traits

Table 5.1 shows frequencies of each level of the eleven qualitative traits recorded in each of the areas studied. Pooled percentages for each studied area are also given. Dark-brown colour was the most predominant colour in Zulu sheep, being either solid or mixed form. Solid dark brown (26.6%) was overall the most common, followed by dark-brown patched with white (23.9%) and brown patched with white (17.5%). Other colours found, in descending order of occurrence were brown (6.9%), fawn (6.8%), black and white (5.6%), fawn and white (5.1%), white (3.4%) and black (1.5%). Sheep from Eshowe were the only population that was predominantly fawn coloured. Seventy three per cent of animals studied in all sheep populations were polled and 26.9% were horned. Of the horned sheep, those with bud horns dominated in all areas studied, except for Nqutu which was dominated by curved horns (66.1%). In total, spiral shaped horns (14.5%) occurred least compared to buds (49.7%) and curved horns (35.8%) (Fig 5.1). However Sheep with spiral shaped horns were proportionately higher in Jozini (33.3%), Msinga (31.1%) and Empangeni (33.3%) than sheep with curved horns. Very few incidences of sheep with gopher ears (2.0%) were identified. The greatest proportion of sheep studied had natural ears (78.2%) while 19.7% of sheep had elf ears (Fig 5.2). Ear orientation was found to be either horizontal (70.3%) or dropping (28.9%). Greater percentages of sheep with dropping ears were found in Eshowe (100.0%) and Empangeni (90.5%) whilst sheep with horizontal ears dominated in Jozini (55.3%), Msinga (85.7%), Estcourt (77.2%), Nongoma (60.8%), Nqutu (87.6%), and Mtubatuba (56.1%). Sixty six per cent of the animals sampled were straight faced whilst 23.9% and 9.8% were convex and concave faced, respectively. Backs were straight (73.9%) in most animals studied. The coat of Zulu sheep was found to be coarse, covered mainly with a mixture of hair and wool (84.8%). Some animals were however covered with hair only (14%) whilst only 0.8% was covered with wool only. The greatest proportion comprised sheep with grey hoofs whilst variegated (grey and white) and white woofs were less common. The tail type was predominantly long fat (39.5%) and long thin (33.7%) across all populations studied. Empangeni however had a relatively high proportion of short fat tails (33.3%) and all other tail types were fairly represented. Estcourt sheep tail types were all long thin except for 2.0% which had docked tails.

Fig 5.1 Different shapes of horns found in Zulu sheep: a) spiral, b) buds and c) curved

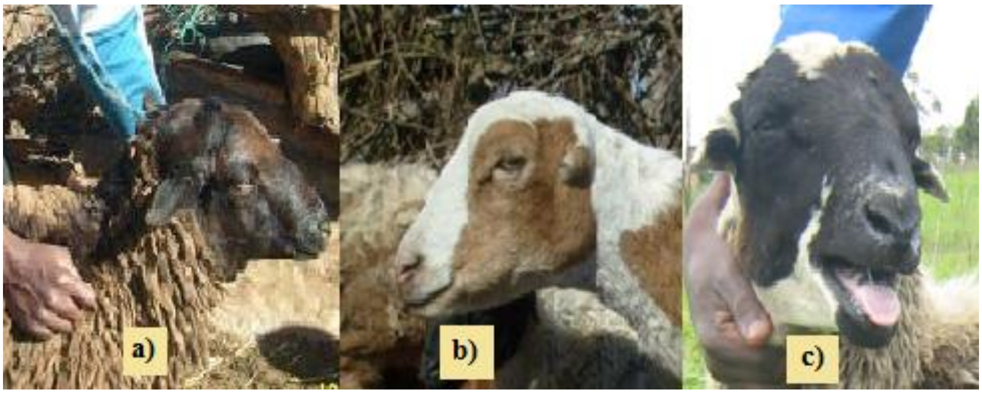

Fig 5.2 Different types of ears found in Zulu sheep: a) natural ears, b) gopher ears and c) elf ears

Table 5.1 Percentages of class levels of qualitative traits scored in Zulu sheep per area studied in KwaZulu-Natal

Traits	Class level	Jozini	Msinga	Eshowe	Estcourt	Nongoma	Empangeni	Nqutu	Mtubatuba	Overall
Horns	Absent	85.4	69.4	83.3	0.0	74.2	71.4	68.4	80.5	73.1
	Present	14.6	30.6	16.7	100.0	25.8	28.6	31.6	19.5	26.9
Horn Shape	Curved	19.0	22.2	100.0	0.0	26.1	16.7	66.1	25.0	35.8
	Spiral	33.3	31.1	0.0	0.0	4.3	33.3	1.8	0.0	14.5
	Buds	47.6	46.7	0.0	100.0	69.6	50.0	32.1	75.0	49.7
Ear Type	Gopher	4.6	0.6	0.0	0.0	7.3	0.0	0.0	0.0	2.0
	Natural	59.6	70.3	100.0	94.1	65.0	66.7	96.6	78.0	78.2
	Elf	35.8	29.0	0.0	5.9	27.6	33.3	3.4	22.0	19.7
Ear Orientation	Horizontal	55.3	85.7	0.0	77.2	60.8	9.5	87.6	56.1	70.3
	Dropping	44.7	14.3	100.0	22.8	39.1	90.5	12.4	43.9	28.9
Face Profile	Straight	50.0	72.3	100.0	59.4	72.4	66.7	71.9	65.9	66.3
	Convex	43.8	18.1	0.0	40.6	14.6	19.0	14.0	14.6	23.9
	Concave	6.2	9.7	0.0	0.0	13.0	14.3	14.0	19.5	9.8
Back Profile	Straight	45.8	72.9	100.0	84.4	79.7	90.9	77.9	70.6	73.9
	Convex	45.8	16.9	0.0	4.4	15.6	9.1	14.7	17.6	18.9
	Concave	8.3	10.2	0.0	11.1	4.7	0.0	7.4	11.8	7.2
Coat Colour	Dark-brown	37.9	25.7	22.7	26.7	14.6	27.3	28.1	9.0	26.6
	Brown	12.1	6.4	9.1	7.9	7.3	2.3	1.1	5.1	6.9
	Fawn	3.7	6.9	68.2	4.0	11.4	6.8	2.2	6.4	6.8
	White	3.7	5.5	0.0	4.0	3.3	0.0	0.0	1.3	3.4
	Dark-brown and White	17.3	26.6	0.0	27.7	19.5	40.9	27.0	24.4	23.9
	Brown and White	17.3	17.3	0.0	16.8	28.5	4.5	11.2	29.5	17.5
	Fawn and White	2.9	5.0	0.0	7.9	7.3	0.0	1.1	19.2	5.1
	Black	1.5	1.4	0.0	2.0	0.0	2.3	2.2	1.3	1.5
	Black and White	3.7	4.5	0.0	3.0	7.3	11.4	12.4	2.6	5.6
	Other	0.0	0.7	0.0	0.0	0.8	4.5	14.6	1.3	2.7
Coat Texture	Fine	18.1	32.2	0.0	100.0	25.0	0.0	41.2	47.1	34.5
	Coarse	81.9	67.8	100.0	0.0	75.0	100.0	58.8	52.9	65.5
Wool/ Hair	Hair	27.8	1.7	0.0	22.2	18.8	18.2	0.0	29.4	14.4
	Wool	2.8	0.0	0.0	0.0	1.6	0.0	0.0	0.0	0.8
	Mixed	69.4	98.3	100.0	77.8	79.7	81.8	100.0	70.6	84.8
Hoof Colour	Grey	89.0	81.3	50.0	83.0	77.2	76.2	84.8	43.9	80.5
	White	4.1	3.2	8.3	7.0	7.3	0.0	2.2	12.2	4.8
	Variegated	6.8	15.5	41.7	10.0	15.4	23.8	12.9	43.9	14.7
Tail type	Long Fat	50.0	34.8	91.7	0.0	46.3	33.3	51.1	32.5	39.5
	Long Thin	24.7	31.6	8.3	98.0	42.3	19.0	5.1	30.0	33.7
	Short Fat	22.6	16.8	0.0	0.0	2.4	33.3	2.8	20.0	10.6
	Short Thin	2.7	1.3	0.0	0.0	8.9	14.3	1.1	2.5	3.0
	Docked	0.0	15.5	0.0	2.0	0.0	0.0	39.9	15.0	13.3

5.3.2 Quantitative traits

Marginal (Least-squared) means for body weights and linear body measurements by area are shown in Table 5.2. Generally body measurements among sampled sheep populations were statistically significant ($p<0.05$). Overall, sheep from Nqutu and Estcourt had the highest values for most of the analysed linear body measurements, while sheep sampled from Empangeni measured least in most traits. Sheep from Msinga, Nongoma and Mtubatuba showed to be statistically similar in most morphometric variables (HG, WH, RH, TD, BL, SC, TC, HW, ShC, RW and RL).

Table 5.2 Marginal means with standard errors (SE) for each of the body measurements of Zulu sheep in selected areas of KwaZulu-Natal

Traits	Empangeni	Jozini	Nongoma	Mtubatuba	Msinga	Eshowe	Nqutu	Estcourt
BW	27.8±0.41^{a}	35.1±0.43^{bc}	31.0±0.39^{ab}	31.4±0.43^{ab}	33.0±0.45^{bc}	37.0±0.42^{cd}	40.1±0.39^{d}	40.9±0.43^{d}
HL	17.6±0.22^{a}	19.3±0.22^{bc}	18.1±0.21^{ab}	20.0±0.22^{c}	18.3±0.21^{ab}	18.6±0.22^{abc}	20.2±0.21^{c}	18.9±0.21^{abc}
HW	11.3±0.12^{cd}	10.2±0.12^{b}	11.2±0.11^{bcd}	12.0±0.12^{d}	11.2±0.13^{bcd}	9.0±0.12^{a}	11.6±0.11^{cd}	10.6±0.11^{bc}
EL	8.6±0.25^{ab}	8.9±0.26^{ab}	8.3±0.28^{a}	10.5±0.25^{b}	8.8±0.25^{ab}	9.8±0.26^{ab}	10.3±0.25^{ab}	9.8±0.28^{ab}
HG	70.8±0.34^{a}	81.3±0.34^{cde}	78.4±0.34^{bcd}	76.2±0.35^{b}	78.7±0.34^{bcd}	82.7±0.35^{def}	84.8±0.32^{ef}	86.3±0.34^{f}
WH	58.3±0.37^{a}	63.7±0.37^{cd}	62.1±0.36^{abc}	61.0±0.37^{abc}	60.9±0.37^{abc}	60.1±0.37^{ab}	67.0±0.35^{d}	61.2±0.37^{abc}
TD	31.9±0.23^{ab}	33.3±0.22^{bc}	31.9±0.21^{ab}	32.1±0.22^{ab}	31.1±0.22^{ab}	34.7±0.22^{cd}	35.9±0.21^{d}	30.2±0.22^{a}
BL	58.2±0.32^{a}	62.7±0.33^{b}	62.5±0.32^{b}	63.1±0.34^{b}	63.7±0.33^{b}	62.5±0.33^{b}	68.5±0.33^{c}	65.8±0.33^{bc}
RH	61.3±0.37^{ab}	65.6±0.37^{b}	63.4±0.36^{ab}	60.8±0.38^{a}	62.8±0.37^{ab}	61.0±0.37^{a}	68.9±0.37^{c}	62.5±0.36^{ab}
RW	15.7±0.26^{abc}	17.7±0.25^{bce}	15.7±0.26^{abc}	15.6±0.26^{ab}	14.4±0.26^{a}	14.0±0.26^{a}	17.2±0.25^{abc}	18.5±0.29^{d}
RL	20.5±0.30^{ab}	20.9±0.27^{ab}	21.5±0.33^{ab}	20.5±0.33^{ab}	20.1±0.31^{a}	21.6±0.32^{ab}	22.5±0.30^{ab}	22.8±0.34^{c}
ShC	8.2±0.16^{a}	9.2±0.15^{ab}	9.1±0.19^{ab}	8.7±0.17^{a}	8.6±0.17^{a}	9.0±0.15^{ab}	9.5±0.17^{ab}	10.3±0.19^{b}
TC	17.8±0.64^{a}	24.4±0.66^{bc}	20.4±0.67^{ab}	20.3±67^{ab}	26.1±0.70^{bc}	27.5±0.67^{c}	24.9±0.66^{bc}	21.6±0.67^{abc}
TL	28.5±0.68^{b}	27.9±0.65^{b}	31.0±0.84^{b}	29.1±0.75^{b}	21.7±0.74^{a}	29.1±0.75^{b}	30.8±0.73^{b}	28.7±0.82^{b}

^{a,b,c,d,e,f} row means with common superscripts do not differ (P> 0.05). HG, heart girth; WH, wither height; RH, rump height; TD, thorax depth; BL, body length; SC, scrotum circumference; TL, tail length, TC, tail circumference; HL, head length; HW, head width; ShC, shin circumference; EL, ear length; RW, rump width; RL, rump length.

5.3.3 Canonical discriminant analysis

Univariate analysis of variance revealed that there were significant differences in morphometric measurements among sheep populations studied. The data matrix was thus further subjected to canonical discriminant analysis for *post hoc* analysis. Out of 13 variables subjected to the analysis 10 were selected by stepwise discriminant procedure. These are shown in Table 5.3. All the selected variables were found to be significant in discriminating among Zulu sheep populations ($p < 0.001$). However, RW followed by HW, HG, TD and TL had more discriminant power as shown by their Wilks' Lambda, F to remove and tolerance ($1-R^2$) values.

Table 5.3 Morphological traits selected by stepwise discriminant analysis

Variable	Wilks' Lambda	F to Remove	P-Level	Tolerance
RW	0.18	16.186	0.001	0.583
HW	0.166	12.04	0.001	0.678
HG	0.155	9.954	0.001	0.621
TD	0.156	9.206	0.001	0.73
TL	0.153	8.347	0.001	0.853
HL	0.147	6.536	0.001	0.625
BL	0.147	6.476	0.001	0.686
TC	0.141	4.676	0.001	0.697
RL	0.14	4.382	0.001	0.617
EL	0.138	3.897	0.001	0.955

HG, heart girth; TD, thorax depth; BL, body length; TL, tail length, TC, tail circumference; HL, head length; HW, head width; EL, ear length; RW, rump width; RL, rump length.

Table 5.4 shows the highest possible correlation between morphological variables and canonical functions extracted by discriminant analysis. Respective eigenvalues and percentage contribution of each canonical function towards total morphometric variance are also shown in the same table. A total of seven canonical functions were extracted from 13 morphological traits (CAN1 to CAN7). CAN1 accounted for 43.8% of total variation followed by CAN2, CAN3, CAN4, CAN5, CAN6, and CAN7 representing 23.7, 12.1, 11.0, 5.1, 2.4, and 1.8% of the total variation, respectively. The first four canonical variates (CAN1 to CAN4) accounted for a total of 90.6% of the total variation. CAN1 had highest positive correlations with RW while it negatively correlated with BL and HW. CAN2 had high absolute correlations with TL, HG and TC. CAN3 had high positive correlations with TD and HL. CAN4 had high absolute correlations with variables; HL, HW, EL and BL. CAN5 and CAN6 were dominated by large loadings from ShC and RL, respectively. The eigenvalues obtained for corresponding canonical functions describe how much discriminating ability a function possesses.

Table 5.4 Total canonical structure of morphological variables of Zulu sheep obtained from eight populations in KwaZulu-Natal

	Canonical functions						
Variables	**CAN1**	**CAN2**	**CAN3**	**CAN4**	**CAN5**	**CAN6**	**CAN7**
RW	0.634*	0.218	-0.293	0.31	-0.25	-0.04	-0.30
TL	0.13	0.500*	0.012	0.09	0.41	-0.40	0.37
HG	0.36	-0.44*	-0.15	0.38	0.30	-0.43	0.18
TC	0.10	-0.44*	0.26	0.09	0.22	-0.18	-0.20
TD	0.16	0.11	0.55*	0.20	0.52	0.04	-0.08
HL	0.25	0.02	0.45*	0.34	-0.05	-0.03	0.31
BL	-0.01	-0.11	-0.03	0.692*	0.38	-0.15	-0.46
HW	-0.32	0.19	0.27	0.559*	-0.28	-0.20	0.27
EL	0.22	0.01	-0.06	0.551*	0.04	0.46	0.28
BW	0.28	-0.22	0.05	0.405*	0.29	-0.26	-0.08
WH	0.28	0.04	0.20	0.290*	0.17	-0.16	0.01
ShC	0.22	-0.16	-0.11	0.17	0.232*	-0.08	-0.09
RL	0.11	0.14	-0.34	0.16	0.225	0.362*	-0.03
Eigenvalue	1.197	0.649	0.331	0.300	0.141	0.065	0.050
% of Variance	43.8	23.7	12.1	11.0	5.1	2.4	1.8
Cumulative %	43.8	67.5	79.6	90.6	95.8	98.2	100.0

Variables ordered by absolute size of correlation within function. *Largest absolute correlation between each variable and any discriminant function. HG, heart girth; WH, wither height; RH, rump height; TD, thorax depth; BL, body length; TL, tail length, TC, tail circumference; HL, head length; HW, head width; ShC, shin circumference; EL, ear length; RW, rump width; RL, rump length.

Mahalanobis' distance matrix is given in Table 5.5. All pairwise distances were significant. The largest distance was between Nqutu and Empangeni (20.37) and the smallest distance was that between Empangeni and Nongoma populations (3.16). Nqutu sheep population generally had the furthest distance to all other populations although the distance was relatively smaller with Estcourt. The dendrogram obtained by cluster analysis is shown in Fig 5.3. Two major groups were shown to exist, one formed by Empangeni, Mtubatuba and Nongoma and the other by

Jozini Msinga and Eshowe. Estcourt and Nqutu joined these major groups as individual entities at distant, with the latter being furthest.

Table 5.5 Mahalanobis distance between Zulu sheep populations of KwaZulu-Natal based on morphometric measurements

	Estcourt	**Jozini**	**Msinga**	**Mtubatuba**	**Nongoma**	**Eshowe**	**Nqutu**
Estcourt	0.00						
Jozini	6.94	0.00					
Msinga	10.79	5.59	0.00				
Mtubatuba	8.82	7.50	6.53	0.00			
Nongoma	8.92	8.84	6.43	4.71	0.00		
Eshowe	4.96	6.33	11.77	5.15	7.48	0.00	
Nqutu	10.87	15.99	16.35	16.91	18.73	13.01	0.00
Empangeni	13.00	9.22	9.65	4.54	3.16	9.53	20.37

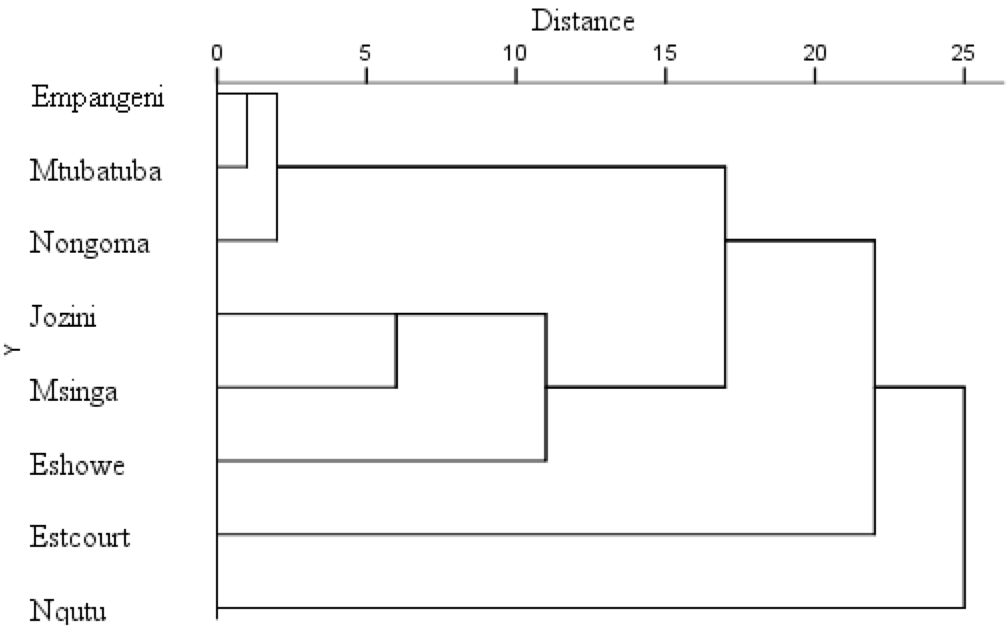

Fig 5.3 Phenogram showing the relationship between Zulu sheep populations

Discriminant function analysis was able to correctly classify 62.2% of individual sheep into their original populations (Table 5.6). Nqutu had the highest (88.9%) correct assignment and Mtubatuba had the lowest (46.7%). About 27.0% of sheep from Mtubatuba were classified as Nongoma, 13.3% as Empangeni and the other 13.3% as Jozini. Also worth noting was 18.2% misclassification of sheep from Eshowe as Nqutu and 13.0% as Estcourt. Jozini and Escourt shared a misclassification of 11.1%. While Empangeni had 18.2% of its sheep classified as Nongoma.

Table 5.6 Predicted group membership percentages of Zulu sheep populations in selected areas of KwaZulu-Natal by discriminant analysis

Area	Jozini	Msinga	Eshowe	Estcourt	Nongoma	Empangeni	Nqutu	Mtubatuba	Total
Jozini	63.9	5.6	9.7	11.1	4.2	0.0	4.2	1.4	100.0
Msinga	6.10	75.50	0.00	6.10	4.10	0.00	6.10	2.00	100.0
Eshowe	4.50	4.50	59.10	13.60	0.00	0.00	18.20	0.00	100.0
Estcourt	21.4	2.40	0.00	76.20	0.00	0.00	0.00	0.00	100.0
Nongoma	5.4	5.40	3.60	3.60	67.90	3.60	0.00	10.70	100.0
Empangeni	0.0	0.00	0.00	0.00	18.20	75.80	0.00	6.10	100.0
Nqutu	0.0	0.00	0.00	0.00	11.10	0.00	88.90	0.00	100.0
Mtubatuba	13.3	0.00	0.00	0.00	26.70	13.30	0.00	46.70	100.0

5.4 Discussion

González *et al.* (2011) clearly demonstrated that morphological (phenotypic) diversity is a good reflector of ecological selection regimes and history of a breed. In addition, Yakubu *et al.* (2010) points out that phenotypes are an expression of genetic characteristics, modified by environmental conditions and that variance in both genetics and environment may affect phenotypic variance. It is in the context of these assertions that this study exclusively depended on morphometric measurements, geographic locations and to some extent qualitative traits to unravel the characteristic of genetic diversity amongst Zulu sheep populations, which is most relevant for managing the present and future genetic diversity of the breed.

Very few references on morphological studies involving sheep in South Africa exist. Fourie *et al.* (2002) in a study to determine the relationship between growth performance of Dorper sheep under extensive conditions in Free State and Northern Cape, provinces in South Africa, gave a description of individual sheep with average height at withers of 63.7 and 62.9 cm, heart girth of 92.8 and 88.3cm and live weight of 57.5 and 50.8kg, respectively. Overall, the Dorper described was bigger than the Zulu sheep described by Kunene *et al.* (2007) in KwaZulu-Natal with WH of 64 cm, HG of 80 cm and BW of 38 kg. This was confirmed by the findings of the present study (see Table 5.2). Kunene *et al.* (2007) also found that gopher ears were less frequent amongst the populations, which this study also confirmed. However coat colour occurrences in Kunene *et al.* (2007) study did not seem to concur with findings of the current study. Brown followed by brown and white was the most dominant colour in their study whereas in this study dark brown and dark brown and white were identified to be the most predominant colours. This could be as a result of differences in naming the colours. What was identified as brown in Kunene *et al.* (2007) study could be what was termed dark brown in the current study. The authors also reported tan colour as one of the colours found in Zulu sheep, which was not used in the current study. This study concurred with Kunene *et al.*, (2007) in the high occurrence of polled sheep against the horned. Other qualitative traits presented in Table 5.1 were not studied by Kunene *et al.* (2007), but have been used extensively elsewhere in characterising small ruminants (Herrera *et al.* 1996; Traoré *et al.*, 2008).

Zulu sheep at Empangeni in the present study were found to be smaller sized compared to sheep from other areas. The results concurred the findings of Kunene *et al.* (2007) who reported that sheep at Owen Sithole College of Agriculture and KwaMthethwa (areas at Empangeni municipality) were smaller than those at Makhathini Research Station. Nqutu and Estcourt, on the other hand had outstandingly larger animals. The former being attributed to crossbreeding with exotic germplasm and the latter being as a result of improved management practices under which the flock is kept. Though not presented in the present study, the farmers at Nqutu reported to have crossbred their sheep with Merino and Dorper breeds whereas sheep in Estcourt are kept under semi intensive management practices where they receive supplementary feeding. This confirmed assertions by Kosgey *et al.* (2008) who indicated that good management practices and improved nutrition can bring about a remarkable improvement in productivity of the presumed less productive indigenous genetic resources. Similarly, Dossa *et al.* (2007) also hypothesised that much of the morphological variation is under genetic control and can respond to improved management practices. Kosgey *et al.* (2008) in Kenya have highlighted that by simple improvements in housing, feeding and basic prophylaxis and breeding practices the productivity of sheep under similar conditions increases significantly.

Although the univariate analysis of variance was able to show that there was significant variation in morphometric traits amongst Zulu sheep populations, canonical discriminant analysis, a multivariate technique, provided a better resolution. The analysis obtained tolerance values greater than 0.5, an indication that there was no collinearity problem among the 11 most discriminating morphological variables. The stepwise discriminant analysis selected rump width, head width, heart girth, thorax depth and tail length to be more powerful in discriminating among Zulu sheep populations. This means that taking these five basic measurements consistently could be more important in differentiating among Zulu sheep populations, than acquiring a substantial number of measurements. Some of the measurements selected in the present study are similar to those obtained by earlier researchers (Riva *et al.*, 2004; Carneiro *et al.*, 2010; Legaz *et al.*, 2011) in morphological differentiation of sheep breeds.

The first two canonical variables explained 67.5% of the total variation, a figure lower than that obtained by Traoré *et al.* (2008) of 100.0% in Burkina Faso sheep and that obtained by Zaitoun *et al.* (2005) of 93.1% in native goat breeds in Jordan. Such a low percentage implies that morphometric differences among populations in this study were not high enough to differentiate sub-populations into distinct breeds. This can be ascribed to the fact that morphological differences are maintained in part by high gene exchange between populations which occur among areas in close proximity. Whereas in both afore-mentioned cases, the researchers were able to clearly differentiate breeds or sub breeds by the canonical variates obtained. The low differentiation assessed among Empangeni, Nongoma and Mtubatuba sheep and Jozini, Msinga and Eshowe sheep using the Mahalanobis distance and the large classification errors obtained using discriminant analysis did not give enough statistical support to separate these sheep populations into different breeds. Implying that though the breed manifested great morphometric variation across populations, individual populations could not be singled out as separate types. Low differentiation among populations by Mahalanobis distances was supported by assignment test results, which classified correctly 62.2% of individual sheep to their original populations. Jimcy *et al.* (2011) ascribed such low assignment rate to either high gene flow between sheep populations or low power to assign because of too few variables used in the analysis. Large distances among Zulu sheep populations in general and among populations of Empangeni, Mtubatuba, and Nongoma and populations of Nqutu and Escourt in particular show noticeable morphological diversities. Nevertheless, relatively shorter distances among Empangeni. Mtubatuba and Nongoma and Jozini, Msinga and Eshowe appear to substantiate the assertion that morphological character systems are to some extent determined by similarities in ecological, geographical and historical variables. Due to spatial proximity to each other, sheep populations of Mtubatuba, Empangeni and Nongoma share some morphostructural similarity.

5.5 Conclusions

The present study revealed significant polymorphism, both in qualitative and morphometric traits, among Zulu sheep populations, inferring considerable genetic variability. Maintaining this genetic variability is very important for the continuity of the breed, as it provides animals with options to respond to change in climate, disease or consumer preference. Though canonical discriminant analysis was able to differentiate among sheep populations from different geographical locations, the total canonical variance could not fully support the hypothesis that these populations have disintegrated into sub breeds. Nqutu sheep population on the other hand, by discriminant analysis of morphological measurements could not be considered under the same grouping as the other Zulu sheep population. This was attributed to excessive inflow of exotic germplasm to the Nqutu population. The possibility of reversal of this population to pure Zulu sheep could be investigated by molecular genetics. Also molecular genetic characterization, which is currently underway, will hopefully help clarify the existing diversity amongst the populations and evolutionary history of the breed. This study also highlighted that phenotypic comparison based on morphological characters can provide a reasonable representation of genetic difference among populations. The present morphometric information could be used as the basis for further characterization and could also aid future decisions on the conservation and improvement of the Zulu sheep.

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CHAPTER 6

GENERAL DISCUSSION

Zulu sheep have over the years developed unique combinations of traits through adaptation to specific ecological, cultural and economic environments of KwaZulu-Natal. Due to the varied environmental characteristic of the province and the broad genetic pool upon which the flock was founded, the breed portrays great diversity within and between its populations. The fact that ecosystems are dynamic and complex, that human preferences change and that some elements of mismanagement are prevalent, will possibly result in the loss of genetic diversity of this breed if no measures are put in place to conserve it. Understanding the characteristics of Zulu sheep in its habitat is an essential step towards development of a sustainable breed improvement and conservation program. The present study was aimed at describing the production environment and the morphological structure of Zulu sheep from both mean and variability point of view. The findings of this study complement those of earlier studies on this breed (Kunene and Fossey, 2006; Kunene *et al.*, 2007; Kunene *et al.*, 2009) and can be used as a baseline to devise strategies for maximum utilization and conservation of the breed.

The finding that amongst interviewed farmers sheep were the least owned livestock species, after cattle and goats indicates that the breed is struggling. This was confirmed by the finding that the rate of decline of sheep flock sizes was higher than that of goats. Cattle on the contrary were reported to be increasing. This is a wake-up call to devise measures of counteracting the genetic decay. A state-monitored nucleus breeding scheme would be an ideal solution (Kunene *et al.*, 2011). Programmes for rapid multiplication and genetic improvement within the breed if promoted and supported would not only act as means of conserving the breed but would as well contribute towards improving livelihoods of farmers (Kunene *et al.*, 2011).

Most farmers began sheep production with an initial stock of three or fewer animals, either bought from other farmers or inherited. This shows that the genetic constitution upon which flocks were founded is narrow and the occurrence of inbreeding is widespread. Moreover, most farmers did not seem to have in place practices to control inbreeding, even though they showed awareness of its deleterious effects. The constraint would have been counteracted had flocks within the same community been mingled during grazing time (Kosgey *et al.*, 2008), but this study revealed that a large percentage of flocks occur in isolation or interact with very few neighbouring flocks. This tends to increase inbreeding and as a consequence, reduce fitness of the breed through inbreeding depression.

The information gathered during the study also showed that farmers highly value the Zulu sheep, for the reasons that it is resistant to diseases and is adapted to harsh environmental conditions of KwaZulu-Natal. This is an opportunity for the government and other interested stake holders to promote the conservation and improvement of the local breed. Farmers who are not satisfied with their breed may not be willing to put effort into improving it (Kosgey *et al.*, 2008). Inability of farmers to co-operate in programmes of conserving and improving the breed would hinder the success of the programmes.

The lower body weight of Zulu sheep implies that their market price may not be as competitive as that of other sheep breeds. However, their attribute of being adapted to the local harsh environmental conditions allows farmers to raise them at lower input levels. This renders raising the breed by the resource poor rural farmers more economically viable compared to the commercial breeds. The study confirmed the finding of Kunene and Fossey (2006) that Zulu sheep can survive on locally available feed resources without major supplements, vaccines and dipping. A slight improvement in terms of feed supplements and healthcare might produce considerable improvements in body weight and overall performance of this breed. This would mean higher live weights and higher returns from sales. Farmers would likely not adopt improved management practices whilst proceeds from sale of animals are low (Kosgey *et al*., 2008). Therefore improvement on performance of Zulu sheep would attract most farmers to actively participate in breeding programmes.

Results presented in chapter 4 provided further details to preliminary reports by Kunene *et al.* (2007) on morphological structure of the Zulu sheep. Males had relatively higher body measurements than females; a reflection of differences in the hormonal secretions and their activities in the two sexes. The principal component analysis technique was used to describe and consolidate the interdependence among thirteen morphometric traits of Zulu sheep. The coalition of traits into principal components (factors) was age dependent. In young sheep (no permanent incisors), two principal components were obtained which explained 66.9% of the total variance. Whereas in the older animals (two pairs of incisors and above), four factors explaining 62.1% of the generalized variance were extracted. The percentages obtained indicated morphological variability within the breed. This in turn reflects genetic variability. The measurements (body weight, heart girth, wither height, thorax depth and body length) associating with PC1 in both young and adult sheep in the current study are by themselves good descriptors of general body size. Their high association with PC1 signifies that they make the greatest contribution towards total variation of morphological structure of Zulu sheep. This means that their selection in breeding programs can result in remarkable responses to selection (R). Body measurements (rump width, rump length and shin circumference) found highly associating with PC2 are conformational in nature, and were indexed 'body shape' in this study. Head length and head width associated highly with PC3, and were indexed 'head size'. These extracted factors could be exploited in breeding and selection programmes to acquire highly coordinated animal bodies using fewer measurements (Yakubu *et al.*, 2009). The principal components extracted in this study can also be used in predicting body weight, counteracting multicollinearity problems that are usually encountered when using linear traits. Multicollinearity renders weight prediction unreliable.

Chapter 5 shows that there was significant polymorphism among Zulu sheep populations. This can be interpreted to mean that there is considerable genetic variability within the breed. Morphological variation among Zulu sheep populations provides a wide range of selection options for a breeding scheme. Reasonable heterosis would be realised if genetically distant animals from different populations are to be crossed. This will not only act as an improvement strategy but will also serve as a mechanism for conserving genetic diversity within the breed. Canonical discriminant analysis was able to differentiate among sheep populations from different geographical locations. Mahalanobis distances revealed two major groups, one formed by Empangeni, Mtubatuba and Nongoma, the other by Jozini, Msinga and Eshowe populations. Estcourt and Nqutu joined these major groups as individual entities at distance. The total canonical variance could not fully support the hypothesis that these populations have disintegrated into sub breeds. Nqutu sheep population, however, was found to be morphologically distanced from the other populations. This was ascribed to crossbreeding of the original Zulu sheep with Merino and Dorper sheep. Thus the population could not be classified under the same grouping as the other Zulu sheep populations. Molecular genetics can help investigate the possibility of reversing this population to pure Zulu sheep.

The result also revealed by stepwise discriminant analysis, that RW chronologically followed by HW, HG, TD and TL, had more discriminant power than other morphological variables measured. This means that these five basic measurements (RW, HW, HG, TD and TL) can be used, if taken consistently, in differentiating between the Zulu sheep populations than acquiring numerous additional measurements. Some of the discriminating variables obtained in the present study were similar to those reported in earlier studies (Herrera *et al.*, 1996; Dossa *et al.*, 2007; Yakubu *et al.*, 2010) on morphological differentiation of sheep and goats.

The results presented in this dissertation could be useful in formulating breed standards and judging panels for morphological evaluation for future selection and breeding improvement strategies. However, an investigation on the genetic characterization of Zulu sheep using microsatellite markers will complement the results obtained from morphometric differentiation. An intervention by Government in conjunction with the livestock owners would be most appropriate in designing and implementation of the improvement and conservation programme (Kunene *et al.*, 2011). *In situ* conservation would generally be more successful if benefits are felt at community level.

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APPENDICES

Appendix 1: Questionnaire used during the survey (Chapter 3)

University of Zululand

Phenotypic Characterization of Zulu Sheep in KwaZulu-Natal, South Africa: Implications for Conservation and Improvement.

QUESTIONNAIRE

1. GENERAL INFORMATION

Name of farmer…………………………..
Communal Area………………………

Date…………………………
Cell no………………………………...

Farm Type……………………
Number of members in household………
Source of income………………..
Major Species………………………...
Approximate age of farmer…………..

Number of Sheep………

Number of other Species
Goat………..Breed…………………..
Cattle……….Breed………………….
Chicken……..Breed…………………
Other………...Breed…………………

Do you know another farmer with Zulu Sheep?......................where…………………….
How many do they have……………………
Does your flock interact with other flocks from the neighbourhood? Yes/No
*If yes, with how many flocks?..........
*Is Livestock your major source of income? Yes/No
*What do you use sheep for? (x)

Meat	Sale	Manure	Other

Awareness regarding conservation of Animal Genetic Resources

No knowledge ( )	Minimal ( )	Average ( )	Well informed ( )

How do you value conservation of Farm Animal Genetic Resources?

Extremely Important ( )	Important ( )	Not Important ( )

Value of Zulu Sheep (as a farmer)

Extremely Important ( )	Important ( )	Not Important ( )

Give reasons for your answer……………………………………………………….

2. PRODUCTION SYSTEM

1.System of production (tick)

Intensive	…
Semi-intensive	
Extensive	
Freerange	
Other (specify)	

2. Housing

	Winter	Summer
Kraal		
Shed		
None		
Other (specify)		

3. Supplementary feeding?

(Yes/No) Specify type of feed if yes

4. How are sheep watered?

	Winter Season	Summer Season
Animal go to water		
Water is fetched and provided		
Both		

5. Source of water

	….	…..
Dam		
River		
Water well		
Bore Hole		
Spring		
Municipal		
Other (specify)		

6. Distance to water

	Winter	Summer
<1km		
1-5km		
At household		

7. Do you produce crops? (Yes/No)

If yes what type of crops……………

Do sheep obtain any nutrition from your cropping? (Yes/No)

8. Do you sell your sheep? (Yes/No)

(a) If yes, what determines your selling of sheep? (e.g need arises, system of production, culling)

....

(b) And which animals do you sell……………………(eg weaners, unproductive ewes)

(c) How much would you sale a mature (i) male...................(ii) female………………..

(d) Trend: Number of livestock owned

	5 yrs ago
Cattle	
Goats	
Sheep	

*(e) What are future plans for rearing sheep

………………………………………………………………………………………

*Sheep Mortalities

Year	2010	2009	2008	2007
Number of mortalities	Males………….. Females………. Lambs……….. Total…………	Males………….. Females………. Lambs……….. Total…………	Males………….. Females………. Lambs……….. Total…………	Males………….. Females………. Lambs……….. Total…………
Reasons for mortalities	…………………… …………………….... …………………… …………………… ……………………	…………………… …………………….... …………………… …………………… ……………………	…………………… …………………….... …………………… …………………… ……………………	…………………… …………………….... …………………… …………………… ……………………

3. BREEDING

1. Primary reasons for keeping rams

Breeding	Socio-Cultural	Other (specify)

2. Criteria for choosing a Ram

	Tick	Rank
Conformation/Shape		
Size		
Colour		
Horns		
Temperament		
Performance		
Availability		
Other (specify)		

3. Mating

Uncontrolled	….
Hand Mating	
Group Mating	
Other specify	

4. Source of Ram

Own (bred)	00
Own (bought)	
Donated	
Borrowed	
Communal Area Male	

5. Flock composition

Mature Rams	…………….
Mature Ewes	
Hoggets	
Lambs	
Total	
Lactating ewes	
Ewes with twins (2010-2011)	/

Where did you get Zulu sheep from?.......................How many founded the flock?…………

How related were they?……………………………………….(bought from the same flock/ bought from the same community/ bought from different communities)

When was the flock founded?..............

Any history of cross breeding (with exotic breeds) (Yes/No)

If yes specify year and with what breed?

………………………………………………………………………………………..

Farmer's awareness to inbreeding and its effects

No knowledge ( )	Minimal ( )	Average ( )	Well informed ( )

What methods are being used to control inbreeding……………………………………………………..

....

Willingness of the farmer to exchange rams as a way of controlling in breeding

Not willing ( )	Not so sure ( )	Willing ( )	Very willing ( )

4. HEALTH

Access to veterinary Service

Government Vet.	…………
Extension Service	
Veterinary drug supplier	
None	
Other	

External Parasite control

Done when need arises	.
Done routinely	
If done routinely specify	

Methods of External Parasite Control

Method	Tick	Frequency in Winter	Frequency in Summer
None			
Dip			
Spray			
Hand dressing			
Pour on			
Traditional			

Specify if traditional

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

Gastro-intestinal parasites Control

Done when need arises	…..
Done routinely	
If done routinely specify	

Method of internal parasite control

Metod	Tick	Frequency in winter	Frequency in Summer
None			
Drench			
Traditional			

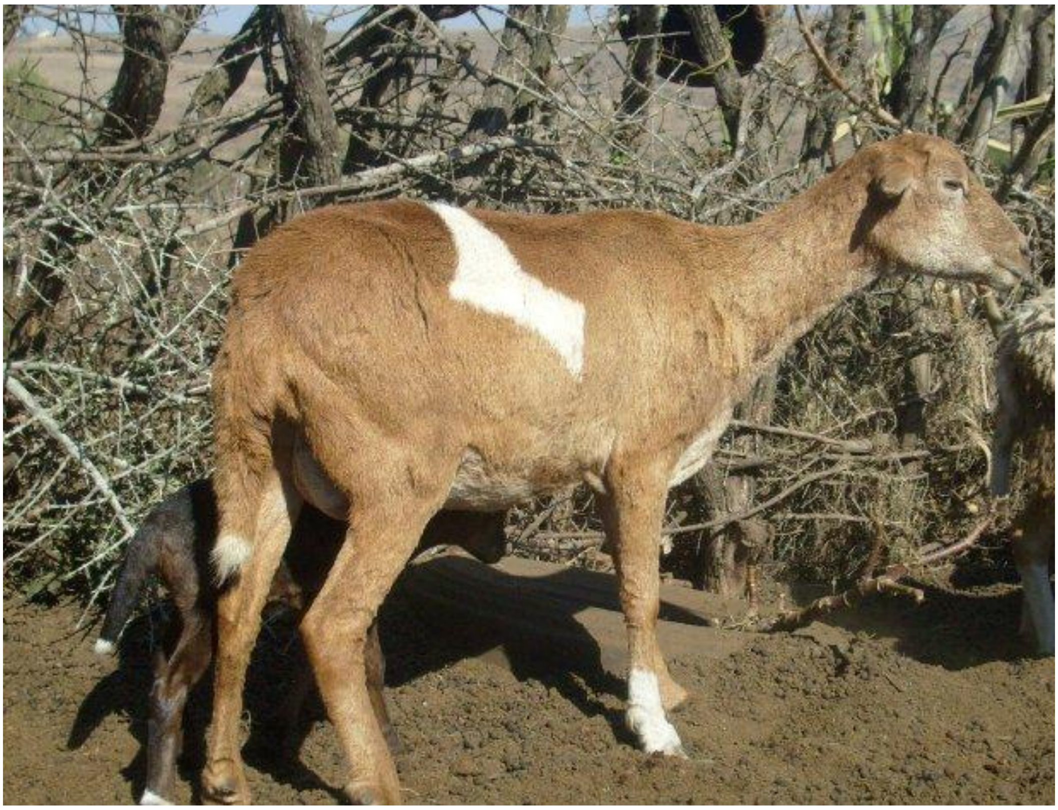
If traditional methods specify…………………………………………………………………..

Appendix 2: Images of Zulu sheep

Zulu sheep ewes


10/07/2010 04:21


11/07/2010 02:38




11/07/2010 02:37


10/07/2010 04:31


10/07/2010 01:44

Zulu sheep rams


10/07/2010 01:44

Zulu sheep flocks


11/07/2010 01:57


26/06/2010 02:45


09/07/2010 04:44