The effects of thicket transformation on the diet and body condition of Angora Goats

By

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Abstract

Climate change is predicted to have a negative effect on the rangelands of sub-Saharan Africa, affecting the distribution, productivity and extent of these rangelands. Similarly, Subtropical Thicket vegetation in the Eastern Cape, South Africa is expected to experience a reduction in plant growth with conditions becoming similar to those experienced under desertification. The transformation of thicket results in a decrease in perennial plant species cover and richness, which is replaced by an ephemeral layer of grasses and forbs. Assessing the responses of herbivores to this transformation thus allows the testing of the hypothesis that climate change and desertification will lead to a broadening of diet and a decline in secondary productivity. In this study, the diet and productivity of Angora goats in intact and transformed thicket in adjacent paddocks was investigated from August 2005 to July 2006. Faecal analysis was used to compare the diets of the Angora goats in the intact and transformed thicket treatments. Goats in the transformed treatment consumed a higher diversity of plant species (94 species) compared to those in the intact thicket (42 species). The higher species richness per faecal sample and the larger seasonal variation in plant species utilized by the goats in the transformed treatment reflected the variability of this treatment in response to rainfall. Dietary shifts to include less palatable species not found in the intact treatment diet were clear, but due to the high rainfall year an abundant ephemeral layer, comprising grasses and forbs, was available in the transformed treatment. The diet quality of the transformed treatment goats was higher, as indexed by faecal lignin, than the intact treatment goats, although there was no statistical difference in the NDF and ash levels between the treatments. There was however, more variation in the nutritional quality of the transformed thicket diet, as indexed by dietary phosphorous, showing that intact thicket retains a more constant nutritional level. There was no difference in the body condition and mohair production of the goats in the two treatments. The hypothesis of broadening of the diet was thus supported, but there was no evidence for the predicted decline in secondary productivity. This study was undertaken during an above average rainfall period and large quantities of nutritious ephemeral grasses were available in the transformed treatment. This resource would not be available in a drought; therefore goats in the intact thicket will likely perform better over longer periods; providing stocking rates are realistic. This is the first study to measure the response of domestic herbivores to transformation either in terms of resource use or production.

Contents

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Chapter One
General Introduction

1.1 Introduction

The United Nations Secretary-General, Ban Ki-Moon, recently called climate change "the moral challenge of our generation." Speaking at the 2007 United Nations Climate Change Conference in Bali he said, "Succeeding generations depend on us" and "we cannot rob our children of their future." This followed the dire warning from Kenyan Environment Minister Kivutha Kibwana at the 2006 conference held in Nairobi, Kenya that "Climate change is rapidly emerging as one of the most serious threats that humanity may ever face." Climate change will have a negative affect on the rangelands of sub-Saharan Africa, which represents up to 83% of the agricultural ecosystem of this area (Elasha *et al.* 2006). The general impacts of climate change will include a reduction in soil fertility, a decrease in livestock productivity through higher temperatures, and changes in the availability of feed and fodder. Together with these changes, there is the increased risk of pest attacks due to the increasing temperatures and therefore, the increase in pest related diseases (FOA 1999). Climate change models suggest that in general the African climate will become more variable. Since 1900 the mean surface temperature in Africa has only increased by 0.5º, yet there could be a rise of between 2-6ºC by 2100 (Hulme *et al.* 2001) and this will effect the distribution, productivity and extent of rangelands. For example, Rutherford *et al.* (1999) and WWF (2001) showed that the area occupied by Subtropical Thicket vegetation in the Eastern Cape, South Africa will undergo a major shift over the next 50 to 100 years, based on models of climatic scenarios. This climatic shift toward warmer weather also allowed for fewer days where soil moisture and temperature were suitable for plant growth, thereby also affecting productivity. At a species level, Robertson & Palmer (2002) predicted that 19.7% of the area where *Portulacaria afra,* the dominant shrub in pristine Subtropical Thicket (Stuart-Hill 1992), is currently found would become unsuitable for the species due to climate change.

Acocks (1975), United Nations (1978) and Roux & Theron (1987) all define desertification as a change from a more productive to a less productive state in an arid or semi-arid region, and it is therefore clear that climate change will lead to this. In addition, domestic herbivory has the potential to reduce the production potential of Thicket due to the feeding behaviour of goats differing from that of indigenous herbivores (Stuart-Hill & Danckwerts 1988). Goats have been shown to feed on the sides of bush clumps, which reduced vegetative recruitment, whereas indigenous browsers (dominated by elephants) have a top-down feeding approach which promotes vegetative reproduction (Stuart-Hill 1992). Aucamp & Tainton (1984) showed that the slow recovery of thicket plant species was also a factor; it might take up to 18 months for *P. afra* to recover from 50% defoliation to its pre-defoliation level. Sigwela (1999) and Sigwela (2004) also showed that more seeds are dispersed in thicket by indigenous browsers than by goats. There is an extensive amount of transformation within the Thicket Biome, which is at risk of being eliminated under current pastoral systems (Hoffman & Everard 1987; Hoffman 1989; Hoffmann & Cowling 1990; Stuart-Hill 1992). Lloyd *et al.* (2002) showed that up to 90% of some thicket types are severely transformed. Although defined in terms of productivity, desertification is most frequently described through change in plant cover and composition, and has clearly been recognised as occurring in the Eastern Cape Subtropical Thicket (Kerley *et al*. 1995).

1.2 Sundays Thicket

Sundays Thicket, one of the 112 vegetation types (Vlok *et al*. 2003) within Subtropical Thicket (Fig 1.1), is made up of a mosaic of tall shrub patches ranging from 2-50 m wide interspersed with lower vegetation and bare patches. Canopy trees such as *Pappea capensis, Euclea undulata* and *Schotia afra*, of less than 5 m tall make up these shrub patches together with succulent *Portulacaria afra* and woody spinescent shrubs such as *Azima tetracantha, Gymnosporia polyacantha, Putterlickia pyracantha, Rhigozum obovatum* and *Rhus longispina* (Vlok & Euston- Brown 2002; Vlok *et al*. 2003). These patches are dense, semi-succulent and thorny (Everard 1987) and have a high diversity of plant species and a range of growth forms (Cowling 1983). The understory usually consists of a diversity of dwarf succulent scrubs and forbs, usually belonging to the Crassulaceae, Mesembryanthemaceae and Aizoaceae families, which have a high frequency of endemism or rarity (Cowling 1983, Johnson *et al.* 1999, Vlok & Euston-

Brown 2002; Vlok *et al*. 2003). Even though the dominant portion of the vegetation consists of a semi-succulent shrub layer, of which most species are palatable, Acocks (1975) states that grass is a subordinate portion of the vegetation. There are certain useful grasses (from a pastoral perspective) that do occur in Thicket such

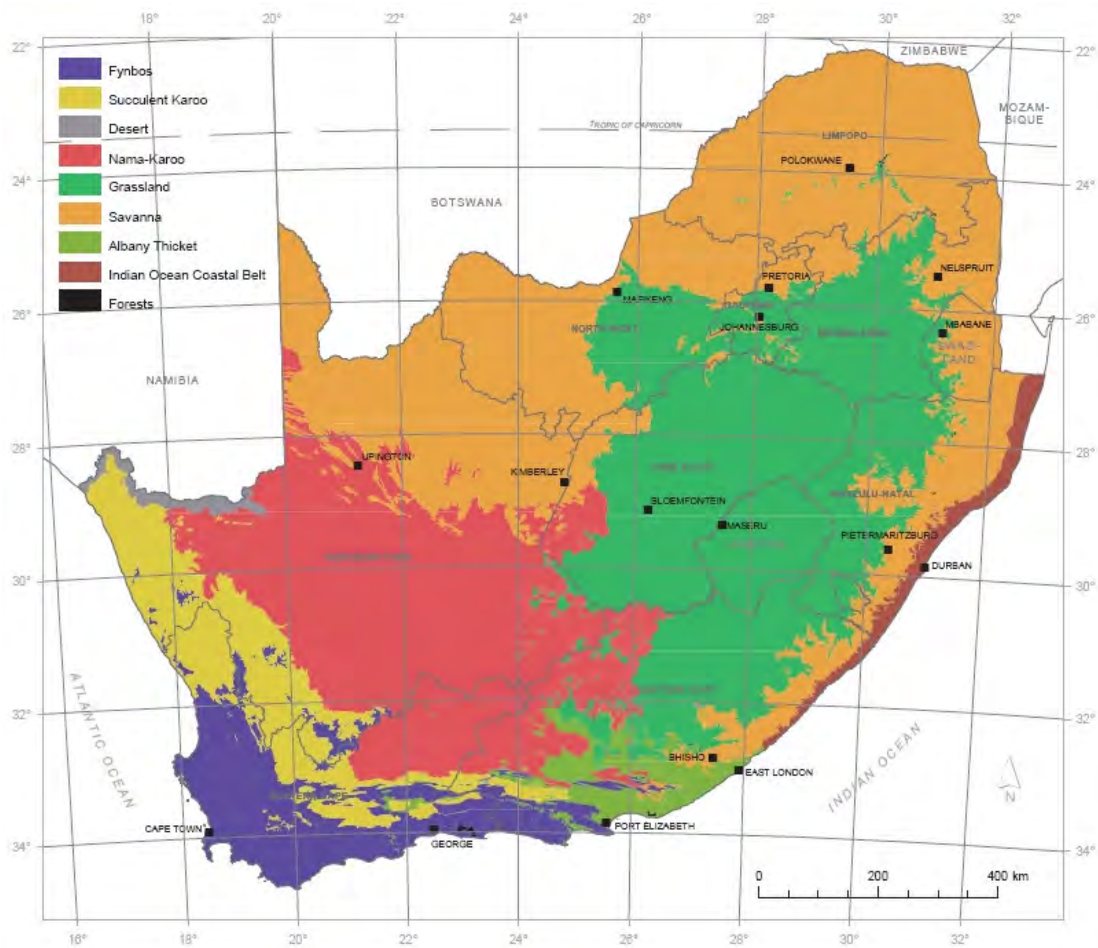

Figure 1.1 Vegetation Biomes of South Africa (from Mucina & Rutherford 2006), showing the distribution of Subtropical Thicket in the south east.

as *Digitaria eriantha*, *Setaria sphacelata*, *Sporobolus fimbriatus*, *Eragrostis curvula, Themeda triandra* and *Panicum spp*. These are sweetveld species and are able to produce a large quantity of forage within a short space of time (Aucamp 1976). During a dry season or drought this natural ephemeral grazing would decline or be absent (Stuart-Hill & Aucamp 1993), whereas there is little change in perennial cover or biomass of the browse component, irrespective of the variation in rainfall (Aucamp & Tainton 1984). Hoffman & Cowling (1990) showed a decline in the cover of tall and mid-high trees, shrubs and utilizable succulents and an increase in dwarf and low deciduous shrubs and ephemeral grasses and herbs under heavy grazing by domestic stock. The matrix of *Portulacaria afra* and other perennial shrubs are then typically replaced by karroid scrubs such as *Pentzia incana,* ephemeral grasses such as *Cynodon dactylon* (Vlok & Euston-Brown 2002; Vlok *et al*. 2003) and exotic African and Namib species (Hoffman & Cowling 1991). Du Toit (1973) describes this false karroid veld as 'useless', although this term is not a conventional ecological or agricultural term. The tree component of this transformed thicket is sparse and termed 'pseudo-savanna' (Lechmere-Oertel *et al*. 2005a). The rate of transformation increases once vegetation cover is reduced, as there is little shade for seedlings, and frost sensitive species have no protection from frosts (Stuart-Hill & Danckwerts 1988). Pioneer grasses do not replace the transformed veld and the desired shrub species are virtually impossible to re-establish (Du Toit 1973; Aucamp 1976; Hoffman & Cowling 1990).

The opening of the canopy also exposes leaf litter and soil to the elements, allowing for their dispersal (Lechmere-Oertel *et al.* 2005a). Lechmere-Oertel *et al.* (2005b) showed a decrease in soil fertility in transformed thicket, which they speculate will decrease the carrying capacity of thicket at a landscape level, there is also an increase in runoff due to the decrease of both organic matter in the soil and permanent leaf litter cover. Palmer *et al.* (1988) also found higher quantities of organic matter, moisture content, Mg, and Ca in soils protected under bush clumps compared to those in the open, due to protection from erosion.

Intact Thicket does not support a regular fire regime (Kerley *et al.* 1995). This is likely due to a high degree of succulence in thicket (Kerley *et al.* 1995) together with a low incidence of lightning (Manry & Knight 1986). Vlok & Euston-Brown (2002) suggest that the incidence of fire may be increasing due to the replacement of the succulent vegetation with more flammable vegetation in transformed thicket. Thicket vegetation is recognised as being vulnerable to transformation due to overgrazing by introduced domestic herbivores such as goats and cattle (Acocks 1975, Hoffman & Everard 1987; Kerley *et al.* 1995). Hoffman & Cowling (1990) demonstrated that overgrazing clearly reduces the cover and dominant perennial species are replaced with annuals, and as such the productivity is decreased. Stuart-Hill & Aucamp (1993) showed that even though thicket in an intermediate phase is able to sustain more grazers than pristine thicket, this is not a stable state as the grasses that the grazers rely on may not be present in drought years. This degradation reduces future management options as it does not regenerate, thus thicket degradation represents a desertified state (Stuart-Hill & Aucamp 1993).

The introduction of goats to Thicket does not seem to be the only problem leading to this transformation. The removal of other large herbivores seems to play an equally influential role. Sigwela (1999) demonstrated that indigenous kudu are more efficient seed dispersers than goats. Elephants too play an important role in maintaining vegetation structure and vegetative recruitment in *Portulacaria afra* (Stuart-Hill 1992). Kerley & Landman (2006) showed how elephants in thicket influence many processes, including plant biomass, landscape patchiness, nutrient cycling and soil features.

The response of herbivores to transformation is not well understood. The loss of secondary production potential (United Nations 1978), and the reduced ability to support herbivores (Kerley *et al*. 1995) in transformed thicket is as a result of a loss in primary production. The decline in grazing productivity, due to the loss of plant biomass (Lechmere-Oertel 2005a) and the replacement of palatable species by unpalatable ones (Hoffman & Cowling 1990) is expected to force herbivores to broaden their diet to include less preferred species resulting in decreased productivity.

A large portion of the South African mohair industry is based in the Thicket Biome (Stuart-Hill 1992). Van der Westhuysen (2005) showed South Africa is the leading producer of mohair in the world, with more that 60% of the product coming from South Africa. Over the past 15 years, mohair production has declined from approximately 26 to 6.6 million kg (Van der Westhuysen 2005). Angora goat farming is still an important farming practice in the Eastern Cape, and therefore the quality of the product must remain high for these mohair producers to retain their market share (Snyman 2002) and as the veld is the only natural source of food for these animals, it should be considered as the farmer's most valuable asset (Stuart-Hill 1992). Based on the above it is clear that the critical resource for pastoralism in Subtropical Thicket is at risk.

The Thicket Biome not only sustains the majority (80%) of South Africa's mohair production but provides a resource base for a number of income generating activities.

Ecotourism, in both private and public conservation areas, is reliant on an intact environment which can support wildlife. Hunting, and economic activities generated by hunters, generated in excess of R118 million in 2000. Similarly there is a reliance on thicket plant species, the Aloe sap industry relies on *Aloe ferox*, as does horticulture through the breeding and selling of thicket plants and the use of plant parts in traditional medicine (Sims-Castley 2002). It is therefore clear that the causes and consequences of thicket transformation should be well understood.

1.3 Research Rational

Patterns of plant community transformation are well documented in thicket (see review above). However, despite the clear recognition that intact thicket is a critical resource for pastoralism (Stuart-Hill & Aucamp 1993), no studies measure the response of domestic herbivores to transformation, either in terms of resource use or in terms of productivity. Therefore, this project seeks to assess impacts of desertification on resource use, quality and secondary productivity by answering the following key questions:

- What is Angora goat diet in transformed and intact thicket habitats?
- Is there a decline in nutritional value of forage available to Angora goats between these treatments?
- Is there a decrease in body condition of Angora goats in transformed habitats compared to those maintained in pristine thicket?
- Is there a decrease in Angora goat fleece quality and production in transformed habitats, compared to those maintained in pristine thicket?

1.4 Hypotheses

This study therefore addressed the following hypotheses, as a contribution to understanding the consequences of transformation in thicket:

- Goats on transformed habitats will have a broader diet than goats on the intact treatment.

  This is based on the recognition that the biomass of preferred, palatable plants species declines in transformed thicket (Hoffman & Cowling 1990, Stuart-Hill &

Aucamp 1993), and goats are therefore expected to have to include less preferred plant species in their diet.

- There will be a decline in diet quality of the goats on the transformed treatment compared to the intact treatments.

  This is an extension of the above hypothesis, as under optimal foraging theory goats are predicted to initially select the most nutritious and palatable plants and plant parts, and if these decline through transformation, then goats will need to ingest less palatable parts (e.g. more woody branches off preferred species) or species.

- Body condition and mohair production will be negatively affected by the poorer diet in the transformed site.

  This reflects one of the fundamental assumptions of the consequences of transformation or desertification, the decrease in productivity, and is an extension of the above two hypotheses.

The research approach undertaken here was to maintain two herds of goats in adjacent paddocks representing transformed and pristine thicket (described in Chapter Two), and measuring diet composition (Chapter Three), quality (Chapter Four) and goat performance in terms of body condition and mohair production (Chapter Five).

Chapter Two

Study Site and Animals

2.1 Location

This study was conducted on the farm Blaaukrantz (33.52241° S; 25.38031° E) in the Kirkwood district of the Eastern Cape Province of South Africa (Figure 2.1). The particular site was selected as it provided an outstanding example of a desertified landscape adjacent to thicket habitat in excellent condition. In addition, this site was used in two major studies (Lechmere-Oertel 2003; Sigwela 2004) in which ecological patterns and processes within these two habitats were investigated, thereby confirming the appropriateness of this site as a model of a desertified contrast, as well as providing valuable background data.

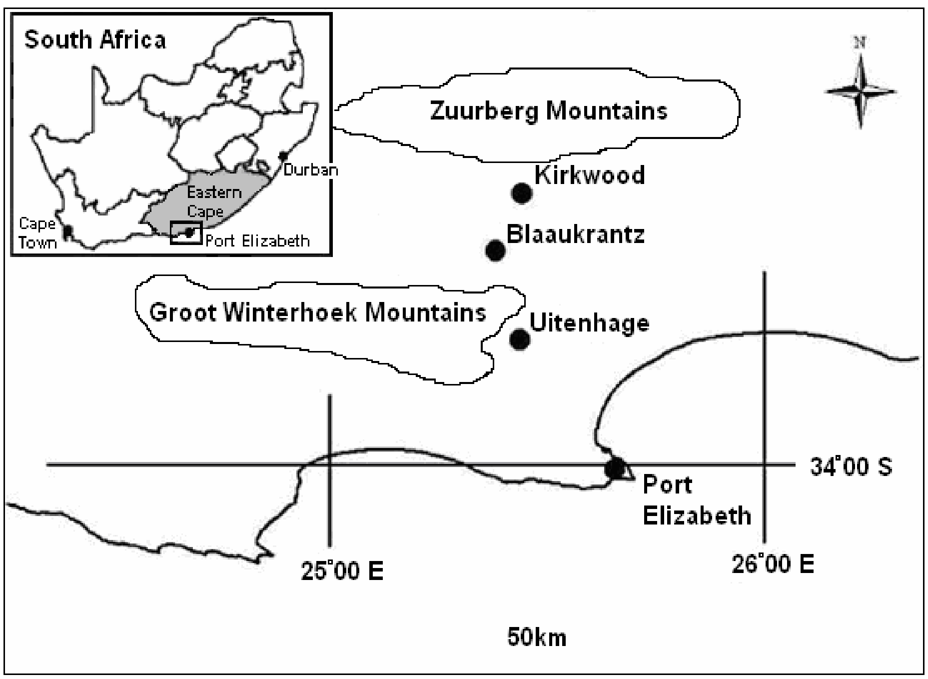

Figure 2.1 The location of the study site 'Blaaukrantz' in relation to major towns in the Eastern Cape, South Africa.

2.2 Geomorphology

The site is situated south of the Zuurburg mountains on rolling hills (Sigwela 2004). This relatively flat area overlays the Uitenhage Group sediments, which weather to fine textured Addo soils (Macvicar 1991). The soil is deep and rich as it is derived from deposits of mudstone and shale (Rust 1988).

Figure 2.2 Photograph of the intact vegetation paddock on the study site showing the dense, diverse woody and succulent trees and shrubs.

Figure 2.3 Photograph of the transformed vegetation paddock on the study site showing the open landscape with scattered trees such as the *Pappea capensis* figured here.

2.3 Vegetation

The vegetation on the study site falls within the Sundays Spekboom Thicket (Vlok & Euston-Brown 2002; Vlok *et al.* 2003; Sigwela 2004; Lechmere-Oertel *et al.* 2005a). Mucina & Rutherford (2006) include Sundays Spekboom Thicket (Vlok & Euston-Brown (2002) within the larger category of Sundays Thicket, which occurs at an altitude between 0 - 800 m. Sundays Spekboom Thicket occurs around the area of Uitenhage down toward the north of Port Elizabeth, into the lower Sundays River Valley to the east of Colchester. It stretches westwards north of the Groot Winterhoek Mountains with the northern boundary at the Zuurburg Mountains. There is also a large area north of the Klein Winterhoek Mountains around Jansenville (Mucina & Rutherford 2006).

According to Vlok *et al.* (2003), intact Sundays Spekboom Thicket has a characteristic two-phase mosaic of vegetated patches, ranging between 2 – 50 m in width, and open areas of lower cover (Figure 2.2). These vegetation patches on the site are comprised of low growing canopy trees (<5 m) such as *Portulacaria afra* and *Euclea undulata,* with an understorey of shrubs and forbs such as *Lycium cinereum* and *Cineraria saxifragra.* Grasses such as *Panicum maximum* and *Cynodon dactylon* occur in the open patches; but unlike the description in Lechmere-Oertel (2003), these grasses comprised a large portion of the vegetation (>10%) on the study site (Chapter Three). The diversity of dwarf succulent shrubs is relatively low.

Lechmere-Oertel *et al.* (2005a) described transformed Spekboom Thicket as being comprised of a layer of ephemeral or weakly perennial grasses and karroid shrubs with scattered trees. Hoffman & Cowling (1990) showed that prolonged continuous grazing (for more that 10 years) reduced the canopy cover and dominant species such as *Euclea undulata* and *Portulacaria afra*, these are replaced by species such as *Putterlikia pyracantha* and the alien invasive *Opuntia ficus-indica.* The transformed site used in this study is consistent with these descriptions, being dominated by the grass *Cynodon dactylon,* numerous forbs, the alien saltbush *Atriplex lindleyi* subsp. *inflata* and the karroid shrub *Pentzia incana.* The tree *Pappea capensis* occurred intermittently in this treatment, giving the characteristic ‘pseudo-savanna’ appearance (Lechmere-Oertel 2003; Lechmere-Oertel *et al.* 2005a) of transformed Sundays Spekboom Thicket (Figure 2.3).

2.4 Climate

Two prevailing weather systems dominate the climate of the Eastern Cape, these being the winter rainfall from the southwest and the summer rainfall from the northeast (Aucamp & Tainton 1984), with autumn and spring maxima in rainfall (Aucamp & Tainton 1984; Hoffmann & Cowling 1990). The rainfall during the study period (August 2005 to July 2006) followed this pattern, with two rainfall highs occurring in late spring (110.5 mm in November 2005), and late autumn (90 mm in May 2006) (Figure 2.4). The year round rainfall (mean = 312.8 mm; 1958 - 2004) pattern in this area is unreliable and droughts of several months are common in this hot, dry climate (Figure 2.5) (Aucamp & Tainton 1984; Everard 1987). There is a 25% chance of not receiving 80% of the mean rainfall in any year (Aucamp & Tainton 1984). The total rainfall over the study period (August 2005 to July 2006) was an above average 401.5 mm (Figure 2.5).

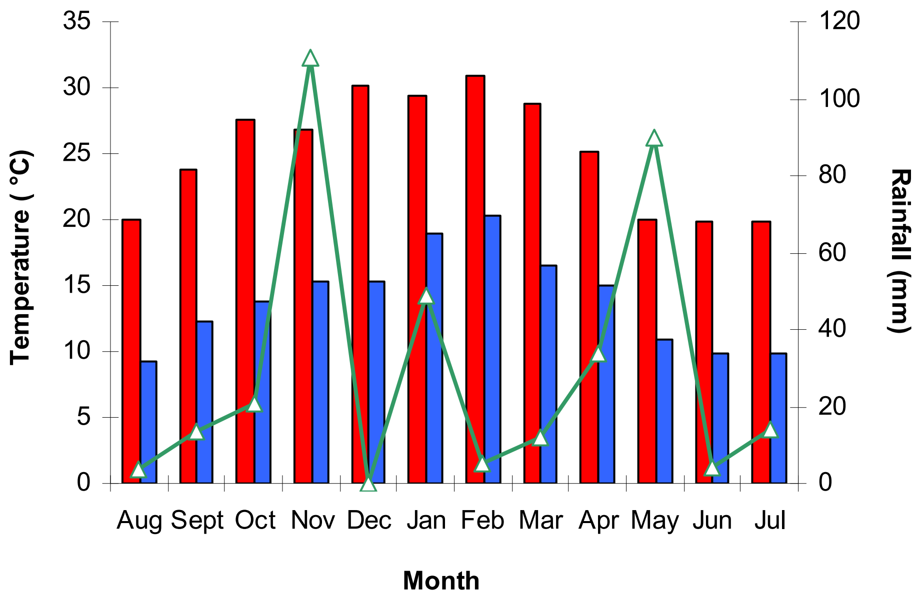

Figure 2.4 Climate diagram from the study site, Blaaukrantz, showing the mean monthly rainfall (green line) and mean monthly day (red bar) and night (blue bar) temperature over study period (August 2005 to July 2006). Rainfall data from Mr. Arthur Rudman, temperature data from HOBO portable weather station (Onset Computer Corporation, Pocasset, MA, USA).

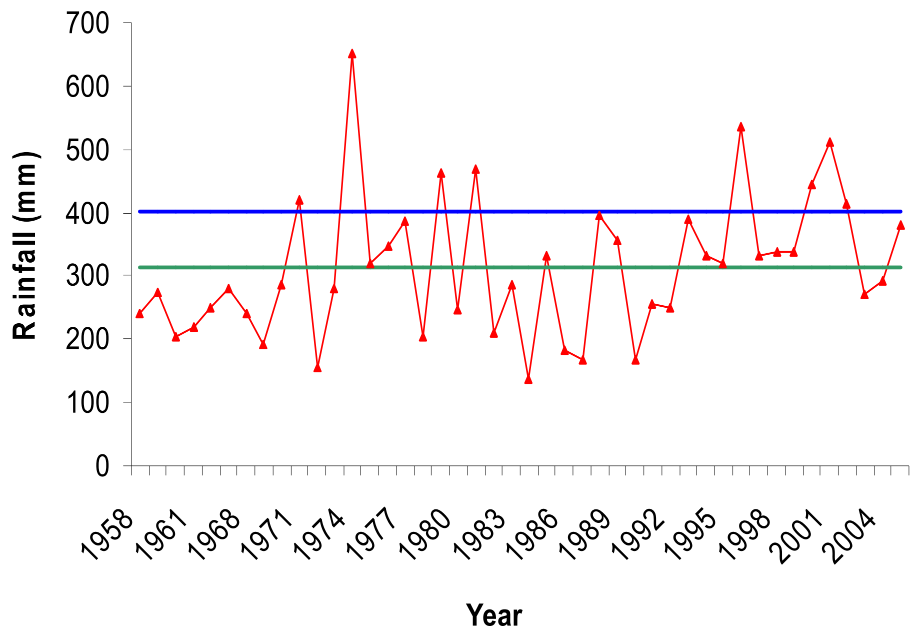

Figure 2.5 Total annual rainfall on the farm Blaaukrantz from 1958 until 2005, showing high variation around the overall mean (green line) and the above average rainfall for the study period (blue line) (data from Mr. Arthur Rudman).

Temperature at the study site was measured by an HOBO portable weather station (Onset Computer Corporation, Pocasset, MA, USA) set-up by the University of the Witwatersrand for a concurrent study (Hetem in prep). Mean daily temperatures were hot in summer, with the mean daily temperature of 30.9°C in February 2006, and mild in winter, with a mean daily temperature of 19.8°C in July 2006 (Figure 2.4).

The hottest black bulb temperature measured during the study was 51.9°C at 13:00 on 7 February 2006 and the coldest temperature was -0.3°C at 06:00 on 28 August 2005. This is consistent with Everard (1987), who showed mean monthly temperatures ranging between 13° – 40°C, with maxima of over 40°C and minima below 0°C.

2.5 Land Use History and site selection

Colonial settlers arrived in the area in the early 1800's but mostly colonized the Sundays River Valley, as there was little permanent surface water in the area. The areas north of Uitenhage were densely thicketed (Skead 2007). Through many years of poor farming practices, much of the area has been cleared to a pseudo-savanna (Lechmere-Oertel 2003). Site selection was based on existing fence line contrasts, which reflect different management regimes. The intact paddock was originally part of the farm Blaaukrantz (originally named Outspan) and shows little sign of vegetation degradation. The transformed paddock, however, was originally part of a neighbouring property; Coles Grove (originally named Skilpad Laagte). The Coles Grove site was previously a "vee kraal" or goat outpost where herders brought their goats overnight. This practice, over many years, resulted in heavy utilization. The site has been under the current ownership for the past 15 years (A. Rudman, pers. com.[1]). Both sites were approximately 50 ha in size. Other herbivore species occurring on the site are limited to a small number of steenbok (*Raphicerus campestris*), common duiker (*Silvicapra grimmia*) and bushbuck (*Tragelaphus scriptus*) (pers. obs.). The total number of herbivores on each site, including the 12 study animals likely did not exceed 20 individuals. This represents a conservative stocking rate of 2.5 ha per animal. Water is provided *ad lib*. by means of a drinking trough in each paddock. The paddocks are completely game fenced to a height of over 2 m with 'bonox' and are electrified, preventing the movement of the animals between the two areas.

2.6 Study Animals

The Angora goat (*Capra aegragus*) originated in the district of Angora in Turkey, Asia Minor. Historical texts show that all domestic goat species today are descendants from the wild Persian goat; these goats had longer hair on parts of its body during the winter. Selective breeding resulted in today's mohair-producing Angora goats (Van der Westhuysen *et al.* 1988). Angora goats now occur not only in Turkey but also in South Africa, Lesotho, New Zealand, Australia, Argentina and the United States of America. South Africa is the world's leading mohair producer, with more than 60% of the world's mohair produced here, and as such is an important industry in the economy of South Africa (Van der Westhuysen 2005).

Angora goats were brought to South Africa in 1838 in the form of one ewe and 12 rams. The rams had, however, been rendered infertile before they left Turkey. As luck would have it, the ewe was pregnant and gave birth to a male kid. These two individuals were bred with local livestock, but the mohair was of poor quality. It was only in 1856

[1] Rudman, A., Blaaukrantz Farm, PO Box 583, Uitenhage, 6230

that further imports occurred, and the mohair industry in South Africa was established. However, there were many rises and falls in the industry due to war, fashion industry trends and massive stock losses due to disease and adverse weather conditions such as cold, wet and windy weather (Van der Westhuysen *et al.* 1988).

Goats are dominant in pastoralism in the southwestern Eastern Cape, with more than 90% of succulent thicket used for goat farming (Moolman & Cowling 1994). The goat is primarily a browser according to Aucamp (1976), and provided enough browse is available, up to 85% of the diet can consist of browse. Sigwela (1999) showed a similarly high 73% of boer goat diet consisting of browse (58% woody shrubs and 15% succulent shrubs). The highly palatable species *P. afra* is a very important component of the diet of goats in Spekboom Thicket (Aucamp 1978; Stuart-Hill & Danckwerts 1988; Sigwela 1999). Aucamp (1978) showed that in thicket, Angora goat diet was made up of equal parts of *Portulacaria afra*, other shrubs and grasses. Sigwela (1999) showed that *Capparis sepiaria* and *Euclea undulata* also played an important role in all seasons in the diet of boer goats, as did *Grewia robusta* (Stuart-Hill & Danckwerts 1988). However, according to Kinghorn (1972), Angora goats are able to widen the scope of their diet to include less palatable vegetation during dry periods.

Twenty-four adult, castrated male Angora goats (kapaters), belonging to Mr. Arthur Rudman, were used for this study. Each treatment paddock was 50 ha in size. Animals were randomly assigned to one of the two treatments, so there were 12 goats per treatment, stocking rates were therefore 4.16 ha per goat for the duration of the study, well within the recommended stocking rate for this site (A. Rudman, pers. com.[2]).

Individual goats were tagged using a pair of coloured plastic ear tags for identification. The animals were introduced to the site in July 2005 after data loggers had been implanted for a concurrent study (Hetem in prep); this allowed them three weeks to acclimatize before the first data were collected. Angora goats are useful models for other ruminants of similar size as they can easily be weighed for body condition analysis, and fibre collected for mohair analysis. Furthermore, fresh faecal samples are easily obtained for dietary composition and nutritional assessment, when the goats are brought into kraal for dipping, dosing or shearing.

[2] Rudman, A., Blaaukrantz Farm, PO Box 583, Uitenhage, 6230

Chapter Three
Dietary shifts in response to thicket transformation

3.1 Introduction

An understanding of diet selection by ruminants in rangeland is important for the proper management of fragile ecosystems and profitable animal production (Holechek *et al.* 1982). How animals use the resources available to them is key to understanding their selection for resources and thus their impact on the environment (Davis *et al*. submitted). It is well known that animals choose different plant species to meet their nutritional requirements, unless they are limited by the availability and accessibility of forage (Le Houérou 1980). Dietary shifts reflect changes in animal requirements and resource availability (Stephens & Krebs 1986; Hughes 1993). Aucamp (1976) and Stuart-Hill & Danckwerts (1988) showed goats to be primarily browsers in thicket, and they are able to utilize brows up to 2m (Stuart-Hill & Danckwerts 1988; Haschick & Kerley 1996). Many researchers (see Papachristou *et al.* 2005) have shown that small ruminant diet selection is influenced by a range of factors such as the relative availability of woody and herbaceous plant species, overall forage availability, stocking rates, stocking periods and competition between species. In all studies, it was shown that browse is an important source of forage for goats throughout the year (Papachristou *et al.* 2005).

Within thicket, mammal herbivores consume a wide range of forage (Kerley *et al.* 2006). Megaherbivore hindgut fermenters have been shown to consume the widest range, with elephants, *Loxodonta africana,* consuming up to 146 plant species (Paley & Kerley 1998; Landman *et al.* 2008; Davis *et al.* submitted) and black rhinoceros, *Diceros bicornis,* 120 (Landman in prep). Ruminants have been shown to be more selective with kudu, *Tragelaphus strepsiceros,* consuming 52 plant species (Sigwela 1999), eland, *Tragelaphus oryx,* 27 (Schlebusch 2002) and bushbuck, *Tragelaphus scriptus,* 26 (Macleod 1992). This may reflect the need for ruminants to be more selective in order to obtain a high quality diet (Kerley *et al.* 2006). Stuart-Hill & Danckwerts (1988) and Sigwela (1999) showed that goats eat a wider spectrum of plant species than wild ruminants and they are, therefore, less selective.

The species that make up the bulk of an animal's diet are, however, just as important as the number of species consumed. Of all the species of plants occurring in thicket, only a few contribute significantly to the diet of goats (Stuart-Hill & Danckwerts 1988; Sigwela 1999).

Within thicket, indigenous plants are the main source of animal feed (Aucamp 1979). The quality of thicket forage is constant and high even in dry periods and if stocking numbers are realistic, ruminants are able to select a high quality diet (Aucamp & Scheltema 1984). The quality of thicket forage is not seen as a restrictive factor, but rather the quantity of available suitable food (Aucamp 1978). Transformation alters forage availability primarily through the removal of preferred species. Previous studies have shown species such as *P. afra* and *G. robusta* to be important in the diet of Angora goats (Aucamp 1978; Stuart-Hill & Danckwerts 1988), however it is these and other palatable species which disappear in degraded thicket, being replaced by less palatable species such as *Lycium* sp. and *Zygophyllum morgansa* (Stuart-Hill & Danckwerts 1988; Stuart-Hill 1992). Therefore, we predict that goats in transformed sites will shift their diet to include less preferred species and hence increase their dietary breadth.

The aim of this section was to test the above hypothesis by investigating the composition of Angora goat diet in both intact and transformed treatments. The possible shift in the dietary composition of Angora Goats between the two treatments was thus investigated.

3.1.1 Dietary Sampling Approach

There are numerous techniques available for assessing the diet of herbivores; namely direct observation, stomach content examination, esophageal or rumen fistulation and faecal analysis. There are advantages and disadvantages to each of these techniques. The accuracies and biases of these four techniques are compared Holechek *et al.* (1982) and McInnis *et al.* (1983), but overall they are comparable in terms of diet descriptions. Direct observation as used by Owen-Smith & Cooper (1985) and Paley & Kerley (1998) involves observing animals in the field and observing the plant species eaten. This method requires little equipment and is quite simple (Holechek *et al.* 1982), but is expensive in terms of manpower required for observations. Furthermore, it may be difficult to accurately assess what the animal is eating if the vegetation is dense and difficult to see through, or you are unable to approach the animal (McAllister & Bornman 1972). Methods such as rumen or esophageal fistulation (Holechek *et al.* 1982; Dove & Mayes 1996) require invasive surgery of the animal, and this option was not available here. Fistulation is also expensive (Holechek *et al.* 1982). Stomach content analysis requires that the animal be killed; as Angora goats are of a high economic value, this procedure would not have been suitable in this study. Faecal analysis was chosen for this study as it is inexpensive (Wrench *et al.* 1997), samples are easy to collect and there is minimal disturbance to the animal (Croker 1959). Storr (1961) showed that the differential digestion of plant species might be a concern. However, the impact of this on the estimate of botanical composition will rarely cause significant errors in diet estimates (Johnson & Wofford 1983). In addition, given that this is a comparative study between two treatments, any such bias is unlikely to influence the findings of this study.

3.2 Materials and Methods

3.2.1 Microhistological dietary determination

Estimating dietary composition using faecal analysis involved the identification of plant epidermal fragments found in the faeces and comparing them to an already existing, extensive photographic plant cuticle reference collection, containing plants collected for previous studies (Van Teylingen 1992; Sigwela 1999; Koekemoer 2001; Landman 2000; Davis 2004). Therefore, species-specific characteristics, such as stomal shape and cell arrangement, shown in the photographic epidermal reference collection allowed epidermal fragments found in the goat faeces to be identified to species level.

Any plant species found to occur on the site, but not found in the existing reference collection, was collected and a permanent epidermal slide made and added to the collection (n = 31, Appendix 1a). For this, two to three leaves were cut into squares of approximately 2 cm^2 each. With larger leaves, the middle section was used as Croker (1959) showed that the cuticle covering the actively growing tissue disintegrates during chewing and therefore, could not withstand nitric acid digestion. The fragments from each plant were gently boiled in 10 ml 10% nitric acid until the mesophyll and epidermis separated (approximately 2-5 minutes, depending on the hardness of the leaf). Further digestion was then stopped by running the leaf fragments gently under water until all the acid was removed. Any remaining mesophyll was scraped off gently with a scalpel. The epidermal fragments were then floated onto a microscope slide and the cuticle layer stained with Ruthenium Red [$Ru_2(OH)Cl_4 \cdot 7NH_3 \cdot 3H_2O$]. The segment was then permanently mounted with DPX microscope mountant (Method adapted from Storr (1961) and McAllister & Bornman (1972)).

Photographs, for the photographic reference collection, were then taken of both the adaxial and abaxial surfaces using a photomicrograph (Model: DFK41F02 TheImagingSource). Care was taken to include important characteristics such as trichomes, silica bodies, cell shape, stoma shape and distribution of stomal guard cells in these images.

Fifteen fresh faecal samples were collected from both herds of 12 goats bi-monthly between August 2005 and July 2006. Note that it was not possible to sample the goats individually, hence fresh faecal samples were considered to be independent samples of the goat population diet. The samples were oven dried at 45°C for 5 days and stored for further analysis. Approximately 10 faecal pellets were randomly selected from each sample and ground in a coffee mill until uniform in size. This procedure was modified from McAllister & Bornman (1972), samples were then boiled in 55% nitric acid for 2 minutes, then diluted to a 10% nitric acid solution using distilled water and boiled for a further 4 minutes. McAllister & Bornman (1972), Van Teylingen (1992) and Gaylard (1994) centrifuged the mixture, discarded the supernatant and analysed the residue. However the method followed by Macleod *et al*. (1996) was used instead, as they found that centrifuging shifted the bias toward monocotyledons, as many dicotyledonous fragments were destroyed in the process. The mixture was instead placed in a 250 µm sieve and rinsed under running tap water until all the acid was cleared. Samples were then stored in FAA (formalin-acetic-acid; 25% water, 60% absolute alcohol, 10% formalin and 5% glacial acetic acid) until analysis.

A sub-sample of the prepared faecal fragments were placed on a gridded microscope slide and viewed at 400X magnification. For each sample, 100 fragments were identified using two 50-fragment subsets. Holechek & Vavra (1981) determined that two such sample slides were sufficient to identify all major plant species found in the diet within 20% of the mean at the 95% probability level.

Ninety samples per site (n = 15 every second month over a year) were analysed. Dietary items identified in the samples were categorised into the following growth forms: Woody shrubs, grasses, forbs, lianas, succulents and geophytes. Any species found which could not be identified using the epidermal reference collection was marked as unidentified. Sketches of all unidentified species were made and used as a further reference (Appendix 1b).

3.2.2 Relative food availability

The canopy line-intercept method was used to determine the relative availability of food for the goats (Barbour *et al*. 1987). Only vegetation accessible to the goats was measured; therefore plants above 2 m (above the foraging height measured by Haschick 1994) and plants occurring in dense bush clumps beyond a reach of 0.75 m, were excluded. Four 50 m transects per paddock were randomly placed. Food availability was measured twice during the study period; spring (high rainfall, November 2005) and winter (lower rainfall, July 2006). Many thicket plant species retain their forage potential throughout the year (Stuart-Hill & Aucamp 1993), however thicket plants which are ephemeral respond to rain and frost (Hoffman 1989). This makes it essential to sample seasonally. Due to the overall high rainfall during this period, the winter rainfall was not as low as expected.

3.2.3 Data analysis

EstiMateS Ver. 7.5 (Colwell 2005) was used to produce an accumulation curve (mean ± 1 SD; 50 randomised interactions) of plant species recorded per goat faecal sample (Appendix 2). The flattening off and decrease in SD is used to determine the sampling efficiency. As the accumulation curves for the transformed data did not flatten off (Appendix 2), total species richness was further determined using the non-parametric incidence-based coverage estimator within *EstiMateS* (ICE; Froggo *et al*. 2003). ICE utilizes the proportions of common, infrequent and unique species to estimate species richness.

Analysis of variance procedures (two-way ANOVA, Turkey's multiple comparison test) were used to test the difference in species richness between the sampled seasons and the treatments. Data were arcsine transformed to satisfy assumptions of normality where necessary (Zar 1999).

Similarities in the diet composition between the two treatments were measured using non-Metric Multidimensional Scaling (n-MDS) plots (1000 permutations; Clark & Warwick 1994). The basis of these plots were Bray-Curtis similarity matrices (Bray & Curtis 1957) on square-root transformed data. Clark & Warwick (1994) consider a stress value of <0.2 as giving a useful 2-d plot, the stress corresponds to how well the plot represents the high dimensional relationship between the faecal samples. A non-parametric two-way analysis of similarity (ANOSIM; 5000 permutations) was further used to test for difference between the diets of the goats in transformed and intact paddocks. Season was included as a factor to account for the temporal variation in sample collection. One-way analysis of similarity (ANOSIM; 5000 permutations) was used to determine the degree of variation between the seasons within treatments. ANOSIM compares between group and within group variation. The test parameter R is scaled within the range of +1 and -1 where values of zero indicate that the null hypothesis is true. Values close to one show that all replicates within sites are more similar to each other than to replicates from other sites (Clark & Warwick 1994, Quinn & Keough 2002). All multivariate analyses were performed using *Primer* Ver.5 (Primer-E Ltd 2001).

Principal dietary items (PDI), food items eaten in the greatest quantities, were identified as those species that contributed more than 2% of the diet (Petrides 1975). Plant species and growth forms that occurred more frequently in the diet than were available in the environment were considered preferred (Petrides 1975). Forage ratio and Ivlev's electivity index (Ivlev 1961) are commonly used as measures of food selection, but are limited by several problems such as non-linearity, bias for rare food items, confidence intervals increase as heterogeneity increases, being undefined or unbounded and lacking symmetry between selected and rejected values (Jacobs 1974). Krebs (1989) suggests methods to minimize these biases. Preference was estimated here using Jacobs' Index (Jacobs 1974):

$$D = (u-a)\,(u+a-2ua)^{-1},$$

where u is the proportional utilization of the food item, and a its proportional availability. The index ranges from -1 to +1, with values between 0 and +1 indicating preference and values between 0 and -1 indicating avoidance.

A χ^2 goodness of fit tested the null hypothesis that growth forms and PDI were consumed in proportion to their availability (Zar 1999). Differences between relative availability and utilization of growth forms and PDI were further assessed by calculating ± 95% confidence intervals for mean utilization of these categories and species (Neu *et al.* 1974). Preference or avoidance was considered significant if the confidence intervals did not overlap with mean relative availability. Sequential Bonferroni corrections were not used to adjust the confidence intervals following the argument for the rejection of this method in ecological studies (Moran 2003). Statistical analyses were performed using *Statistica* Ver. 7 (StatSoft Inc. 2004).

3.3 Results

3.3.1 Diet Composition

Forty-two plant species occurred in the diet of the goats in the control, intact paddock, whereas 94 species were found to occur in the diet of the goats in the transformed paddock, showing a greater diversity in the diet of the goats within the transformed paddock. Thirty-one species were common to both (Appendix 3). Cumulative species curves (Appendix 2) for goat diet in the intact paddock reached asymptotes, with ICE showing minimal species missed. However, the curves for goat diet in the transformed paddock did not reach asymptotes (Appendix 2) and ICE estimated that a number of species were missed (Table 3.1), which may indicate the amount of incidental or ephemeral species consumed by goats. All major dietary items were identified.

Species richness of the diet of the goats in the transformed paddock was greater than that of the diet for goats in the intact paddock ($F_{5,168} = 48.800$, $p < 0.001$). There was also a significant season by treatment difference ($F_{5,168} = 35.170$, $p < 0.001$), and no difference between the treatments in January and July (Tukey HSD Test, Figure 3.1).

Table 3.1 Number of observed species in diet over all sampling periods compared to ICE estimators.

Treatment	Season	Observed species in diet	ICE
Intact	September	28	28.30
Intact	November	26	26.24
Intact	January	28	29.32
Intact	March	28	30.49
Intact	May	31	31.79
Intact	July	26	27.02
Transformed	September	79	89.59
Transformed	November	55	66.66
Transformed	January	38	51.66
Transformed	March	53	73.91
Transformed	May	31	33.94
Transformed	July	33	38.24

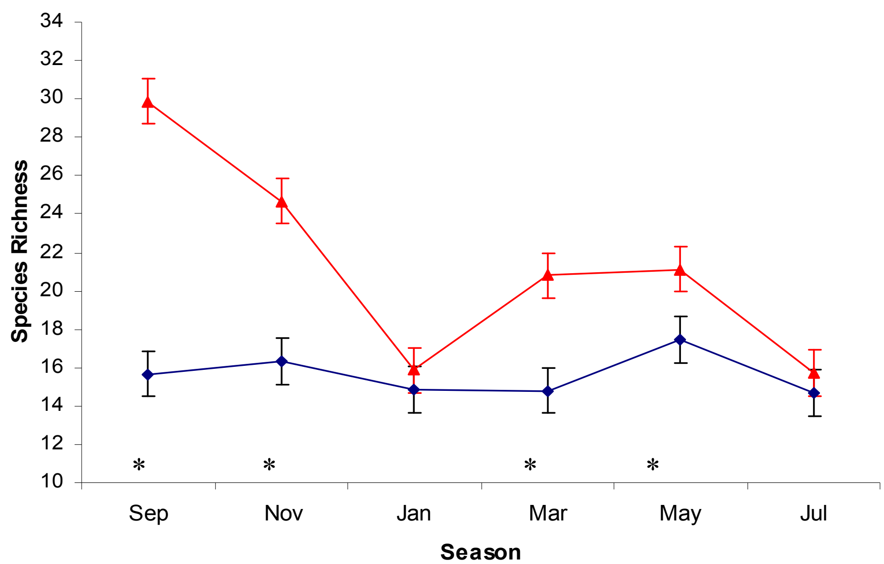

Figure 3.1 Species richness (± 0.95% confidence intervals) of plants in the diet of Angora goats in the intact (blue line) and transformed (red line) paddocks. (Tukey HSD Test: * = significant difference between treatments within sampling period).

The n-Multidimensional ordination plot stress factor of 0.16 showed that the 2-dimensional plot is useful in illustrating the trends in species composition between transformed and intact paddocks. The difference between treatments was significant ($R = 0.967$, $p < 0.001$), showing a large amount of dissimilarity in the goat diet between the two treatments. The seasonal variation within the intact treatment was less (R = 0.691, $p < 0.001$.) than the seasonal variation within the transformed diet (R= 0.802, $p < 0.001$). This trend is visible in Figure 3.2, with intact samples showing a tighter clustering within and between seasons than the transformed samples.

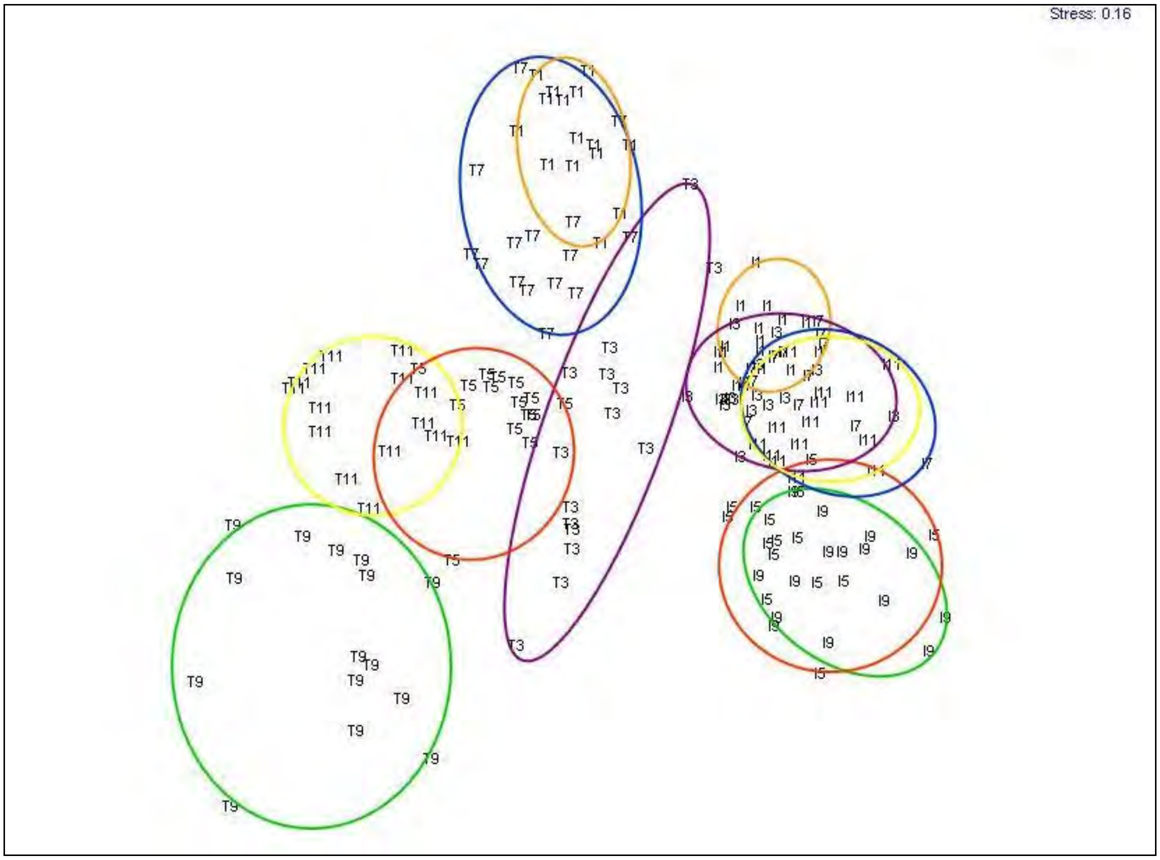

Figure 3.2 n-Multidimensional scaling ordination (1000 permutations) of the intact (I; n = 90) and transformed (T; n = 90) Angora goat diet samples. (Green - September, Yellow - November, Orange - January, Purple - March, Red - May, Blue - July).

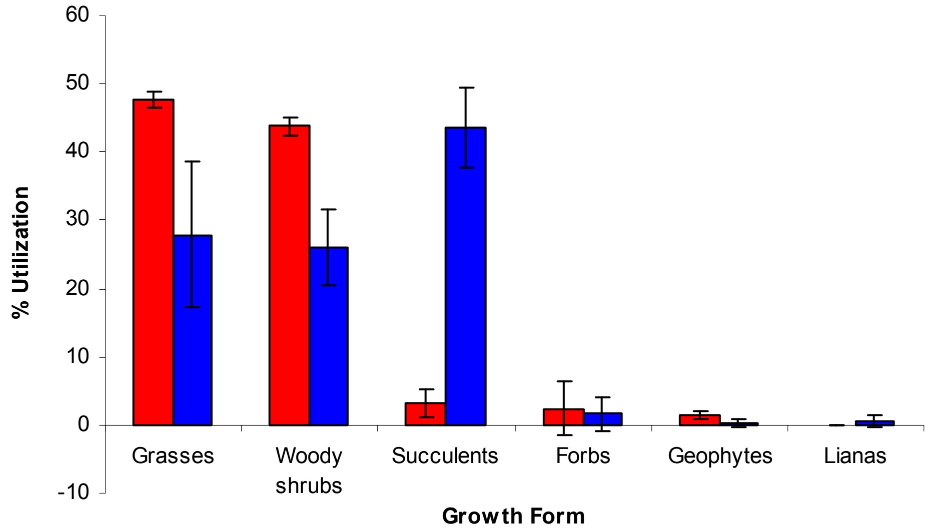

Figure 3.3 Utilization (mean ± 1 S.D.) of growth forms by Angora goats in transformed (red) and intact (blue) paddocks.

The diet of the goats differed between sites in regard to the plant growth forms, with succulents (43.6%), woody shrubs (26.1%) and grasses (27.7%) making up the bulk of the intact diet, but with grasses (47.7%) and woody shrubs (43.7%) making up the bulk of the transformed diet (Figure 3.3).

Sixteen PDI were found in the diet of the goats in the transformed paddock; these contributed 79.9% of the total diet. Nine PDI were found in the diet of goats in the intact paddock, which contributed to 81.9% of the diet. *Panicum deustum* (12.8%) was the dominant species in the transformed treatment diet, whereas *P. afra* (41.7%) dominated the intact treatment diet. Eight species; *P. afra, P. deustum, G. robusta, C. dactylon, Panicum maximum, E. curvula, Eragrostis obtusa* and *P. capensis,* were PDI in both treatments (Figure 3.4).

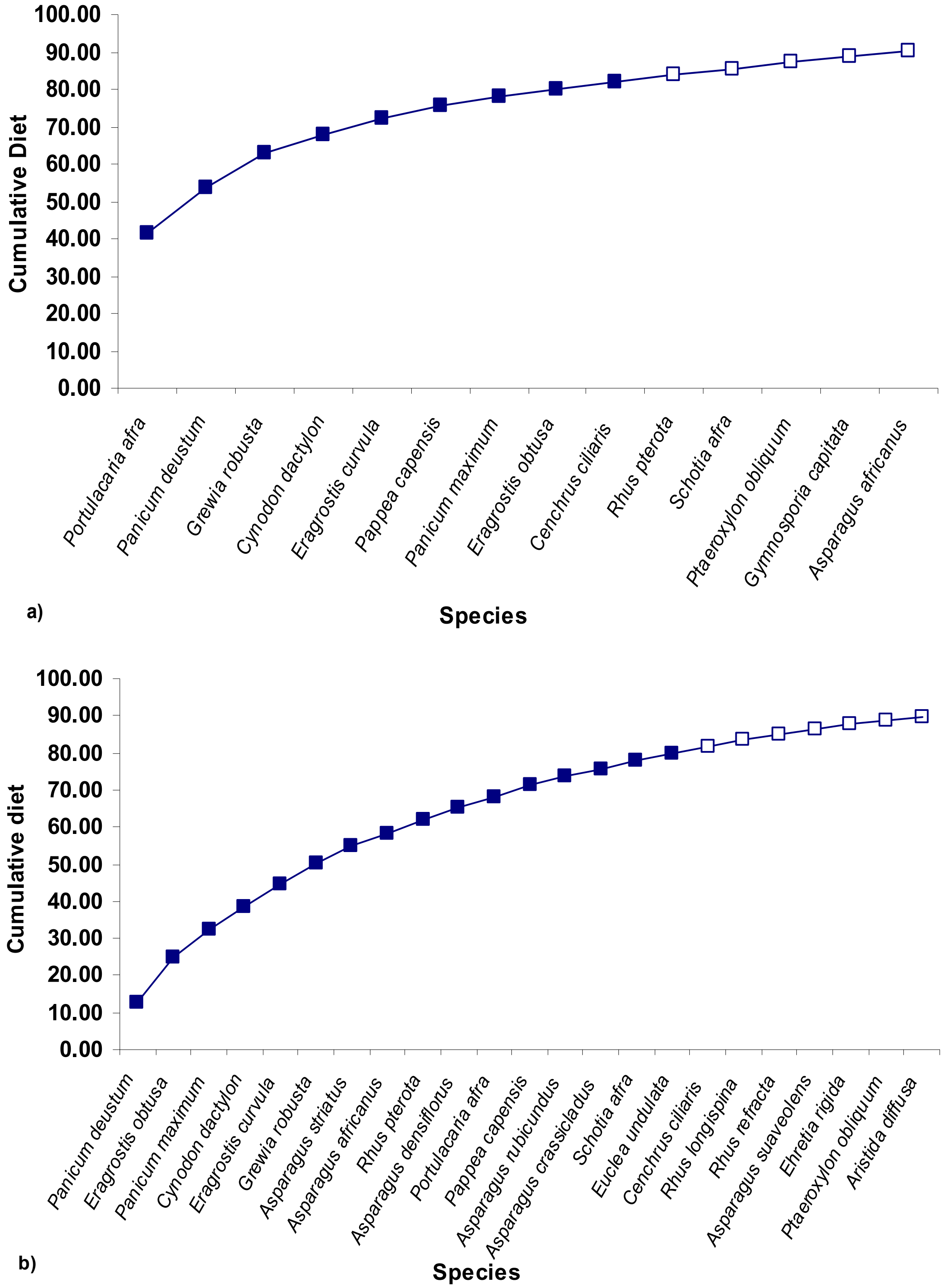

Figure 3.4 The cumulative contribution of different plant species making up to 90% of the diet of goats in a) intact paddock and b) transformed paddock. Shaded blocks indicate Principal dietary items.

3.3.2 Relative food availability

The available forage in the intact treatment was dominated by succulents (November 46%; July 36%) followed by woody shrubs (November 29.5%; July 31.5%) and grasses (November 23.8%; July 30.3%). Forbs (November 0.4%; July 1.5%), lianas (November 0.2%; July 0.2%) and geophytes (July 0.1%) made up a very small proportion of available forage. The transformed treatment, however had a distinct lack of succulents available (November 0.04%; July 1.32%) with grasses (November 54.4%; July 30.1%) and forbs (November 18.5%; July 49.9%) making up the bulk of available forage. Woody shrubs (November 18.7%; July 16.1%) and lianas (November 0.04%) were less available than in the intact treatment but more geophytes were available (November 8.4%; July 2.6%).

Growth forms in the transformed treatment were not utilized in proportion to their availability (November $\chi^2_5 = 237.03$; $p < 0.001$ and July $\chi^2_4 = 115.07$; $p < 0.001$), whilst the intact treatment showed no significant difference between utilization and availability in the corresponding months (November $\chi^2_4 = 2.78$; $p < 0.59$ and July $\chi^2_4 = 1.75$; $p < 0.78$). Within the transformed treatment, the two major contributors to the Angora goat diet, woody shrubs and grasses, were utilized in accordance to their availability. High preference was shown for succulents ($D = 0.96$) in November, but forbs ($D = -0.85$), geophytes ($D = -0.69$) and lianas ($D = -1$) were avoided. July showed less variation, with forbs ($D = -0.99$) and geophytes ($D = -0.85$) being avoided (Figure 3.5).

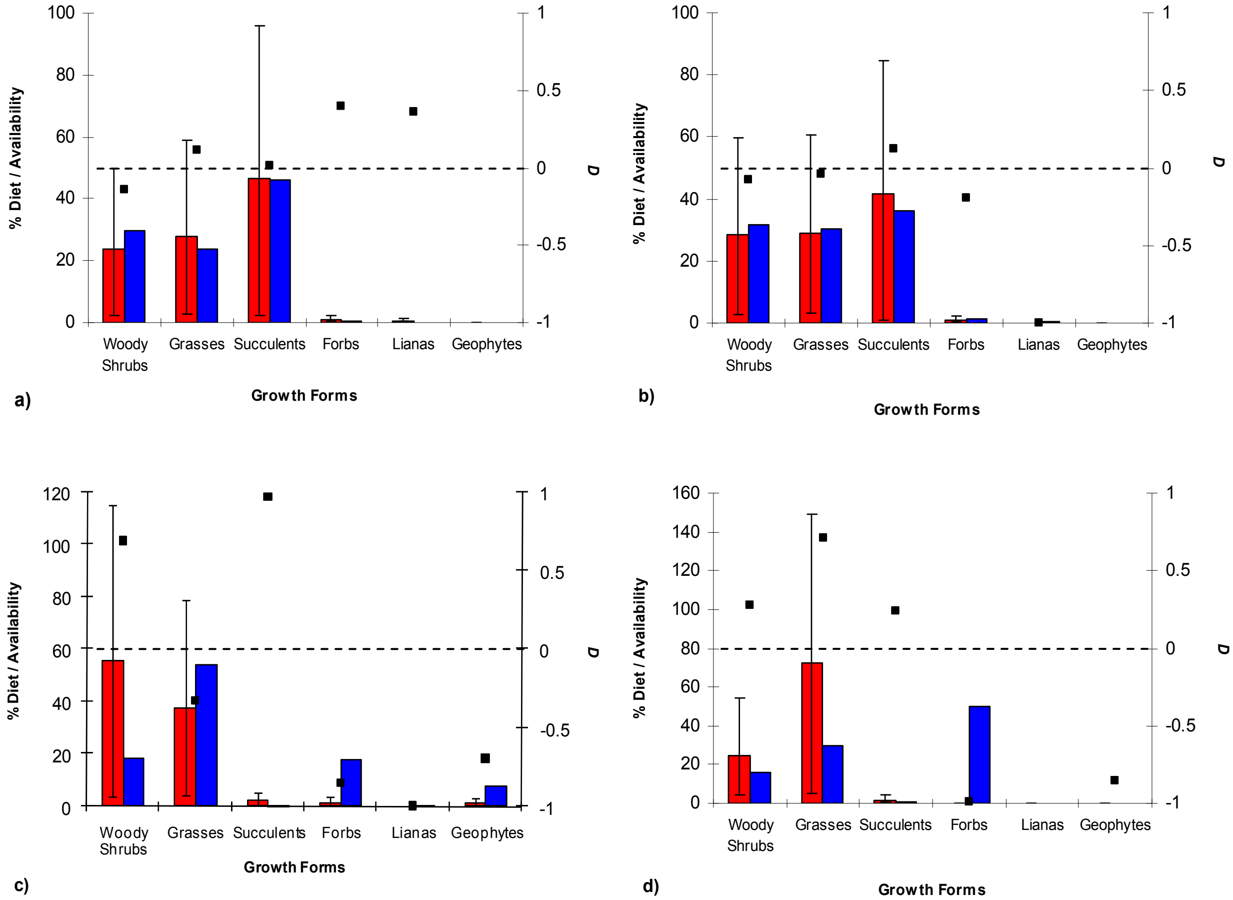

Figure 3.5 Utilization (mean ± 95% confidence interval; red bars) and mean relative availability (blue bars) of plant growth forms identified in the diet of Angora goats. Jacobs' Index values (black squares) indicate preference ($D > 0$) or avoidance ($D < 0$). Preference or avoidance was considered significant if the confidence interval did not overlap with the mean relative availability. (a) November intact b) July intact c) November transformed d) July transformed).

Principal dietary items for both treatments were not utilized in proportion to their relative availability: Intact November ($\chi^2_7 = 42.86$; p = <0.001), Intact July ($\chi^2_8 = 52.90$; p = <0.001), Transformed November ($\chi^2_{14} = 103.24$; $p < 0.001$), Transformed July ($\chi^2_{11} = 9272.22$; $p < 0.001$).

Within the intact treatment, fewer PDI were preferred than in the transformed treatment. In the intact treatment, eight PDI occurred in the diet during November of which *Ptaeroxylon obliquum* (D = 1), *E. curvula* (D = 0.72) and *P. maximum* (D = 1) were preferred and *C. dactylon* (D = -0.52) avoided. Of the nine PDI, only *Cenchrus*

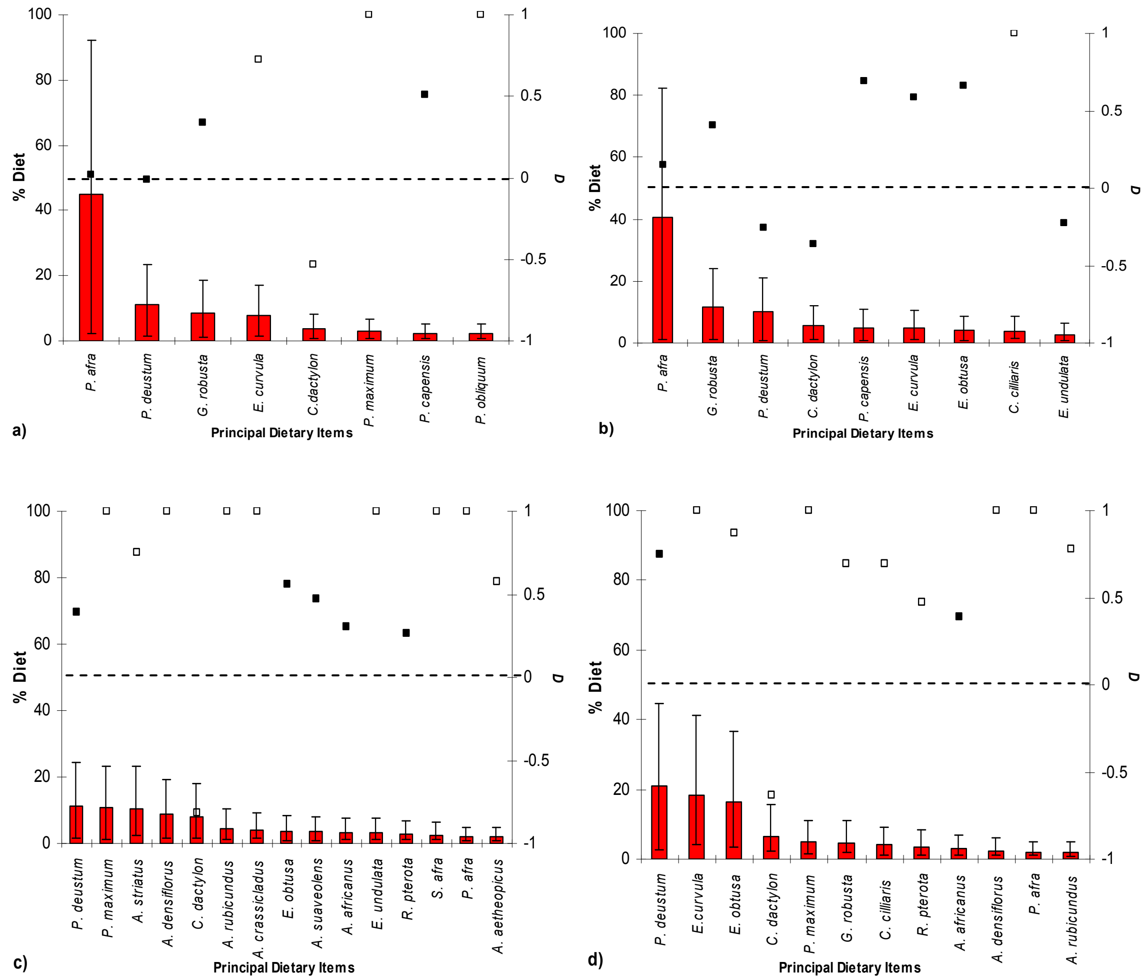

Figure 3.6 Utilization (mean ± 95% confidence interval; red bars) of principal dietary items identified in the diet of Angora goats in the two treatments. White squares represent Jacobs' index values for significant preference ($D > 0$) or avoidance ($D < 0$); black squares represent Jacobs's index values for PDI utilized in proportion to their relative availability. (a) November intact b) July intact c) November transformed d) July transformed).

ciliaris (D = 1) was preferred in the diet in July. All other PDI in the intact treatment were utilized in proportion to their relative availability (Figure 3.6).

Asparagus aethiopicus (D = 0.57), *Asparagus crassicladus* (D = 1), *Asparagus densiflorus* (D = 1), *Asparagus rubicundus* (D = 1), *Asparagus striatus* (D = 0.75), *E. undulata* (D = 1), *S. afra* (D = 1), *P. maximum* (D = 1) and *P. afra* (D = 1) were all preferred in the transformed diet during November. *C. dactylon* was however avoided (D = -0.81). The remaining five PDI were utilized in proportion to their availability. *C. dactylon* (D = -0.63) was again the only avoided species within the PDI in July, and of these items only two were consumed in proportion to their relative availability. Preferred items were *A. densiflorus* (*D* = 1), *A. rubicundus* (*D* = 0.77*), G. robusta* (*D* = 0.69), *R. pterota* (*D* = 0.47), *C. cilliaris* (*D* = 0.69), *P. maximum* (*D* = 1)*, E. curvula* (*D* = 0.99), *E. obtusa* (*D* = 0.87*) and P. afra* (*D* = 1) (Figure 3.6).

The very large χ^2 value for the July transformed treatment can be explained by one species *E. curvula,* which was utilized in proportions far greater than its relative availability (χ^2= 8952.33; $p < 0.001$). *C. dactylon* was the most common grass available, but even though it is a PDI, it was not utilized in proportion to its availability and was avoided in most instances.

3.4 Discussion

Faecal analysis has various shortcomings (Holechek *et al.* 1982; McInnis *et al.* 1983), it can however be considered reliable in a comparative study such as this one, as biases are standardised across treatments. The species accumulation curves clearly reached asymptotes for the intact treatments, showing that 15 samples were sufficient in describing the diet under these conditions. The species accumulation curves for the transformed treatment didn't flatten off, but only 22 species contributed 90% of the diet, leaving 72 species making up the final 10%. This shows the very high amount of incidental or ephemeral species consumed in this treatment, but as all PDI were identified in all months, the technique used in this research is reliable.

Species with high utilization but not availability in the field should be treated with caution. Species with very similar epidermal structures may be clumped together, the epidermal layer may be resistant to digestion or it may be highly preferred and therefore searched for by the goats (Sigwela 1999). There were a number of such species in the transformed treatment. This again reflects the diversity of ephemeral species, not all of which were encountered on plant transects.

Previous studies on goat diet in Subtropical Thicket focused on boer goats (Stuart-Hill & Danckwerts 1988; Sigwela 1999). Aucamp (1978) provides the only published data on Angora goat diet in the region. He showed that Angora goats utilize equal proportions of *P. afra*, other shrubs and grasses (Aucamp 1978). This study therefore, provides a critical first quantitative description of Angora goat diet in Sundays Thicket.

This is surprising considering the importance of this species in the region and the concerns regarding its impact on thicket vegetation. As over 60% of thicket is considered severely transformed (Lloyd *et al.* 2002), the reaction of this, economically important, species to its changing habitat is also of concern.

Stuart-Hill (1992) and Moolman & Cowling (1994) used the differences between goat-dominated grazing areas and goat exclusion areas to assess the effects on plant communities. Stuart-Hill (1992) showed goats to be responsible for the decrease in percentage frequency of *P. afra, G. robusta* and *R. obovatum,* whilst Moolman & Cowling (1994) showed a compositional shift in areas grazed by goats compared to elephant areas. However, these differences may be due to stocking rates and not goat impacts, only direct observations could ascertain this (Moolman & Cowling 1994). Goats are seen to have a major impact on geophyte structure and low succulent shrub components of thicket (Moolman & Cowling 1994). As a whole, it appears that most authors have assumed that impacted plants are eaten by goats. Recently however, Landman *et al*. (2008) have shown that for elephants this assumption is not uniformly justified. Elephants are said to be responsible for the disappearance of regionally rare and endemic species but not all these species occur in the diet and therefore observed changes are not necessarily due to elephant herbivory (Landman *et al*. 2008). The same may be true for goats.

The dietary information obtained in this study agrees broadly with Aucamp's (1978) ratio of 1:1:1 *P. afra*, other shrubs and grasses. In thicket, Angora goats focus primarily on woody and succulent shrubs, with grasses making up 27% of the intact treatment diet. Grasses were more important in the transformed treatment, comprising about 48% of the diet. In both treatments, specific grasses were important even though they make up only a third of the intact diet where high quality browse is available. *P. deustum* contributed to about 12% of the diet in both treatments and was the most important species in the transformed treatment and the second most important in the intact treatment.

Raats *et al.* (1996) showed that in semi-arid subtropical savannas, the diet selected by goats (boer goats) varied by season, with grasses, forbs and browse use being mixed during the wet season. Browse tends to be utilized more in the dry season as many browse species provide good quality forage during dry periods (Papachristou *et al.* 2005). In Noorsveld, Du Toit & Blom (1995) showed Angora goats to have a similar seasonal variation in diet. In spring, animals selectively grazed grasses, during summer noors and grass, and in autumn and winter their diets closely resembled the available forage. Palatable grasses were grazed whenever they were available (Du Toit & Blom 1995). In the Nama-karoo Davis *et al*. (1986) showed dietary shifts to less palatable species and fewer ephemerals during drought for springbok (*Antidorcas marsupialis*) compared to previous studies (Bigalke 1972). Similarly, merino sheep (*Ovis aries*) in the same region lacked ephemerals in their diet even though they had previously been shown (Botha 1981) to select for this growth form (Davis *et al*. 1986). This decrease in ephemeral utilization, by both species, is as a result of the decreased availability of ephemeral species during drought. Therefore, even though dietary shifts can be both seasonal or as a result of drought, these shifts reflect herbivore reliance on available forage.

3.4.1 Treatment effects

The availability of browse differed considerably between the treatments. Succulent shrubs, particularly *P. afra,* dominated the intact treatment followed by woody shrubs such as *G. robusta, R. obovatum* and *Lycium cinereum*. According to Stuart-Hill (1992), goats browse heavily on all these plants, except *L. cinereum*, resulting in a decrease in their availability. These palatable species occurred in low quantities on the transformed site and were utilized by the goats. Although availability was very low; some species, such as *P.afra*, were preferred in the transformed site showing that they were actively sought after. Although there was less grass available than woody shrubs, certain grasses such as *C. dactylon* and *P. deustum* occurred in the diet in large quantities in the intact treatment. The ephemeral component of the transformed site vegetation dominated the available forage, with forbs and grasses having a higher availability than woody shrubs. The dominant woody shrubs were various *Asparagus* species and the karoo dwarf shrub *P. incana*.

More than double the number of plant species (n = 94) were consumed by goats in the transformed habitat compared to the intact habitat (n = 42). The number of species consumed in the intact treatment was similar to the 45 species described by Sigwela

(1999) for boer goats but was more than the 23 species described by Stuart-Hill & Danckwerts (1988).

Seasonal shifts due to food availability are clearly shown in the transformed diet. Dietary shifts can occur in response to some external factor, and can also be a reflection of variations in dietary availability (Smith 1990). These external factors could be the changes in rainfall or the availability of ephemeral species. Further there was also a considerable difference in diet variability between the treatments, with the diet of transformed treatment goats being more variable throughout the year than that of the intact treatment goats. Stuart-Hill & Aucamp (1993) showed that vegetation varies with rainfall but that this trend is complicated by veld transformation resulting in a more variable vegetation structure. Thus, this study reflects the same trends with greater dietary variability due to rainfall in the transformed treatment.

The large difference in species richness between the treatments agrees with Kinghorn (1972), who showed that Angora goats are able to widen the scope of their diet during dry periods to include less palatable species. This is especially illustrated by species richness in the diet of transformed treatment goats in September 2005. Two possible scenarios can explain this very high species richness. Scott *et al*. (1996) showed that in a new environment social interaction has more influence than dietary preference on diet selection; however, the goats on the intact treatment did not show this trend as their diet remained constant throughout the year. Rainfall was low leading up to the study with 24 mm in May 2005 being the last recorded rainfall before the study began in August 2005. Therefore it is more likely that this low rainfall resulted in a decrease in available forage in the transformed treatment forcing the goats to consume a wide range of plants. This again illustrates the reliance on rainfall in transformed habitats (Robertson 1988; Stuart-Hill & Aucamp 1993).

Good rains fell in November of the study, leading to an increase in available preferred food. Species richness in the transformed treatment goat diets dropped steadily in the months following these good rains until there was no difference between species richness in intact and transformed diets in January. Species richness in the transformed treatment goat diet increased again in February. This may be due to high temperatures and lower rainfall causing a dying-off of grasses, which did not recover until the heavy rains in May which again caused another decrease in species richness. Species richness in the intact treatment goat diet remained steady throughout the year. This showed the availability of high quality food for the goats throughout the year.

The results would likely have been far different if the study had taken place in a dry year. The expected results would probably have been similar to the September data as that was a dry month following three months of no rain. Aucamp (1978) showed monthly variation in the diet of Angora goats, with diet selection remaining fairly constant, except following elevated rainfall which may have caused the increase in available grass as forage. It is clear that the changes in resource availability are reflected by changes in the diet.

Based on the above it may be concluded that the hypothesis that goats maintained in transformed thicket habitats will have a broader diet than goats in intact untransformed thicket is supported. This clearly reflects the fact that the biomass and availability of preferred, palatable plants species declines in transformed thicket (Hoffman & Cowling 1990, Stuart-Hill & Aucamp 1993, this study). This is the first demonstration of this effect.

3.4.2 Preference

There were 16 PDI found in the transformed treatment goat diet whilst only nine were found in the intact treatment goat diet. Eight of the PDI in the intact treatment goat diet were PDI's in the transformed treatment goat diet, except *C. ciliaris*. *C. ciliaris* still occurred in the transformed treatment goat diet, but not as a PDI. Five species of *Asparagus* were PDI's in the transformed treatment goat diet. It is evident that the goats in transformed treatment have shifted their diet to include species not considered preferred in the control (intact site) diet.

The majority of the PDI in intact the treatment goat diet were utilized in accordance with their availability, whilst most of the PDI in the transformed treatment goat diet were actively selected for and therefore preferred. *E. curvula, P. maximum* and *C. ciliaris* are all considered as good grazing grasses (Van Oudtshoorn 1999), as is *P. deustum* (Van Oudtshoorn 1999) which was the second most important plant in the diet but was not preferred. *P. deustum* is readily available but the availability of these other grasses was low, therefore the goats had to actively search for them.

The PDI in the transformed treatment were almost all preferred showing that the goats selected these species in this habitat. There were fewer grass species selected in the November goat diet compared to the July goat diet in this treatment. The grasses were not yet available due to the low rainfall in the preceding months, rainfall over the rest of the year allowed the ephemeral portion of the treatment to flourish and therefore, grasses were more available in July. The higher number of PDI in the November goat diet in this treatment is likely related to the low rainfall over the preceding months. This pattern of broadening the diet is in accordance with Kinghorn's (1972) statement that Angora goats are able to increase diet breadth during dry periods. The increase in diet breadth in the transformed treatment goat diet shows that preferred species are not readily available and needed to be selected for. There were a number of grasses that served as PDI in the transformed treatment goat diet; due to these species being ephemeral, they would not be available in a dry period.

P. afra is considered to be the most important plant for the production of goat forage in thicket (Aucamp 1979). The vegetation of the intact site is dominated by *P. afra* and it is the dominant species in the intact treatment goat diet. Presumably, due to years of overgrazing by goats at high stocking rates (Lechmere-Oertel 2003, Sigwela 2004), the availability of *P. afra* in the transformed treatment vegetation is very low. It was available in such small quantities that it was not encountered on transects, but was observed in the diet. It is still a PDI and preferred species in transformed treatment goat diet and the goats are therefore still actively searching for this species in this habitat. This indicates that goat browsing may have been largely to blame for the loss of this species, as suggested by Stuart-Hill (1992) and Moolman & Cowling (1994).

In contrast, species such as *Albuca* sp., a geophyte, was not utilized although available in high quantities. In general, geophytes were significantly avoided and succulents utilized in proportion to their availability, except in the November transformed treatment goat diet, where the preference for succulents was due in total to the preference for *P. afra*. This is not in line with Moolman and Cowling (1994) who stated that goats were a major impact on the structure of the geophyte and low shrub component of thicket. Kerley & Landman (2006) suggested that the opening up of bush clumps by elephants provided other herbivores access to food they previously could not have accessed. Therefore, goat herbivory may not be solely responsible for the disappearance of representatives of these growth forms.

The couch grass *C. dactylon* was avoided in both treatments but was still a PDI. Even though *C. dactylon* is considered a grass with high grazing value (Van Oudtshoorn 1999), it produces cyanogenic compounds as a defence against heavy grazing by herbivores, thus resulting in a limited intake rate (Timson 1943).

The aim of this chapter was to investigate the change in goat diet resulting from habitat transformation. The high diversity and high nutritional quality of the vegetation in intact Subtropical Thicket (Kerley *et al*. 1995), have allowed Angora goats to display a high degree of selectivity in their diet. In contrast and as predicted, goats in transformed thicket broadened their diet to include less palatable species that were not preferred in the intact Thicket. In particular, and as predicted by Stuart-Hill & Aucamp (1993), there was a greater reliance on grasses by goats in the transformed thicket treatment, which reflects the need for goats to use less preferred species to make up for the limited availability of normally preferred species such as *P. afra*. Similarly there was a decrease in utilization of certain species in favour of more preferred species in intact treatment. Dietary shifts in the transformed reflect changes in resource availability.

Chapter Four

Dietary quality changes in response to thicket transformation

4.1 Introduction

The nutritional value of natural pastures can vary tremendously due to rainfall, season, veld type and veld management (Van der Westhuysen *et al*. 1988). Intact thicket however retains its high nutritional value year round, even in drought (Aucamp *et al.* 1978; Stuart-Hill & Aucamp 1993; Kerley *et al*. 1995) and the performance of herbivores reflects this pattern (Aucamp *et al.* 1978). As transformation results in a loss of valuable thicket forage species (Hoffman & Everard 1987; Hoffman 1989; Hoffmann & Cowling 1990; Stuart-Hill 1992, Chapter Three), it is likely that the nutritional value of the veld, and subsequently, animal performance will also be affected.

Optimal foraging theory predicts that animals will select foodstuffs of a high nutritional value when there is an abundance of such foodstuffs, however as food availability decreases, so does the selectivity of the animal (Krebs 1985). Selection of forage presumes differences in morphology and nutritive values between plants and plant parts (Van Soest 1982). As the nutritional quality of intact thicket remains relatively constant, even during dry periods; it seems to be quantity and not quality which is the limiting factor to browsing herbivores. Goats are therefore able to select a high quality diet provided that their stocking rates are realistic (Aucamp *et al.* 1978) and preferred forage is available. The productivity of browse can, however, easily be overestimated (Aucamp *et al.* 1982) allowing herbivores to destroy the vegetation, without any immediate detrimental effects to themselves (Stuart-Hill & Danckwerts 1988). One of the consequences of the heavy browsing of preferred plant species is the alteration of growth form to leave more heavily coppiced (Stuart-Hill 1992) or divaricated individuals due to the loss in growing points resulting in an increase in branches to compensate for this loss (Stuart-Hill & Danckwerts 1988). These plants will offer lower leaf to shoot ratios to herbivores (Ganga & Scogings 2007), and hence browsers will be forced to ingest more woody material of lower nutritional quality, even though they may still be able to forage on apparently nutritious and preferred species.

It can thus be expected that desertification of thicket will alter the nutritional quality of browse available to herbivores in two ways; through the loss of high nutritional quality parts (leaves and non-lignified stems) of preferred plant species, and through the loss of these species, leading to a switch in diet to less preferred, lower quality plant species. The aim of this chapter is therefore to investigate the variation in diet quality achieved by Angora goats between the two thicket habitats, intact and transformed (desertified) in order to test the above hypothesis. Furthermore, the nutritional quality of the diet can give an indication of whether the goats in the transformed habitat are under nutritional stress due to the nature of the available food, and hence test the hypothesis that desertification leads to a loss of not only primary productivity (United Nations 1978), but also of secondary productivity (Stuart-Hill & Aucamp 1993), and provide a causal mechanism for this.

4.1.1 Dietary faecal analysis

Herbivore diet quality can be assessed by various techniques. Direct observations are difficult to assess the exact portions of plant species consumed due to variations in bite size, and are time consuming (Mbatha & Ward 2006) and do not account for plant part selection (Wrench *et al*. 1997). Rumen fistulation, although more direct, is invasive, costly and ethically questionable (Wrench *et al*. 1997). Oesophageal fistulation is unsuitable for dietary phosphorous assessment due to salivary phosphorous contamination (Holechek *et al.* 1985).

In contrast, faecal nutrient quality has been proposed as a non-invasive and feasible alternate to techniques requiring undue stress on the animal or death in the measurement of herbivore diet quality (Leslie & Starkey 1985). Faecal nutrient levels have successfully been used to predict dietary nutrients in elk (Mould & Robbins 1981; Leslie & Starkey 1985), black tailed deer (Leslie & Starkey 1985), white tailed deer (Jenks *et al.* 1989) and domestic stock (Holechek *et al.* 1982). Hobbs (1987) was however critical of this method as he stated that the faecal technique did not allow for quantitative comparisons of diet quality among wild herbivores, and can only be used qualitatively to show large differences in diet quality. Biases may be created due to the protein-complexing properties of phenolics and tannins in plants (McLeod 1974; Mould

& Robbins 1981; Hobbs 1987). Due to this faecal nitrogen was not used in this study as Angora goat diet is dominated by browse species (Chapter Three) that are expected to have high levels of secondary compounds and hence a bias against measuring dietary nitrogen. This problem would be compounded as the intact treatment goat diet is dominated by browse, whereas grass dominated the diet of goats in the transformed treatment (Chapter Three).

Leslie & Starkey (1985), Howery & Pfister (1990), Wrench *et al*. (1997), Mbata & Ward (2006) showed that faecal phosphorous can give similar results in terms of assessing diet quality, as faecal nitrogen, without being influenced by secondary metabolites. Dietary phosphorous can be successfully predicted through faecal phosphorous (Wrench *et al*. 1997). As a consequence, this was one of the indices of diet quality used in this study. Similarly, ash is composed of macro and trace minerals and thus also shows the nutrient status of forage and is not significantly influenced by digestion. Faecal NDF (Neutral detergent fibre) composed of hemicellulose, cellulose, lignin, cutin, silica and some cell wall protein is also a useful measure of diet quality (e.g. Hall-Martin *et al.* 1982). In addition, ADF (Acid detergent fibre) and lignin, which influence the digestibility of forage and are lowest in plants that are young and shooting and highest in older portions of especially woody species (Van Soest 1982) has also been shown to be useable in the faecal assessment of diet quality (Erasmus *et al.* 1978).

These diet quality measures were therefore selected as previous studies showed that a relationship existed between these nutrients in the diet and the faeces of ungulates (Van Soest 1982; Hall-Martin *et al.* 1982; Wrench *et al*. 1996).

This chapter thus describes variation in nutritional quality, as indexed by faecal quality, of goats foraging in transformed and untransformed thicket habitats in order to address the above hypotheses.

4.2 Materials and Methods

4.2.1 Faecal analysis

Fresh faecal samples were collected seasonally between August 2005 and July 2006 for each treatment. Samples (n = 5) were analysed seasonally for diet quality. Only fresh samples were collected to ensure that concentrations of phosphorous were not affected

(Wrench *et al.* 1996). Samples were oven dried at 45 ºC for five days and stored in paper bags until analysis. Wrench *et al.* (1996) found that there was no effect of such drying and storage on the faecal phosphorous up to one year after collection. Approximately 20 faecal pellets were selected from each sample and ground in a coffee mill until they could pass through a 1 mm sieve.

The faeces were analysed for % phosphorous, % ash and % fibre (NDF; ADF- and Lignin). Phosphorous was determined using atomic absorption flame spectroscopy. NDF, ADF and lignin was analysed in a VELP model FIWE 6 extractor for raw fibre analysis. Ash was determined during NDF analysis after ashing at 500 ºC. All analysis followed AOCA (1995) methods and were conducted at ChemQuest Industrial Services, NMMU, a SANAS accredited laboratory.

4.2.2 Data analysis

Analysis of variance procedures (two-way ANOVA followed by Turkey's HSD multiple comparison test) were used to test the difference in faecal nutrients between treatments and seasons. Data were arcsine transformed to meet assumptions of normality where necessary (Zar 1999). All results are expressed as percentage dry matter. Statistical analyses were performed using *Statistica* Ver. 7 (StatSoft Inc. 2004).

4.3 Results

The mean faecal phosphorous values showed no significant difference between the treatments, but there were significant seasonal difference within treatments ($F_{3;32} = 32.19$; $p < 0.001$). Tukeys' HSD showed no difference between the intact treatment summer, autumn, winter and the transformed treatment autumn and winter values following the low spring values for both treatments. Transformed treatment values dropped following summer, but remained constant over autumn and winter (Figure 4.1 a).

Ash values showed a similar trend, with no significant difference between the treatments but a significant seasonal difference ($F_{3; 32} = 12.45$; $p < 0.001$). Tukeys' HSD showed that there was no significant seasonal difference between the ash values in the intact treatment (Figure 4.1 b).

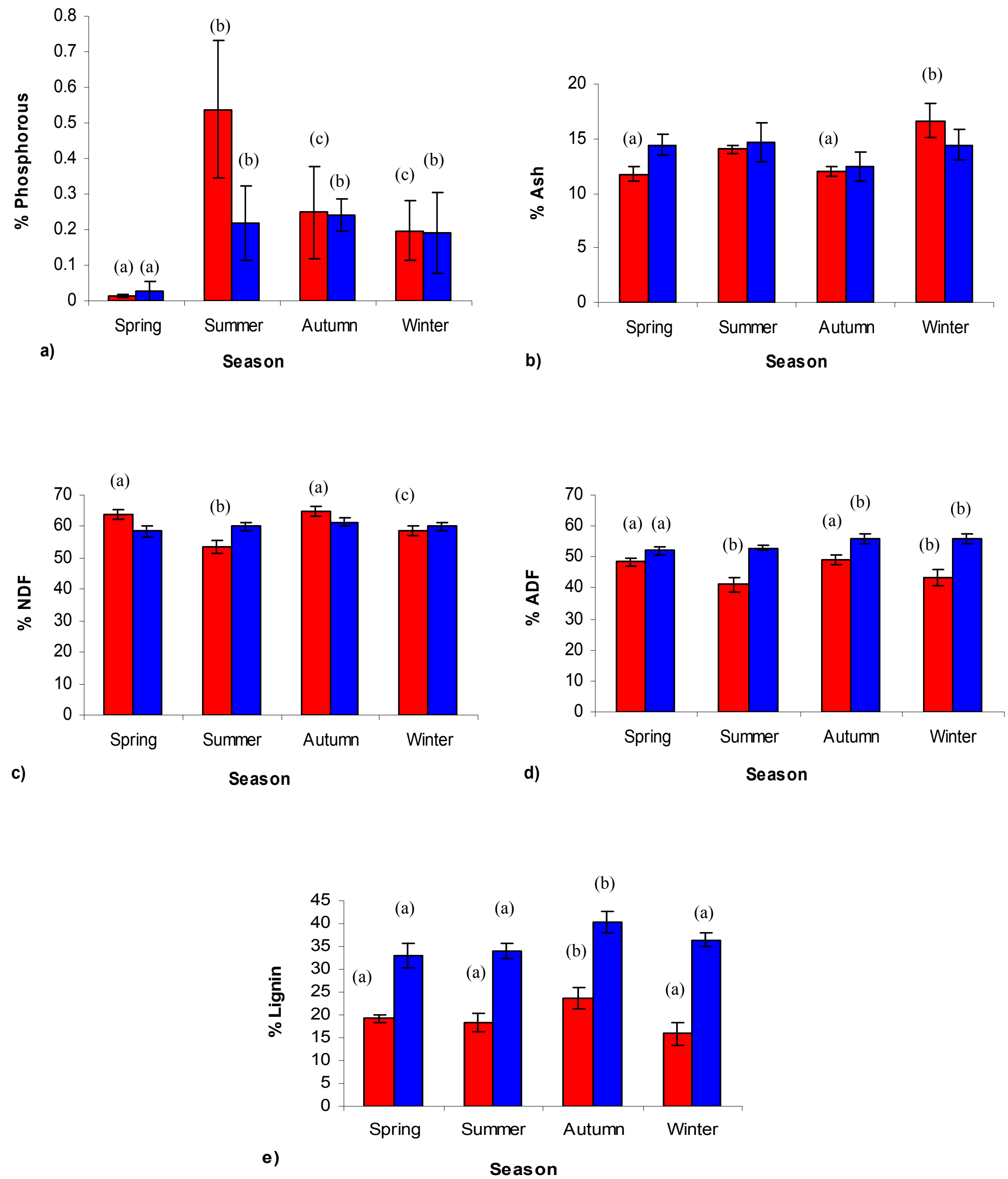

Figure 4.1 Seasonal faecal nutrient values (mean ± 1 SD). (Transformed treatment– red bar; Intact treatment – blue bar) (a) phosphorous; b) ash; c) NDF; d) ADF; e) Lignin). Different letters [a,b,c] above the bars indicate significant differences (Tukey HSD, $p < 0.05$) within treatments, no letter indicates no significant difference to other seasons.

NDF showed no treatment effect but there was a significant seasonal difference ($F_{3;32} = 29.47$; $p < 0.001$). Tukeys' HSD again showed no statistical difference in the intact treatment diet (Figure 4.1 c).

ADF and lignin both showed significant treatment differences (ADF: $F_{1;32} = 273.07$, $p < 0.001$; Lignin: $F_{1;32} = 662.47$, $p < 0.001$) with both being higher in the faeces of goats in the intact thicket treatment. In addition these showed seasonal (ADF: $F_{3;32} = 18.47$, $p < 0.001$; Lignin: $F_{3;32} = 20.3$, $p < 0.001$) differences. ADF and lignin were higher in autumn (Figure 4.1 d & e).

4.4 Discussion

Faecal nutrient levels have successfully been used to predict dietary nutrients in many studies (Mould & Robbins 1981; Holechek *et al.* 1982; Leslie & Starkey 1985; Jenks *et al.* 1989). Certain factors can affect the nutrient concentrations in faeces (Wrench *et al.* 1996). For example, age since defecation and exposure to rainfall can effect phosphorous concentrations in faeces, therefore only fresh samples were collected and only when it was not raining. All samples were collected at the same time for each season, thereby reducing other environmental influences between treatments in this comparative study. Analyses were all done at the same time using the same methods, chemicals and equipment, thereby reducing biases in the analysis. Data and methods used in this study are therefore robust and the comparison between treatments is therefore justified.

Hall-Martin *et al.* (1982) linked seasonal nutrient variations in black rhinoceros in the Eastern Cape, to rainfall, whereas Erasmus & Hall-Martin (1985) were able to demonstrate site specific differences in elephant diet between thicket habitats and Afromontane forests. In addition, Van Teylingen (1992) showed that oribi (*Ourebia ourebi*) faecal nutrients reflected dietary differences and population performance in two different habitats. Leslie & Starkey (1985) showed that faecal phosphorous in elk and deer displayed seasonal trends. Faecal phosphorous peaked during growing seasons of summer and spring and reached their lowest points during winter (Leslie & Starkey 1985). Thus the approach used here to assess variation in diet quality between the two treatments is valid.

Rainfall in this study showed two peaks; one in November 2005 and another in May 2006 (Chapter Two). The rainfall preceding the study was low with 24 mm in May 2005 being the last rainfall recorded before the study began in August 2005.

Season and rainfall affected the faecal phosphorous values in this study with extremely low levels occurring in both treatments during the dry spring months. Faecal phosphorous increased in the wet season and remained stable, in the intact treatment, throughout the rest of the study. These results are consistent with previous studies that showed phosphorous uptake by plants to be positively correlated with soil moisture (see Mbatha & Ward 2006) and growing season (Leslie & Starkey 1985). Hence the significant increase in faecal phosphorous levels in summer, especially in the transformed treatment, can be attributed to the abundance of new grasses and actively growing shoots (pers. obs.). This allowed for increased selectivity by the goats as shown by the decreasing species richness in the summer diet (Chapter Three). The subsequent drop in faecal phosphorous in the transformed treatment is likely due to a decrease in rainfall and extremely high temperatures in February 2005. Decreased rainfall results in die-off of grasses (Robertson 1988).

Ash has been shown to be negatively correlated to NDF as it is an indication of the nutrient status of ingested forage (Macleod *et al.* 1996). The same is shown in this study with ash values being lower in spring and autumn than summer and winter in the transformed treatment after rainfall peaks. The fact that there was no significant difference between the ash values in the intact treatment reflects the consistently high feed value of Succulent Thicket (Aucamp *et al.* 1978).

NDF allows the estimation of cell wall digestibility. Thus the degree of NDF variation indicates differences in the degree of digestibility and/or the availability of feed (Erasmus *et al.* 1978). The seasonal differences in NDF values within the transformed treatment are shown to be correlated to rainfall and hence the increased availability of grasses and new growth which have a high nutritive value (Van Soest 1982). This agrees with the Hall-Martin *et al.* (1982) who found a similar rainfall correlation in the diet of black rhinoceros. NDF has been shown to increase with increasing twig diameter (Ganqa & Scogings 2007) and with increasing maturity due to the increased lignification and decreased leaf to stem ratio (Van Soest 1982).

Browse of woody species contains compounds that reduce forage quality because they are nearly indigestible (e.g. lignin) (Van Soest 1975; Papachristou *et al.* 2005). Therefore, lignin contents correlates to the palatability of food consumed (Van Soest 1975; Erasmus *et al.* 1978). The ADF and lignin value showed large differences between corresponding months in the two treatments. This is due to the intact treatment goats' diet comprising about 70% woody shrubs and succulents which are high in lignin whilst only 46% of the transformed treatment goat diet comprised woody and succulent shrubs. Grasses made up the majority, 48%, of the transformed treatment diet (Chapter Three). Plant tissues which are high in fibre (cellulose, lignin etc) are more difficult for herbivores to extract nutrients from. The seasonal differences correspond to the decrease in growth, in autumn and winter, and the loss of foliage in deciduous species resulting in a lower leaf to stem ratio (Van Soest 1982).

The aim of this study was to investigate the nutritional consequences of thicket transformation on Angora goats in order to test the specific hypothesis that desertification of thicket will alter the nutritional quality of browse available to herbivores. The data do not support this hypothesis, and it would appear in fact that the diet quality, as indexed by lignin, was lower in the intact thicket compared to the transformed thicket. The high quality grass layer available to goats in the transformed treatment allowed them in the most part to perform, in terms of diet quality, as well as the intact goats. The smaller quantity of lignin and ADF in the transformed treatment goat diet may actually give them an advantage as lignin reduces digestibility (Van Soest 1982). This study was not undertaken in a typical year, with rainfall being above average (Chapter Two). Due to the ephemeral nature of the plant species relied upon by the transformed treatment goats it is unlikely that the transformed treatment goats would perform as well nutritionally in a dry year when these plants are not available.

Goats in both treatments showed variability in the quality of their forage; however the transformed treatment showed greater seasonal variability in goat diet. Stuart-Hill & Aucamp (1993) showed that variation in thicket quality, due to rainfall, increased due to transformation. The more constant quality of the intact treatment goat diet agrees with Aucamp *et al.* (1978) who showed that thicket vegetation remains nutritious throughout the year, and that it is quantity and not quality which is the limiting factor to browsing herbivores in succulent thicket.

There was a large quantity of available forage in both treatments throughout the study period; not only due to the high rainfall but also due to the low stocking rates (Chapter Two). In a dry year ephemeral grasses such as *C. dactylon* and *E. obtusa* would not be available (Stuart-Hill & Aucamp 1993) and the goats would be forced to consume a diet of less preferred species or less nutritious plant parts of preferred species. Therefore, higher lignin values are expected in transformed habitats during dry years as the goats would be forced to feed on plants which have a lower leaf to shoot ratio and have become increasingly lignified due to ageing (Van Soest 1982). This can be seen in species such as *P. capensis* where heavy browsing has resulted in umbrella shaped trees (Lechmere-Oertel 2005a) where little foliage of this preferred species is available to the goats. The increase in lignin in the diet would in turn affect the ADF and NDF values; as these increase with increasing lignification (Van Soest 1982). It is therefore clear that in dry years there would be a decrease in diet quality.

As already stated this study did not support the hypothesis that food quality declined in the transformed treatment, and in fact suggest that under the conditions of this study, the dietary quality in the transformed treatment may have been higher (as indexed by faecal lignin). An additional effect of transformation however is the overall decline in the mass of available forage. Both Ralph (2001) and Kamineth (2001) showed a decline in the mass of forage in transformed areas. A consequence of this decline would be that goats would have to spend more time and energy in locating forage resources, which would to an extent offset some of the benefits of the improved quality of forage shown here.

There was no loss in quality in the transformed treatment goat diet but this should not be seen as a reason to allow further thicket transformation. The high rainfall during this study and subsequent availability of a nutritious ephemeral layer allowed the goats to forage on a high quality diet. During dry years and even in winter of average rainfall years, as the Eastern Cape is a summer rainfall region, there would be a decline in quality and a loss in productivity.

Chapter Five

Goat Body Condition and Mohair Production in relation to transformation of thicket

5.1 Introduction

One of the reasons that desertification, whether brought about by climate change or inappropriate management, is of concern is that it has been defined in terms of a decline in productivity of rangelands in arid and semi-arid ecosystems (United Nations 1978). There are however few tests of this effect at the level of secondary productivity, i.e. that of the herbivores dependent on these rangelands. For example, Dean & MacDonald (1994) showed a decline in the population of small stock in the Karoo, South Africa and associated this with a decline in productivity brought about by desertification. Stuart-Hill & Aucamp (1993) showed that the secondary productivity (as measured by carrying capacity) of thicket declined as a function of transformation, but that this was also a function of rainfall. The specific mechanism of a decline in secondary productivity would be that body condition and mohair production (in the case of Angora goats) will be negatively affected by a decline in dietary resources.

In this study it was originally hypothesized that thicket transformation would lead to an increase in dietary breadth (supported by the findings of Chapter Three) and a decline in dietary quality (not supported by the findings of Chapter Four). This original hypothesis then suggested that there should be a decline in secondary productivity (i.e. goat body condition and hair production), and this is addressed in this chapter, even though the expected decline in diet quality has not been demonstrated.

Forage quality for Angora goats varies in quality and the quantity of available forage as a function of site, season and rainfall, and these have been linked to variations in mohair production, body weight and animal condition (Sahlu *et al*. 1999). Sahlu *et al.* (1999) suggests that a better understanding of the effects of nutrition on mohair production and body weight may lead to increased productivity and lessen costs, through appropriate management of limiting factors. Similarly, Van der Westhuysen *et al*. (1988) stated there are a number of factors that affect mohair quality and production, these factors are interdependent and cannot be seen as stand-alone factors. Factors such as follicle density and therefore fibre density are genetically determined. Production factors such as mohair mass, presence of kemp and body mass are all based on genetics but the expression of their genetic potential is based on environmental factors. The age of the goat is the most important factor determining the quality and quantity of mohair produced. Production of hair (mass) increases from birth and peaks around the age of three or four, and then gradually declines. Under peak conditions in South Africa, kapaters (wethers) will produce between five and six kg of fleece per year (Van der Westhuysen *et al*. 1988). Many goats are kept in areas where drought is common (McGregor 2006). Van der Westhuysen *et al*. (1988) report that there are some indications of seasonal effects on mohair production but the effects of age, nutrition and reproduction are more distinct. Since mohair production is mainly dependent on the nutritional value of its diet and Angora goats have higher energy requirements than other small stock making them more susceptible to nutritional stress (Huston *et al.* 1971), there will be a decrease in the mohair production during drought periods (Van der Westhuysen *et al*. 1988). According to Aucamp & Tainton (1984), intact thicket vegetation remains nutritious throughout the year. This high feed value should be reflected by the animals' performance, both in maintaining body mass and in mohair production throughout the year. Adequate nutrition is required to maintain normal body function such as growth and reproduction and for the production of mohair; however undernutrition results in the reduction of growth, mohair production and fibre diameter resulting in a finer, lighter fleece (Van der Westhuysen *et al*. 1988).

The aim of this chapter is to evaluate the effect of thicket transformation on the body mass and mohair production of Angora goats, in order to address the question "Does altered habitat lead to a decline in body condition and an altered production of mohair?" The effects of genetics and age highlighted above was controlled for by randomly allocating a group of same-aged goats from a common genetic pool to either one of the two treatments, as explained in Chapter Two.

5.2 Materials and Methods

Twelve Angora goats were randomly allocated to an intact thicket treatment or a transformed thicket treatment, as described in Chapter Two. The animals were maintained in the treatment from July 2005 to August 2006, and diet quality and composition assessed as described in Chapters Three and Four. The animals were subjected to standard husbandry practices, and body condition and mohair production measured and compared between treatments.

5.2.1 Body condition

Goats from both treatments (n = 24, 12 per treatment) were weighed every 4 weeks between August 2005 and July 2006. Bath *et al*. (1966) showed that ruminants fasted before weighing result in more accurate measurements that do not reflect recent meals. The goats were collected from their respective paddocks on the evening prior to weighing. They were held in separate kraals overnight without food and water until early the following morning. The goats each had a pair of coloured ear tags for easy identification when weighing. Each individual was weighed to the nearest 0.5 kg. Weights were standardized after shearing (which occurred after one, six and 12 months of the study, as determined by standard husbandry) to include the weight of the mohair for subsequent weighing months.

Analysis of variance procedures (two-way ANOVA, Turkey's multiple comparison test) were used to test the difference in weight change between treatments and months (Zar 1999). Shearing or dipping took place after weighing and the goats were then returned to their paddocks.

5.2.2 Mohair production and quality

Mohair quality can be determined through visual appraisal as described in Van der Westhuysen *et al.* (1988) together with micron readings from the OFDA2000 instrument (Gerrit Fourie, pers. comm.[3]). Van der Westhuysen *et al.* (1988) explains how factors such as length, style and character are used to measure the quality of mohair. Mohair grows at a rate of 20 to 25 mm per month on average, so the length of the mohair is primarily determined by the intervals between shearing (Van der Westhuysen *et al.* 1988). The length of each clip is measured on a mohair ruler, good quality mohair should be between a C and B length (100-150mm); as fibres which are too short are not useful to

[3] Fourie, G., Cape Mohair and Wool, Port Elizabeth, South Africa.

the textile industry, and fibres which are too long become entangled in the machines used to process mohair (Gerrit Fourie, pers. comm.[4]). Van der Westhuysen *et al.* (1988) states that style and character can only be judged subjectively on appearance, as they are not measurable entities. The style of the mohair may be described as solid-twisted ringlets and the character as the waviness or the crimp shown in that staple. A good balance between the two factors is ideal; however style and character are not as important to the price as fibre diameter (Van der Westhuysen *et al*. 1988). The OFDA2000 (Optical-based Fibre Diameter Analyser, BSC Electronics (Pty) Ltd., Australia) instrument is able to measure the following characteristics; mean fibre diameter, co-efficient of variation of diameter, percentage of fibres less than 30 μm (comfort factor), percentage of fibres less than 15 μm, curvature and standard deviation of curvature, staple diameter profile, staple length and position of finest and broadest points along the staple (OFDA2000). A portion of a staple is teased out and placed on a wire frame slide which is closed to hold the fibres in place. This frame is then placed on the OFDA2000 and transversed under a low-powered microscope, whilst being illuminated from below by a strobe. This calculates diameter along the length of the staple (Baxter 2000).

Mohair samples were collected from each study animal after one, six and 12 months of the study. Given the short time period in the treatment, fleeces from first shearing were not analyzed. Samples were measured using the OFDA2000; fibre diameter, mohair quality and length were obtained. Difference between the weights (kg) of fleece, length (cm) and diameter (μm) (after six and 12 months) between treatments were determined using a Students' t-test. Data were log transformed to satisfy assumptions of normality where necessary (Zar 1999). Data were compared between sites for both sample sets (six and 12 months) but as the fibres were taken from different parts of the goats' body during the different sampling sessions, the two data sets cannot be compared (See Taddeo *et al.* 2000). Statistical analyses were performed using *Statistica* Ver. 7 (StatSoft Inc. 2004).

[4] Fourie, G., Cape Mohair and Wool, Port Elizabeth, South Africa.

5.3 Results

5.3.1 Body condition

There was no significant difference ($F_{12,286} = 1.1358$; $p = 0.33063$) between the overall weight of the goats over the study period between the two treatments. The variation in weight gain and loss was more pronounced in the transformed treatment (Figure 5.1).

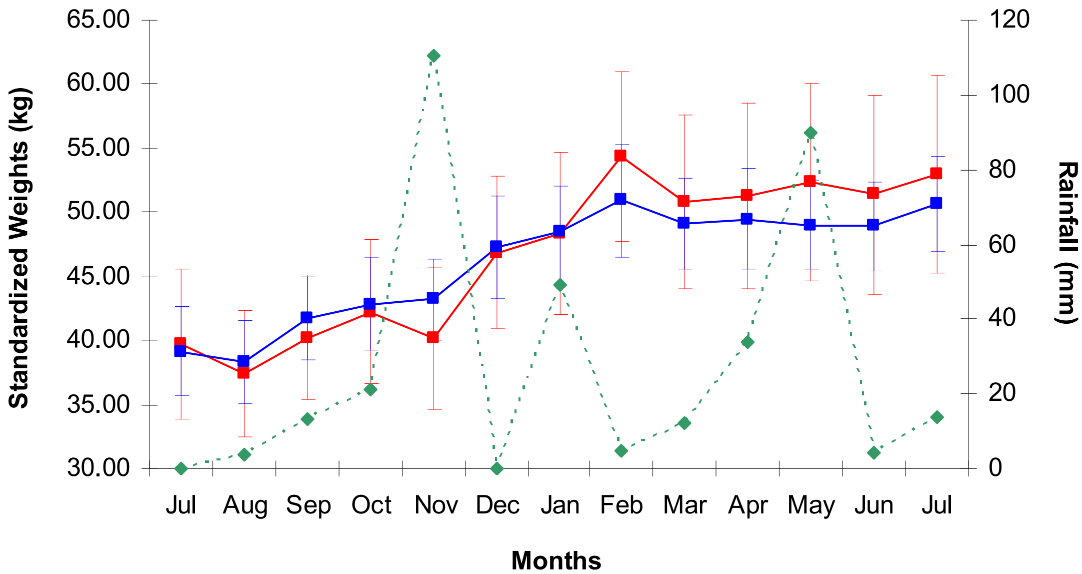

Figure 5.1 Standardized body weights (i.e. including mohair removed during shearing) (mean ± 1 SD) of Angora goats between transformed and intact thicket treatments plotted against monthly rainfall. (transformed - red; intact – blue; green dash - rainfall).

5.3.2 Mohair production and quality

The mohair quality (as indexed by the diameter, µm) did not differ significantly between the two treatments (Table 5.1) at both six ($t_{22} = 0.52$; $p = 0.603$) and 12 months ($t_{22} = -0.04$; $p = 0.64$). The staple length for both sampling periods (6 month: $t_{22} = -0.08$; $p = 0.929$; 12 month: $t_{22} = -0.36$; $p = 0.715$) and the six month mohair weight ($t_{22} = -1.52$; $p = 0.141$) were also not different ($p > 0.05$). However there was a significant difference between the mohair weight in the two treatments after 12 months ($t_{22} = -5.00$; $p < 0.001$), as this was lower in the intact than the transformed treatments (Table 5.1) .

Table 5.1. Mohair quality (mean ± SD) and fleece production (mean ± SD) in the intact and transformed treatments.

Variable	Intact	Transformed	t-values
Mohair diameter at 6 months (μm)	47.058	45.908	0.526; p = 0.603
Mohair diameter at 12 months (μm)	42.712	42.808	-0.045; p = 0.964
Mohair length at 6 months (cm)	111.25	111.667	-0.08; p = 0.929
Mohair length at 12 months (cm)	94.167	95.833	-0.36; p = 0.715
Mohair weight at 6 months (kg)	2.875	3.208	-1.526; p = 0.141
Mohair weight at 12 months (kg)	1.941	2.625	-5.005; p < 0.001

5.4 Discussion

Body mass and mohair production have successfully been shown to correlate with dietary nutrients (Huston *et al*. 1971; Russel 1992) as fibre growth is primarily regulated through follicle nutrient supply (Reis & Sahlu 1994) and the maintenance of body weight is correlated with the availability and quality of forage (Strickland *et al*. 2005). Primary productivity, as indicated by nutrient quality of the veld, has been shown to affect the secondary production potential of these rangelands (Stuart-Hill & Aucamp 1993; Dean & MacDonald 1994) thus the use of body mass and mohair production as indicators of the secondary production potential of the veld is valid.

Body mass was determined through weighing after a night of fasting as this negates the effects of the mass of the rumen content (Bath *et al*. 1966). Weighing was completed before any treatments such as dipping or shearing. The same equipment was used throughout the study. Mohair quality was determined using the OFDA2000 instrument which has previously been used with success in other studies (Litherland *et al*. 2000). Data and methods used in this study are therefore robust and the comparison between them is justified.

The data do not support the original hypothesis that transformation will cause a decline in secondary productivity as measured by body mass and mohair production. This was however expected after the expected decline in diet quality (Chapter Four) was not demonstrated. The high quality forage throughout the study period (Chapter Four) resulted in there being no significant difference in the body mass between the two treatments. This is likely due to the high rainfall throughout the study period which provided the goats with high quality forage in the form of abundant grass and forbs resulting in a decrease in foraging effort. Growth throughout the year was not steady with the transformed treatment showing greater variability, this reflects the increased variability in the quality of transformed landscapes due to rainfall (Stuart-Hill & Aucamp 1993). Weight decreased in both treatments in the first month, this was expected as they had been operated on for a concurrent study (Hetem in prep). The larger weight decrease occurring in the transformed treatment goats compared to the intact treatment goats in November, may be caused by the lack of shelter during high rainfall only a month after shearing. There was a similar, but not as pronounced, weight loss in May after high rainfall, but the goats had a full coat at that time. Henley (2001) showed that transformation leads to an increase in extreme air and soil temperatures due to its open nature. Thus there is a greater chance that Angora goats in open habitats could succumb to bad weather. There was an abundance of grass, especially in the transformed treatment, during warm, rainy January, which accounts for the weight gain in both treatments. High temperatures and lack of rain in February could have caused a die-off in available grasses (Robertson 1988) causing weight loss, which was not recovered during the winter months. Strickland *et al.* (2005) showed that differing environmental conditions such as temperature and rainfall affected not only the quantity and availability of forage but also effected the thermoregulation of the animal which may influence metabolic requirements and resulting energy requirements for the maintenance of body weight.

Previous studies have shown that mohair production is influenced by diet. Sahlu *et al.* (1999) showed that restricted feed intake could have longer-term effects on mohair growth than on the body weight of animals. They suggested that feed intake be kept constant as to prevent negative influences on long-term fibre production. Litherland *et al.* (2000) showed seasonal effects on the production and quality of the mohair. This was not demonstrated in this study as the nutrient quality of the veld did not differ significantly between seasons and treatments, except for lignin and ADF (Chapter Four) which did not appear to affect the secondary productivity of these treatments.

The mohair production showed no significant difference between the two treatments except for the weight of the mohair at the 12-month shearing, this being lower in the intact treatment compared to the transformed treatment. This unexpected result (production was predicted to be lower in the transformed treatment) is counterintuitive and may be caused by snagging of the animals' fleeces on the thick bush as they moved through the vegetation in the intact treatment. This may result in hair being combed off the animals. This weight difference cannot be a production issue as the fleece diameters and lengths showed no significant difference. This hypothesis may be tested by collecting snagged mohair from the vegetation in the two treatments and measuring its abundance.

The altered habitat in this case did not lead to a decline in secondary productivity as defined by a change in body mass or altered mohair production. This study was undertaken in a good year with high rainfall. However, the transformed treatment goats are reliant on an ephemeral plant layer (Chapter Three), which may not be available during a drought period (Stuart-Hill & Aucamp 1993). As open landscapes, such as transformed thicket, have little shelter from inclement weather, we can postulate that it is not only the change in diet which can cause stress in Angora goats but the change in vegetation growth forms, which influences the shelter available to the animals. In March 2007, thousands of Angora goats were killed by persistent rainfall and icy winds in the drier districts of the Eastern Cape (Bezuidenhout 2007).

Long-term high quality mohair is reliant on constant good nutrition (Sahlu *et al.* 1999). Thus the increased variability in the production potential of transformed landscapes can have a negative effect on the quality of mohair. Even short-term periods of nutrient restriction can cause a decline in mohair quality (Sahlu *et al*. 1999) as dry periods cause sections of finer fleece (Van der Westhuysen *et al*. 1988). Even though transformed thicket can sustain more grazers (Stuart-Hill & Aucamp 1993), this is an unstable state (Lechmere-Oertel 2005a). As intact thicket retains its nutrients even in drought (Aucamp 1978), it is important for the future of the mohair industry in the Eastern Cape that thicket vegetation be properly managed for long-term sustainability. Currently South Africa is renowned for its high quality mohair but this quality needs to be maintained in order for South Africa to retain its share of the world market (Snyman 2002).

Chapter Six

General Discussion

Succulent thicket is unique compared to other semi-arid rangelands, as in its intact natural state it is a very stable ecosystem (Kerley *et al*. 1995). However, transformation of this thicket through domestic herbivory has shown to lead to a loss of thicket plant species (Moolman & Cowling 1994), the replacement of palatable species by unpalatable ones (Hoffman & Cowling 1990; Stuart-Hill 1992), the invasion of alien plant species (Stuart-Hill & Danckwerts 1988), a decline in plant biomass (Ralph 2001; Kamineth 2001) and thus the decrease in secondary productivity (Stuart-Hill & Aucamp 1993). As the United Nations (1978) define desertification as a loss in productivity in semi-arid or arid rangelands it is clear that transformation of thicket leads to desertification. In contrast to the stable state of intact succulent thicket (Kerley *et al*. 1995), Stuart-Hill & Aucamp (1993) showed that transformed succulent thicket is not a stable state with the ephemeral resource layer being reliant on rainfall for production. During a drought or dry season, this ephemeral grazing would probably be absent (Stuart-Hill & Danckwerts 1988). This transformation from a perennial to an ephemeral resource base is worrying, as the low resilience and long recovery period of thicket suggests that changes in vegetation structure are irreversible (Hoffman & Cowling 1990). Climate change scenarios, in the Thicket Biome, point to warmer weather and a 25% decline in rainfall over the Eastern Cape, South Africa (WWF 2001). The resulting loss of plant species, due to the fewer number of days where soil temperature and moisture are suitable for plant growth, will in turn decrease the production potential of thicket vegetation (Rutherford *et al.* 1999; WWF 2001), thus the loss of production potential represents a desertified state (United Nations 1978). There is a decrease in soil fertility (Lechmere-Oertel 2005b), changes in the availability of palatable thicket plant species (Hoffman & Cowling 1990; Stuart-Hill 1992; Moolman & Cowling 1994; Chapter Three) and reduced secondary productivity (Stuart-Hill & Aucamp 1993) in transformed thicket; this reflects the predictions of the FOA (1999) that climate change will reduce soil quality, change vegetation availability and reduce secondary productivity. This similarity between climate change predictions and transformation effects allows the use of thicket transformation to predict the effects of climatic change on herbivores within the Succulent Thicket Biome.

In order to understand the influence of transformation, and thus predict the effects of climate change on domestic herbivores in thicket, Angora goats, an economically important species in thicket and a useful model browser, were used to test hypotheses around altered feeding and secondary productivity. This study investigated changes in diet and body condition of Angora goats; through the use of faecal dietary analysis for both composition and quality. Body mass and mohair production and quality were used as indicators of body condition. As no previous studies have measured the response of domestic herbivores to transformation in thicket, an understanding of the effects of thicket transformation on Angora goats is fundamental for the future management of this species under increasing habitat transformation and climate change.

A limitation of this study was the fact that it was not possible to replicate the treatments in space (multiple trials) and time (multiple years). This is a frequent constraint on trials of this nature, and it is virtually impossible to overcome this, especially at the level of an MSc study. As a consequence it was necessary to treat goat individuals within treatments as independent samples. Ideally there should have been multiple independent sites, each with a fence line contrast treatment used here. Each flock could be treated as an independent sample. The results of this study should therefore be interpreted with this constraint in mind.

In answering the questions posed at the start of this study (Chapter One) it was shown that goats maintained in the transformed thicket habitat had a broader diet (94 species) than the goats in the intact untransformed thicket (42 species) (Chapter Three). This clearly reflects the fact that the biomass and availability of preferred, palatable plants species has declined in the transformed habitat (Hoffman & Cowling 1990; Stuart-Hill & Aucamp 1993; Lechmere-Oertel 2005a; Ralph 2001; Kamineth 2001; this study) and the goats were forced to include less palatable species in their diet. Dominant thicket species such as *P. afra, G. robusta, P. capensis* and *E. undulata,* have nearly disappeared from the transformed treatment (as predicted by Stuart-Hill 1992), and are thus only found in small quantities in the diet. The high quantity of ephemeral grasses found in the diet, such as *C. dactylon, E. obtusa* and *E. curvula*, reflects the abundance of these species in the transformed paddock during this study. The reliance on the ephemeral plant layer will result in a loss of production by the goats in drought years, as cover and biomass track rainfall (Stuart-Hill & Aucamp 1993). The transformed thicket landscape is not a stable state and is likely to continue changing (Lechmere-Oertel *et al*. 2005a), as processes are set in motion whereby desertification becomes self-accelerating (United Nations 1978). This study was undertaken in a high rainfall year, and ephemeral grazing was available, the goats still widened their diet and included less palatable species, especially in lower rainfall months.

The intact treatment diet showed less seasonal variation than what occurred in the transformed treatment diet. Species richness values of goat diet for the intact treatment remained fairly constant throughout the year, but the species richness values for the transformed treatment responded to rainfall patterns with a wider, more variable diet following low rainfall months. As climate change models predict a 25% decrease in the rainfall in the Eastern Cape (WWF 2001); the production potential of transformed landscapes will become even more variable (Stuart-Hill & Aucamp 1993) and there would be a shift from intact thicket to degraded thicket due to a loss of species (WWF 2001). The predicted increasing variability of the climate under climate change scenarios (Hulme *et al.* 2001) would have a more pronounced effect on already transformed habitats compared to intact habitats.

Within the intact treatment goat diet *P. afra* dominated the available browse and over 40% of the diet of the goats comprised this species. *P. afra* is one of the first species to disappear under severe grazing by domestic herbivores (Hoffman & Cowling 1990; Stuart-Hill 1992). Similarly climate change models predict that 19.7% of the area where *P. afra* grows will become unsuitable for the species due to climate change (Robertson & Palmer 2002). The loss of intact thicket and dietary important species, for Angora goats, such as *P. afra* due to climate change or transformation, could be detrimental during dry periods as ephemeral species will not be available.

Specific hypotheses addressed in this study (Chapter Four) were not supported; there was no decline in the diet quality of the goats in the transformed treatment compared to the intact treatment. However this was a high rainfall year and there was an abundance of ephemeral grasses and forbs. Optimal foraging predicts that goats will select the most nutritious and palatable plants and plant parts first, and if these decline through transformation, the goats will need to ingest less palatable species or plant parts. The goats in the transformed treatment were less selective than those in the intact treatment (Chapter Three) but the quantity of ephemeral grasses available and the new growth on woody shrubs (per. obs.) allowed them to ingest a high quality diet. This forage would probably not be available during drought due to its ephemeral basis. The nutritional quality, as indexed by lignin, was lower in the intact treatment goat diet, this is due to the dominance of browse species in the diet (Chapter Three). However, diet quality showed higher seasonal variation in the transformed treatment goat diet. Many thicket species retain their forage potential throughout the year (Stuart-Hill & Aucamp 1993) while ephemeral plant species respond to rain and frost (Hoffman 1989). The potential for a sudden change in diet quality in transformed thicket as a response to rain can effect goats negatively, as a change in the diet of ruminants is followed by a change in the microbial population responsible for digestion. This change may take up to 14 days and the more drastic the diet change the longer the adaptation process. The degree of digestion determines the feed utilization and performance of the animal. This change is influenced by the available nutrients in the diet (Van der Westhuysen *et al.* 1988). Thus the increased variability in both the transformed landscape, the decline in overall plant biomass and predicted climate change would negatively influence the performance of Angora goats in these habitats in the longer term. As desertification is defined as a change from a more productive to a less productive state (Acocks 1975; United Nations 1978; Roux & Theron 1987), the aim of Chapter Five was to show a link to the nutritional quality of the goats' diet as expressed by a decline in secondary productivity. The high quality diet ingested was adequate for the goats in both treatments to grow, providing that stocking rates are realistic, Angora goats are able to select a diet sufficiently high in quality to ensure unrestricted growth throughout the year (Aucamp 1974). No difference between mohair production and quality was shown between the treatments. We would have expected a finer lighter fleece to be produced by the transformed treatment goats (Van der Westhuysen *et al.* 1988) but due to the high quality food available this was not seen. This study was undertaken in a high rainfall year; in a year of low rainfall or drought, supplement feeding would likely be necessary in the transformed treatment in order to maintain productivity (Van der Westhuysen *et al*. 1988). The transformation of thicket, and the resulting variation in nutrition, due to the changing availability of ephemeral vegetation, results in negative effects on long term fibre production (Sahlu *et al*. 1999). Poor nutrition results in a thinner, lighter fleece (Van der Westhuysen *et al*. 1988), thus the variation over the staple length would increase. Even short term periods of low food intake can negatively affect the production of mohair (Sahlu *et al.* 1999). The quality of mohair needs too remain consistently high for producers to retain their international market share (Snyman 2002). Thus the effects of climate change, due to the decrease in palatable species, could result in a decline in the quality of mohair produced in succulent thicket.

Stuart-Hill & Aucamp (1993) showed that carrying capacity changed considerably depending on annual rainfall and this was complicated by veld degradation which caused greater variability in available forage. In wet seasons when there is a large amount of ephemeral vegetation, grazers benefit from the open bushveld, even though this is considered to be the lower range of ecological status. Dense bushveld (high ecological status) is more productive in other seasons and more consistent in this productivity (Stuart-Hill & Aucamp 1993). In the short term transformed thicket may be able to support more grazers but allowing thicket to degrade reduces future management options, as transformed thicket does not appear to regenerate, thus degraded thicket is an unstable base (Lechmere-Oertel *et al*. 2007) for pastoralism for which intact thicket is optimum (Stuart-Hill & Aucamp 1993). It is predicted that had this study been undertaken in a drought period, the results would have been very different, with goats in the transformed site being forced to subsist on poor quality forage, thus secondary productivity, as indexed by carrying capacity, is more variable in transformed habitats, even though this could not be shown in this short term study. As climate change models predict not only a rise in temperature but also a decline in rainfall; we can predict that there will be less ephemeral vegetation available in transformed thicket resulting in a heavy decline in the secondary production potential of these rangelands.

The loss of secondary productivity due to climate change will have an economic knock-on effect, as 80% of the mohair industry in SA is based in thicket. The transformation of thicket could result in economic losses if habitat is no longer suitable for goats. Income generated from mohair farming in thicket is over R192 million rand annually. There are a number of other industries which rely on intact thicket for their sustainability (see Chapter One). These industries alone bring in, in excess of R170 million per annum, thus a loss in the production potential of the Thicket due to transformation or climate change could have far reaching effects both economically and socially, as many jobs are sustained by these industries (Sims-Castley 2002).

The loss of palatable thicket species through transformation is likely to affect indigenous ruminant diets (e.g. kudu, bushbuck, etc) in a similar way. Modelled on the effects of transformation on Angora goats; thicket herbivores, relying on browse species, are likely to show a dietary shift to less preferred species if the available browse component of their diet decreased. The shift and subsequent effect on quality is likely to be more pronounced than in goats, which are mixed feeders, as Sigwela (1999) showed that kudu in thicket rely mainly on browse, with only 4% of their diet comprising grass. There was a large potential for dietary overlap between kudu and boer goats, especially during dry seasons, reflecting potential competition for resources. Macleod *et al*. (1996) showed that in dune thicket the diet of bushbuck consisted mainly of browse. The indigenous herbivore ruminants have been shown to be more selective in their diet than goats (Kerley *et al*. 2006), thus the need for dietary shift in the face of changing plant communities is greater than in goats and the potential detrimental effects in indigenous species will be greater due to their more specialised feeding. This has implications for the conservation and management of indigenous herbivores in thicket habitat that need to be further explored. Many species such as kudu, bushbuck and duiker have survived outside reserves in the Eastern Cape due to both the nature of their browse dominated diet and their ability to use dense thicket vegetation as cover. These species are at risk from an opening up of habitats and the decrease in forage. The effect of climate change and the resulting loss in habitat and available forage on endangered species such as black rhinoceros needs to be investigated.

The ephemeral plant basis of the goat diet in the transformed treatment allows us to predict consequences of desertification due to transformation or climate change, even though certain predictions of this study were not met. Stuart-Hill & Aucamp (1993) showed that the ephemeral plant layer would not be present in dry years; therefore we can predict that the nutritional value of transformed thicket would be low in dry years resulting in a loss in secondary productivity in Angora goats. The diet quality data of this study do not show that there is a cost to transforming thicket; but this was a wet year and the stocking rates were low in both paddocks. Therefore there was an abundance of high quality forage in the form of ephemeral species which would be absent in dry years or at high stocking densities due to increased competition for resources.

Consequently, it is important for the future of Succulent Thicket vegetation that vegetation be properly managed. The implications for both conservation and production in transformed thicket are very serious (Lechmere-Oertel 2005a). Due to the predicted changes in vegetation due to climate change and the increasing heat and decreasing precipitation, fire may increasingly be an issue in thicket; which in its pristine condition does not support a regular fire regime (Kerley *et al*. 1995). WWF (2001) suggest that the use of grazing as a management tool should be used with caution, especially in dry years. Low stocking rates, adequate rest periods to allow the recovery of thicket plant species and the replacement of domestic stock with indigenous herbivores (Kerley *et al.* 1995) may be the answers to protecting pristine Succulent Thicket.

A key lesson from this study is that long term processes such as climate change and desertification can not be effectively studied on the short term. A study such as this which provides a snap shot of what is a poorly understood long term process may simply confuse the issues regarding the effects of such processes (as shown for the secondary productivity results here). Even Stuart-Hill & Aucamp's (1993) study which was undertaken over three years, and fortuitously included a dryer and wetter period, was too short to properly understand the longer term dynamics of these rangelands. It may therefore be concluded that this and similar studies should be undertaken as part of a much larger approach to understand climate change and its consequences.

6.1 Future research

One of the main short comings of this research was the limited time frame. A long term study would take into account the annual variation in rainfall and temperature. The study would therefore address a similar hypothesis as the current study:

- Results from a dry year would show large treatment effects with the intact site providing a more stable forage base, comprising largely perennial species. This is based on the recognition that the biomass of preferred, palatable plants species declines in transformed thicket (Hoffman & Cowling 1990; Stuart-Hill & Aucamp 1993), and that there is more variability in the secondary production potential of transformed thicket as a response to rain (Stuart-Hill & Aucamp 1993). Goats have been shown to shift their diet to include less palatable species, but low rainfall would result in the decrease in both dietary quality and body condition.

The consequence of the decline in thicket forage availability shown by Ralph (2001) and Kamineth (2001) will lead to wider dispersion of forage resources and the need for greater foraging effort by herbivores in transformed thicket.

- This hypothesis should be tested by measuring foraging effort in Angora goats which have been shown to be excellent models of thicket browsers. Such a study would complement the data presented here and provide further understanding of the consequences of thicket transformation.

The implications of thicket transformation for the conservation and management of indigenous herbivores can be further explored through the implementing of the following research:

- The use of domestic herbivores has proved useful in assessing the dietary and productivity responses of ruminants to transformation of thicket and hence addresses hypotheses of the effects of climate change on this guild. This approach should now be expanded to address the responses of indigenous herbivores, and specifically focus on the consequences for the conservation of these species.
- The relatively small size of goats limits their ability to harvest forage. It has been predicted (Kerley & Landman 2006) that elephants, due to their large body size, would be able to not only transform thicket through over utilization, but would then be able to maintain productivity through their ability to subsist on poor quality forage. In addition, elephant are not able to subsist on ephemeral plants, due to their requirements for large volumes of forage. This hypothesis should be addressed, using the approaches employed in the present study.

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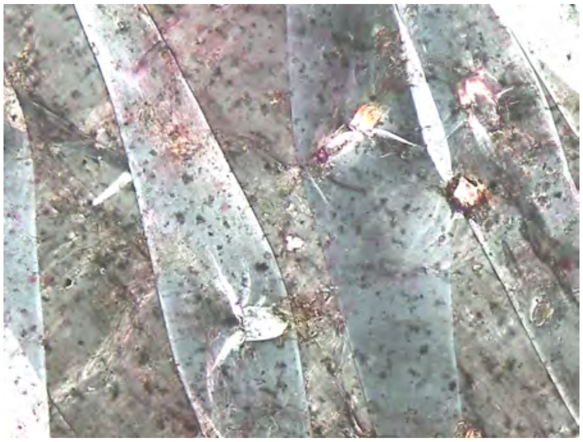
Appendices

Appendix 1a - Photomicrographs of plant species found on study site



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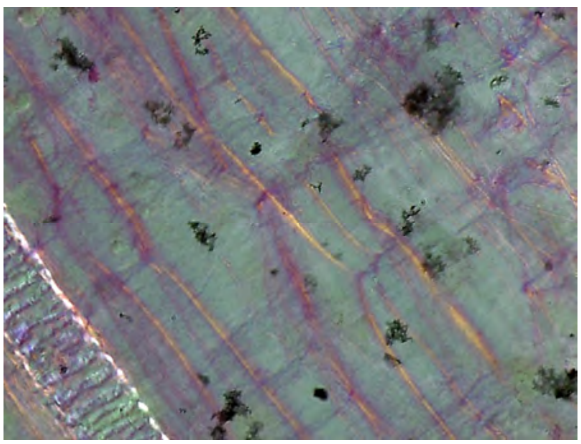
1b



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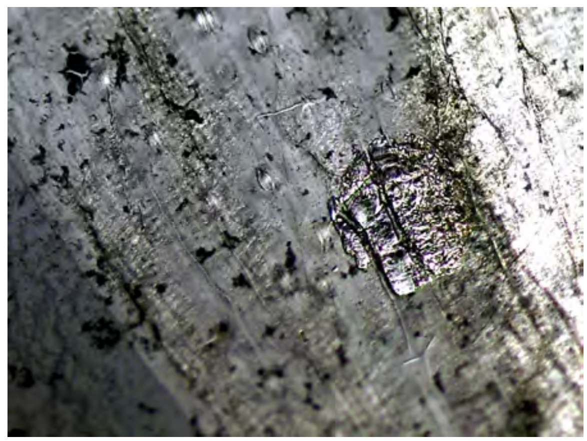

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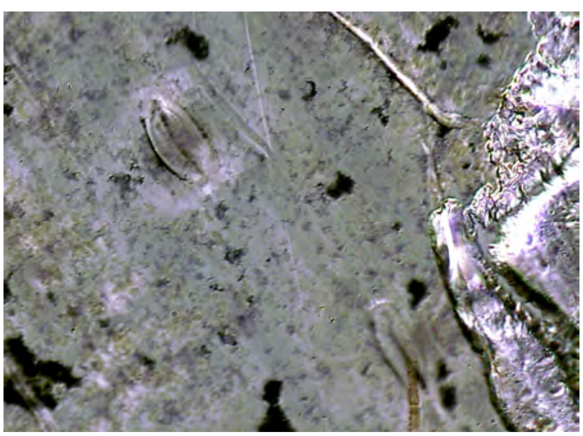

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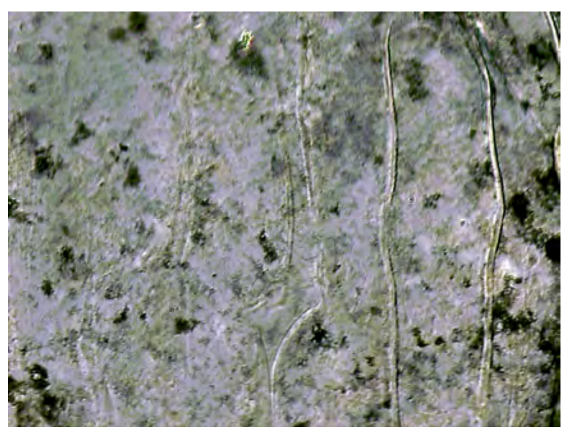
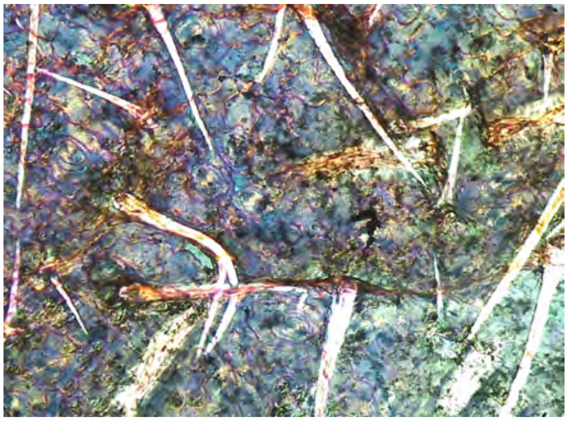


3c

Plate 1. 1a and 1b: *Aizoon glinoides* 100x; 2: *Albuca sp.* 400x;
3a: *Anthospermum aethiopicum* 100x; 3b and 3c: *Anthospermum aethiopicum* 400x.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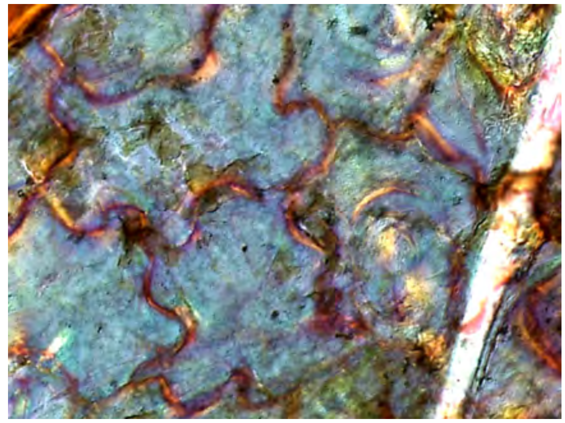
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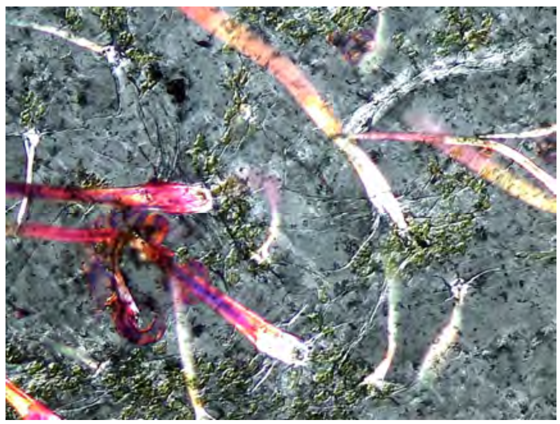
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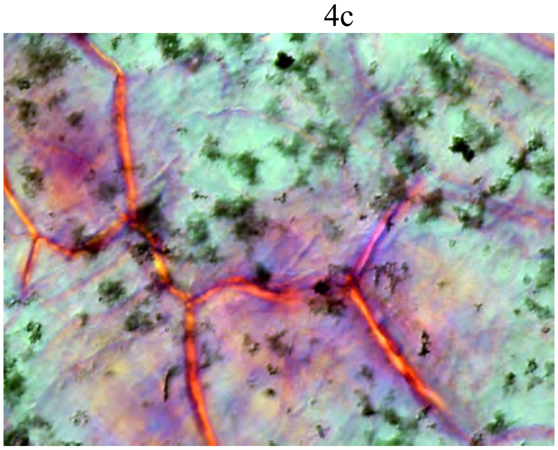
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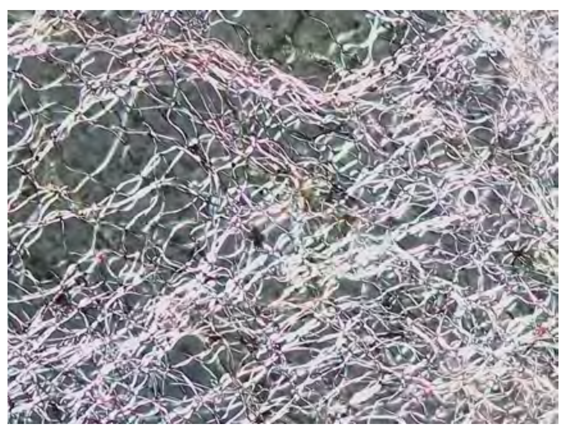

5b

Plate 2. 4a: *Cissampelos capensis* 100x; 4b and 4c: *Cissampelos capensis* 400x; 5a: *Arctotheca calendula* 400x; 5b: *Arctotheca calendula* 100x.

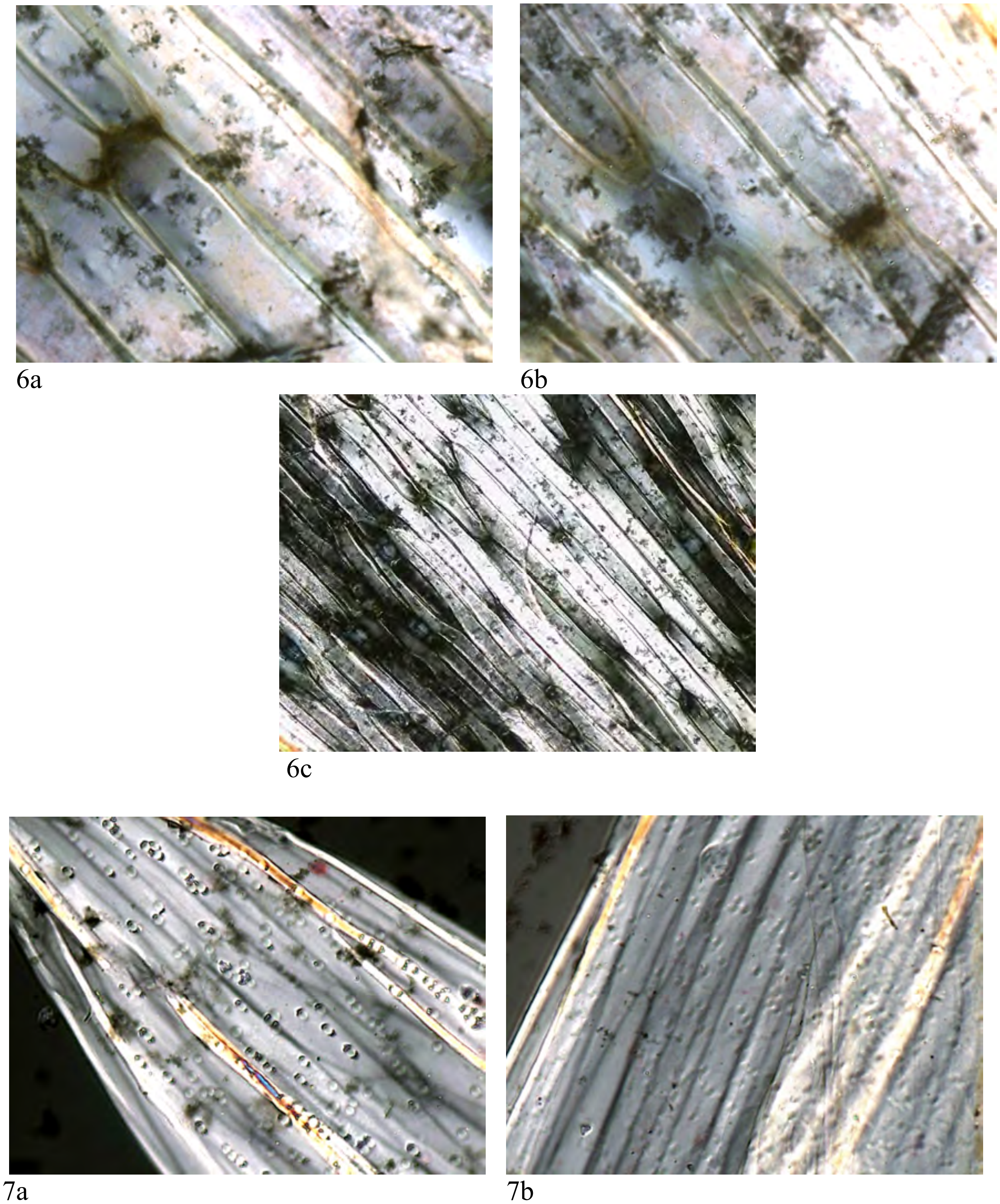
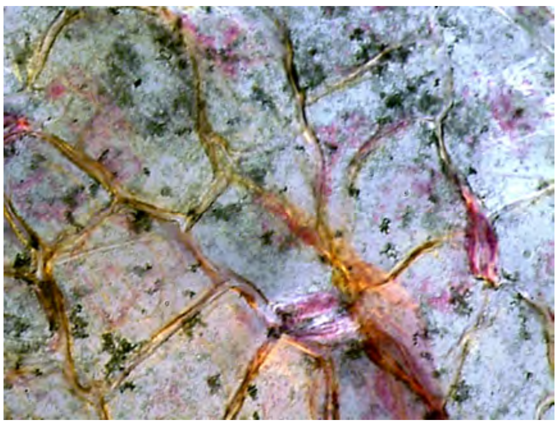


Plate 3. 6a and 6b: *Asparagus aethiopicus* 400x; 6c: *Asparagus aethiopicus* 100x; 7a and 7b: *Asparagus setaceus* 400x.

8

9a



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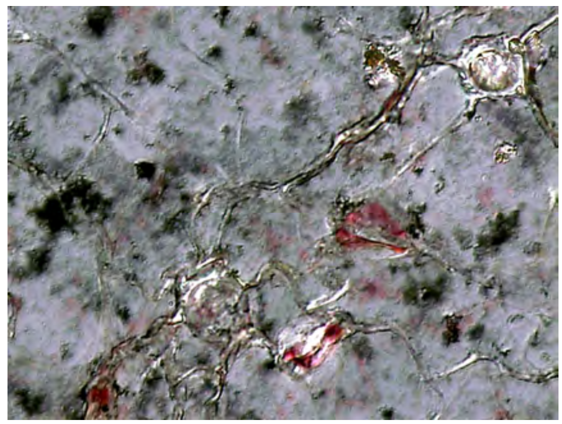

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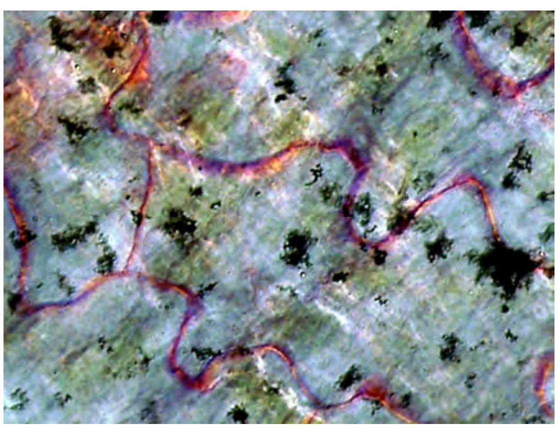

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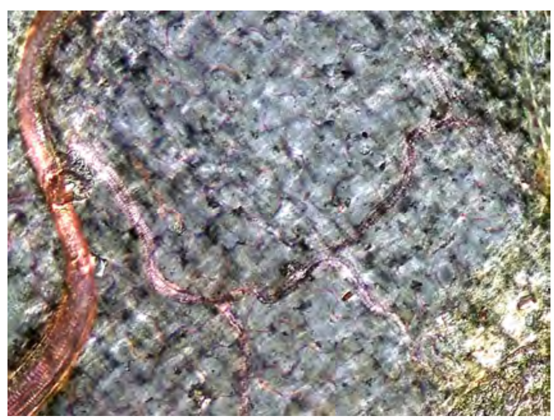
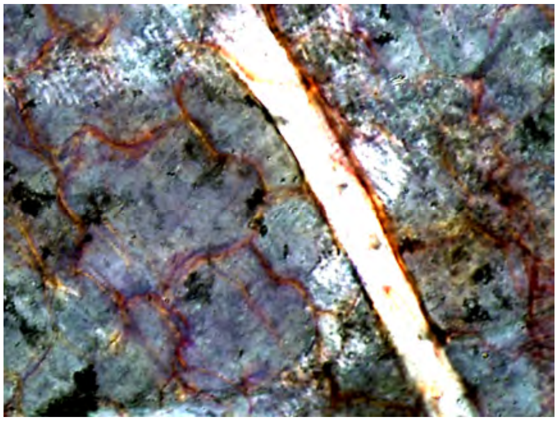


10b

Plate 4. 8: *Atriplex lindleyi sub inflata* 100x; 9a: *Chenopodium album*100x; 9b and 9c: *Chenopodium album* 400x; 10a: *Cineraria saxifragra* 400x; 10b: *Cineraria saxifragra* 100x.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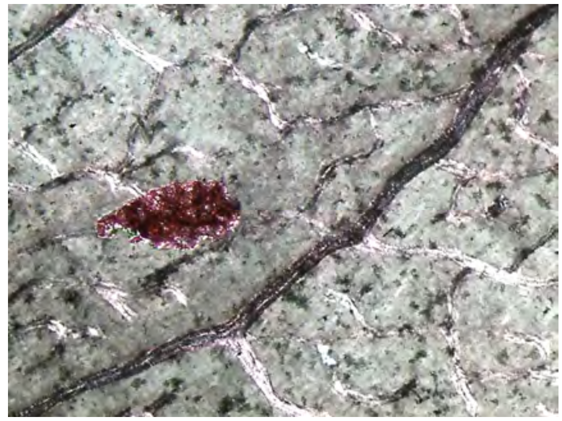
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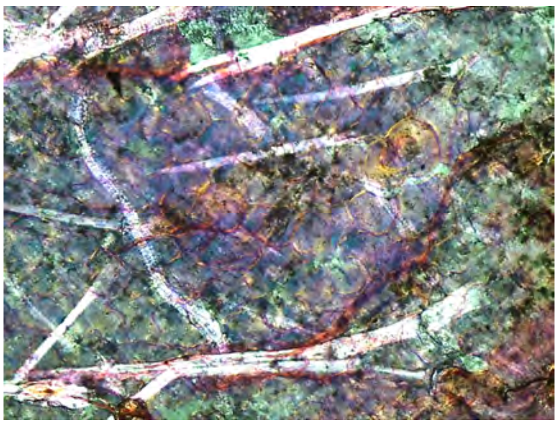
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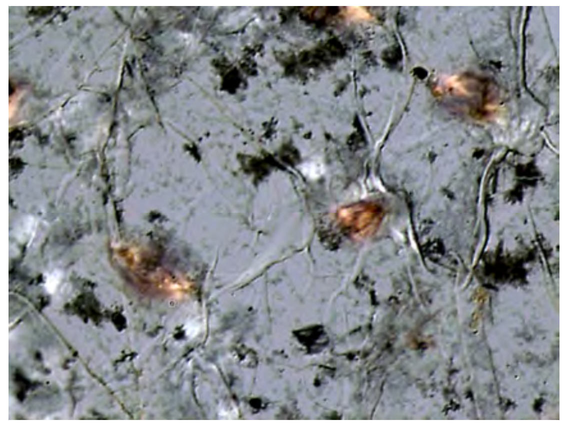
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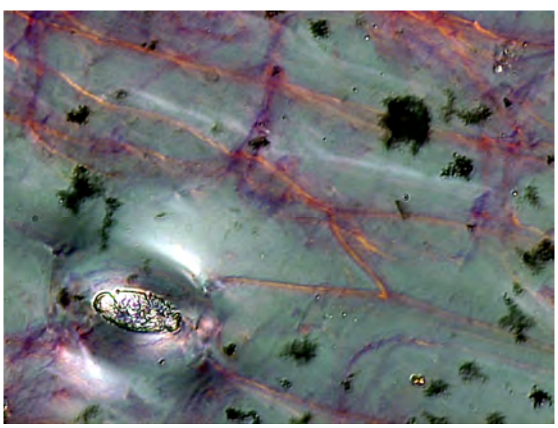
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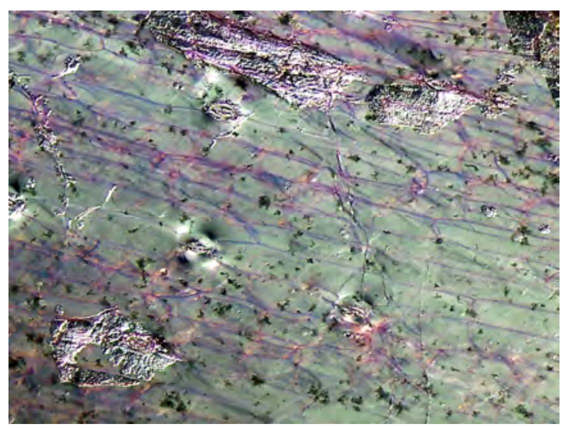
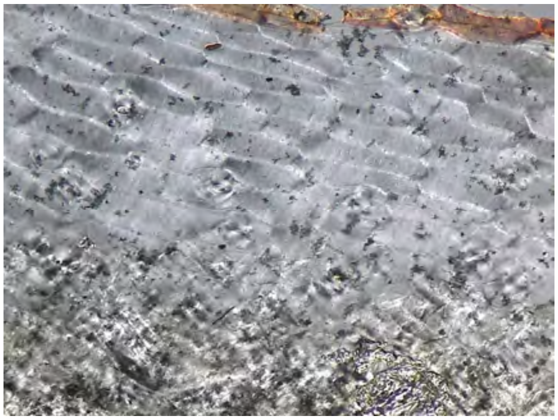
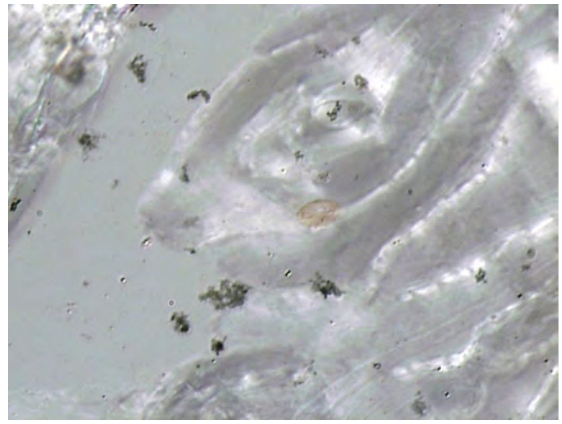
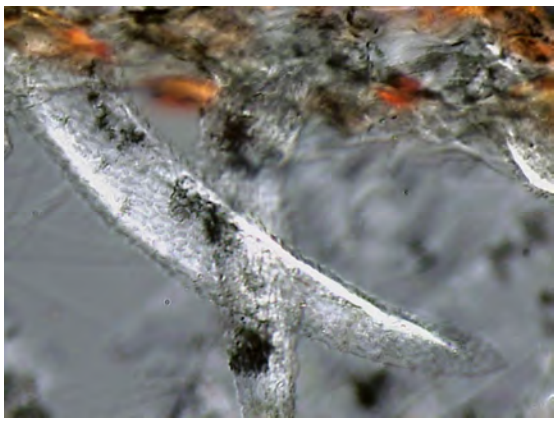
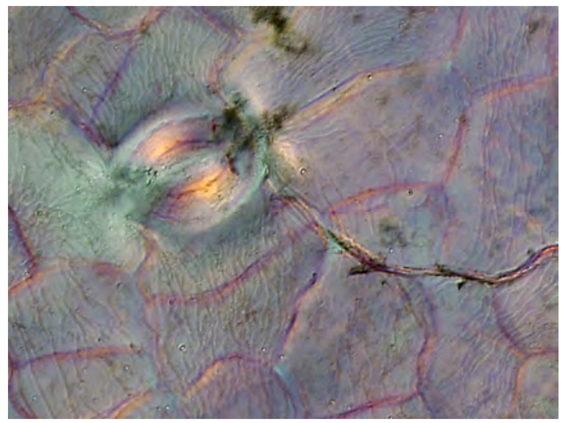

13b

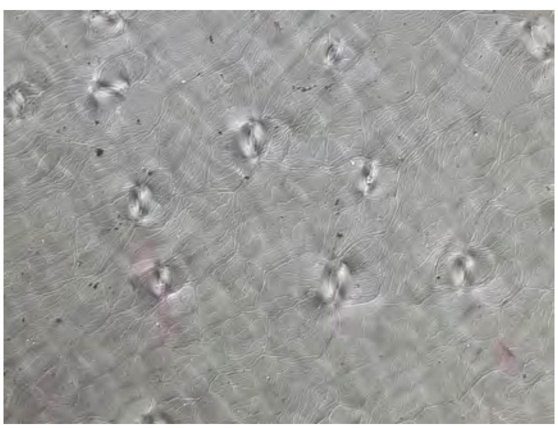
Plate 5. 11a: *Felicia amoena* 400x; 11b and 11c: *Felicia amoena* 100x;
12: *Felicia filifolia* 400x; 13a: *Ledebouria sp* 400x;
13b: *Ledebouria sp* 100x.


14a


14b


14c


15a


15b

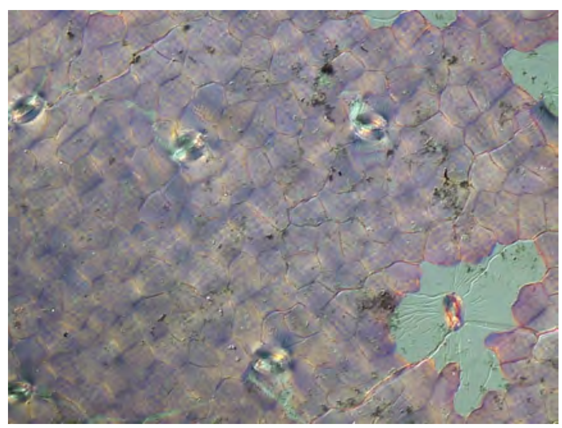
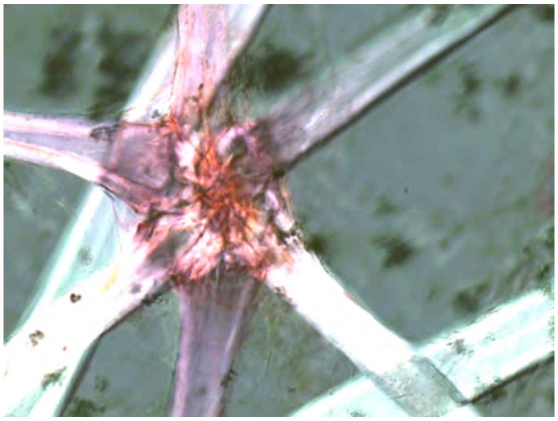
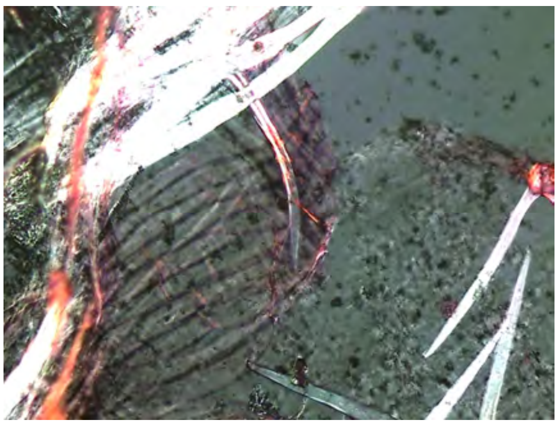

15c

Plate 6. 14a: *Lepidium africanum* 100x; 14b and 14c: *Lepidium africanum*
15a: *Lycium ferocissimum* 400x; 15b and 15c: *Lycium ferocissimum* 100x.

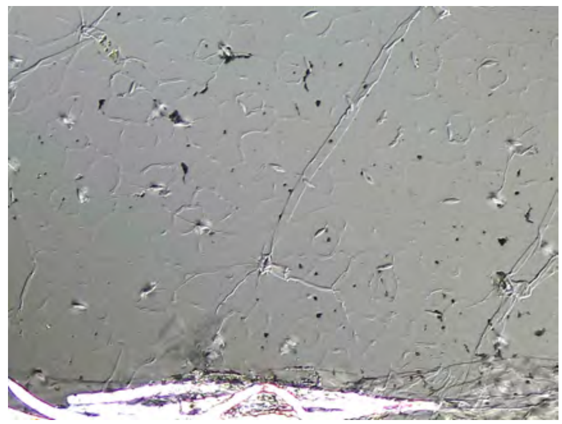


16a

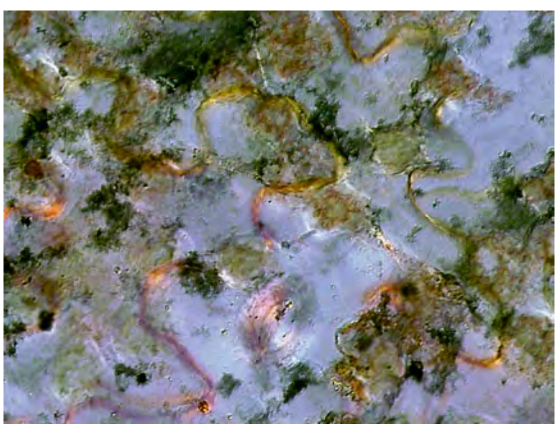
16b



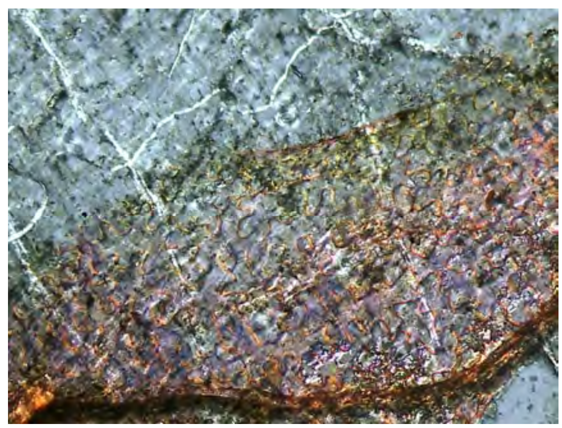
16c



17



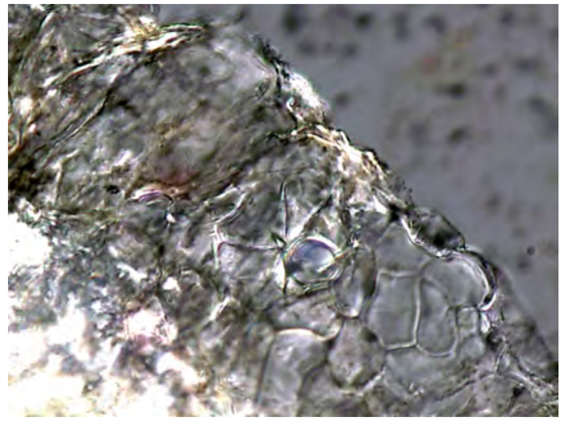
18a

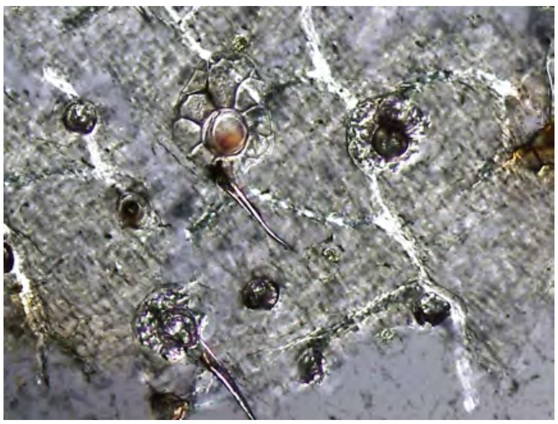


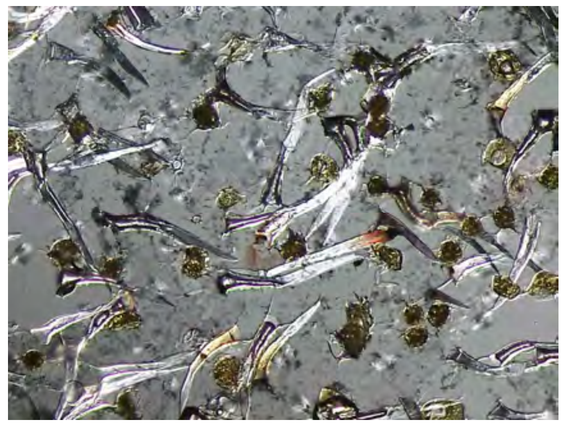
18b

Plate 7. 16a: *Malva parviflora* 400x; 16b and 16c: *Malva parviflora* 100x ; 17: *Medicago laciniata* 100x; 18a: *Nemesia affinis* 400x; 18b: *Nemesia affinis* 100x.


19a


19b


20a


20b

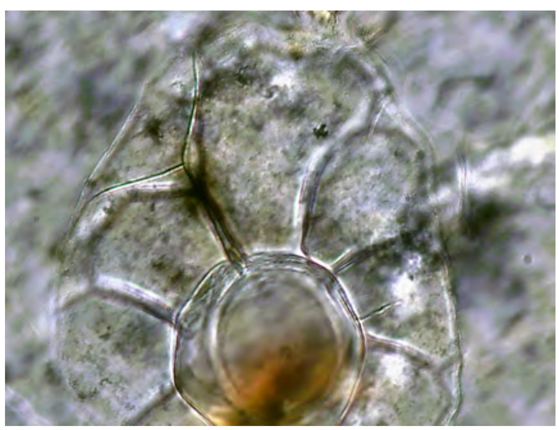
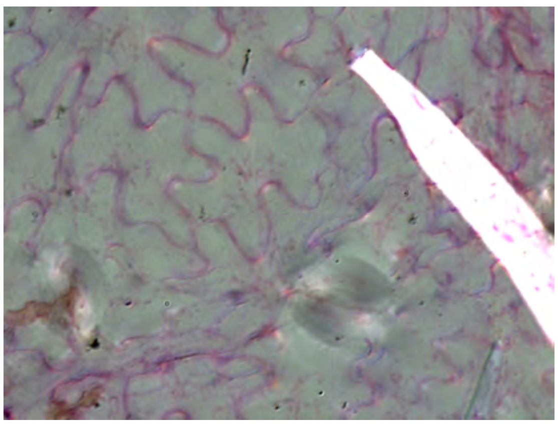
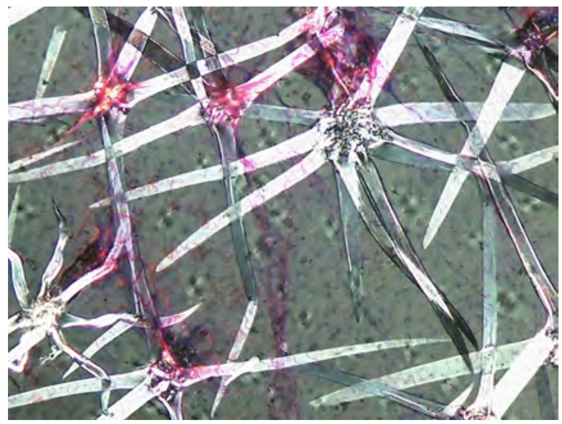

20c

Plate 8. 19a and 19b: *Pentzia incana* 400x; 20a and 20b: *Plectranthus sp.* 100x; 20c: *Plectranthus sp.* 400x.

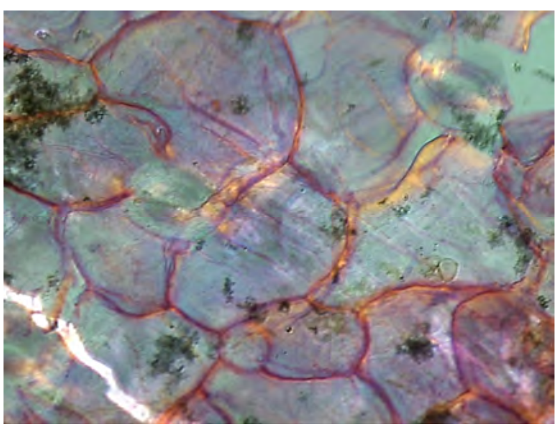
21



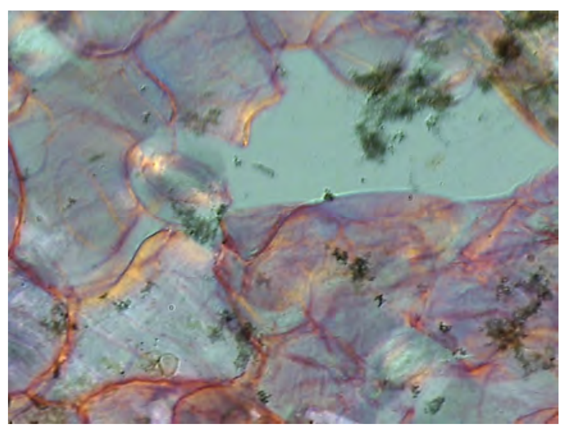
22a



22b

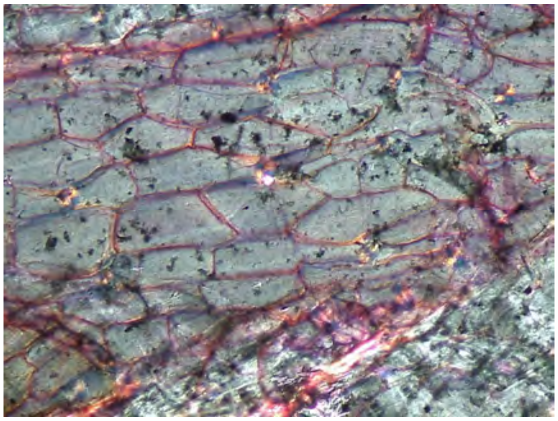


23a

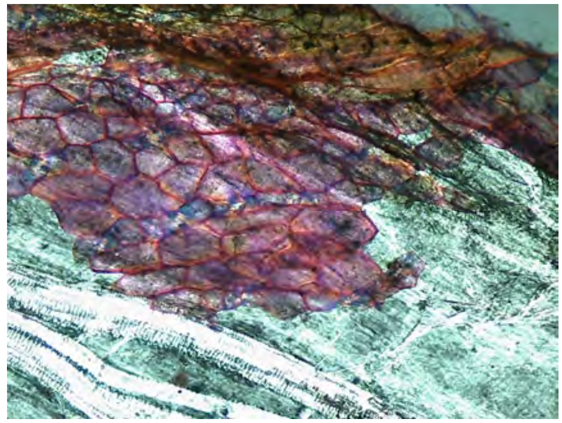


23b

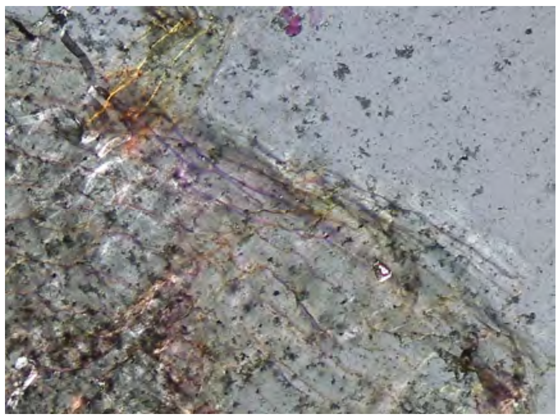
Plate 9. 21: *Putterlickia verrucosa* 100x; 22a: *Solanum tomentosum* 400x; 22b: *Solanum tomentosum* 100x; 23a and 23b: Unidentified species 1 400x.



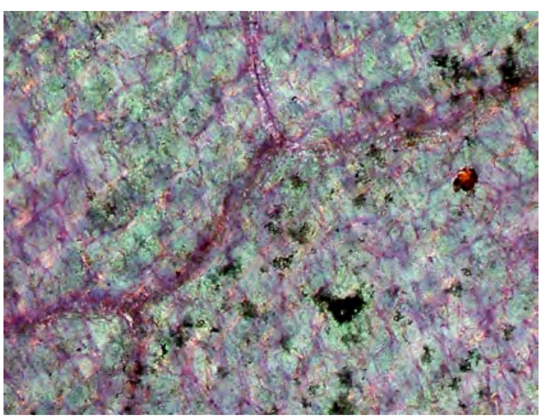
24a



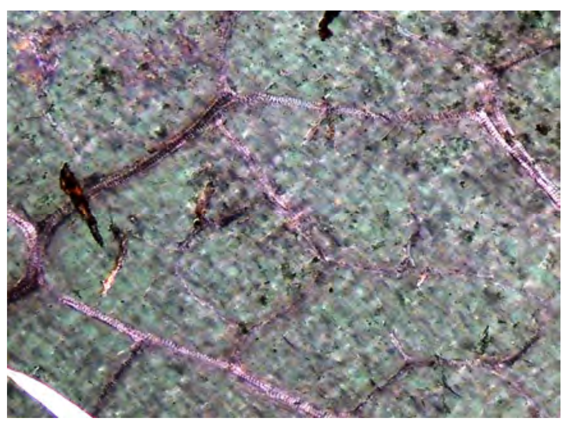
24b



25

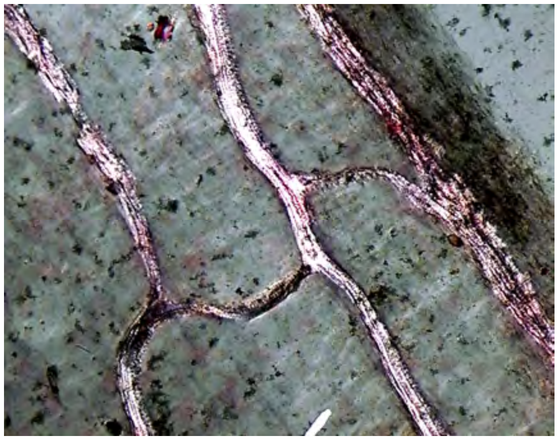


26a

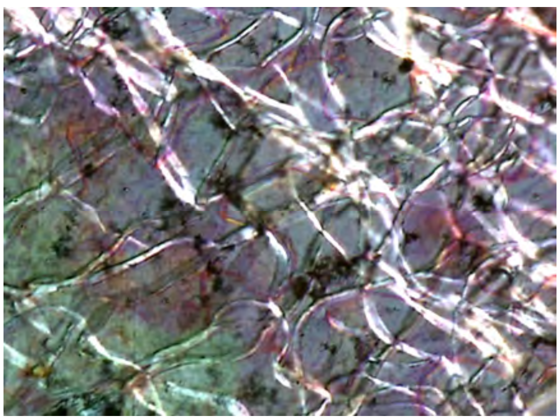


26b

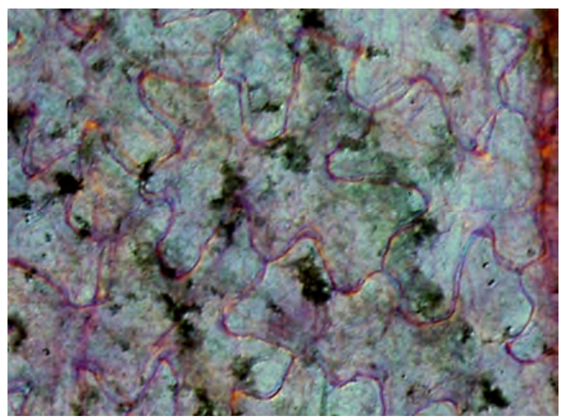
Plate 10. 24a and 24b: Unidentified species 7 100x; 25: Unidentified species 13 100x; 26a and 26b: *Diascia sp* 100x.



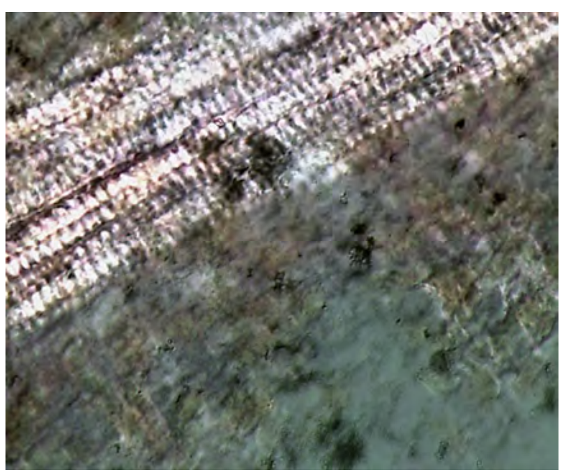
27



28a

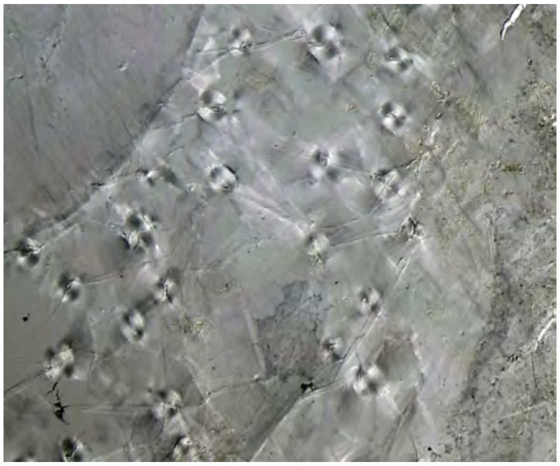


28b

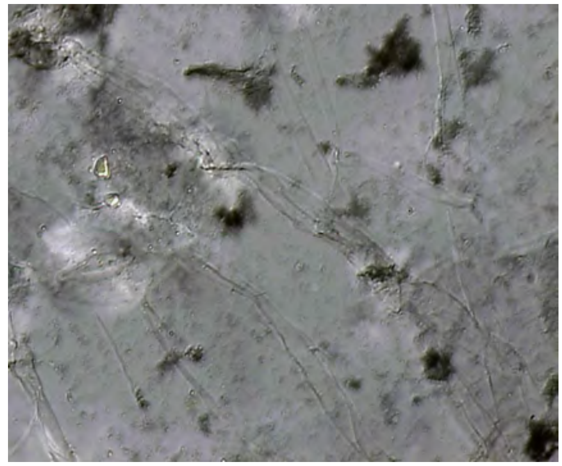


29

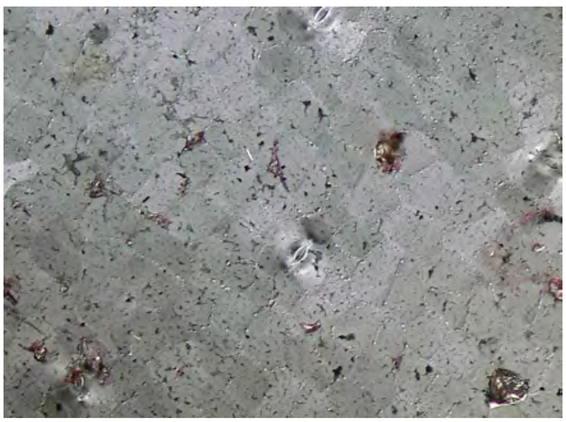
Plate 11. 27: Unidentified species 34 100x; 28a and 28b: Unidentified species 36 100x; 29: Unidentified species 37 100x.



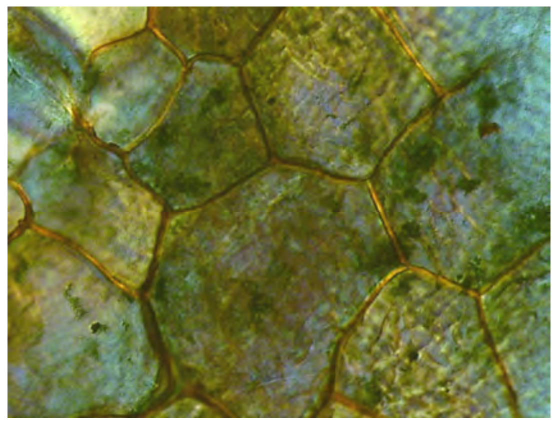
30a



30b



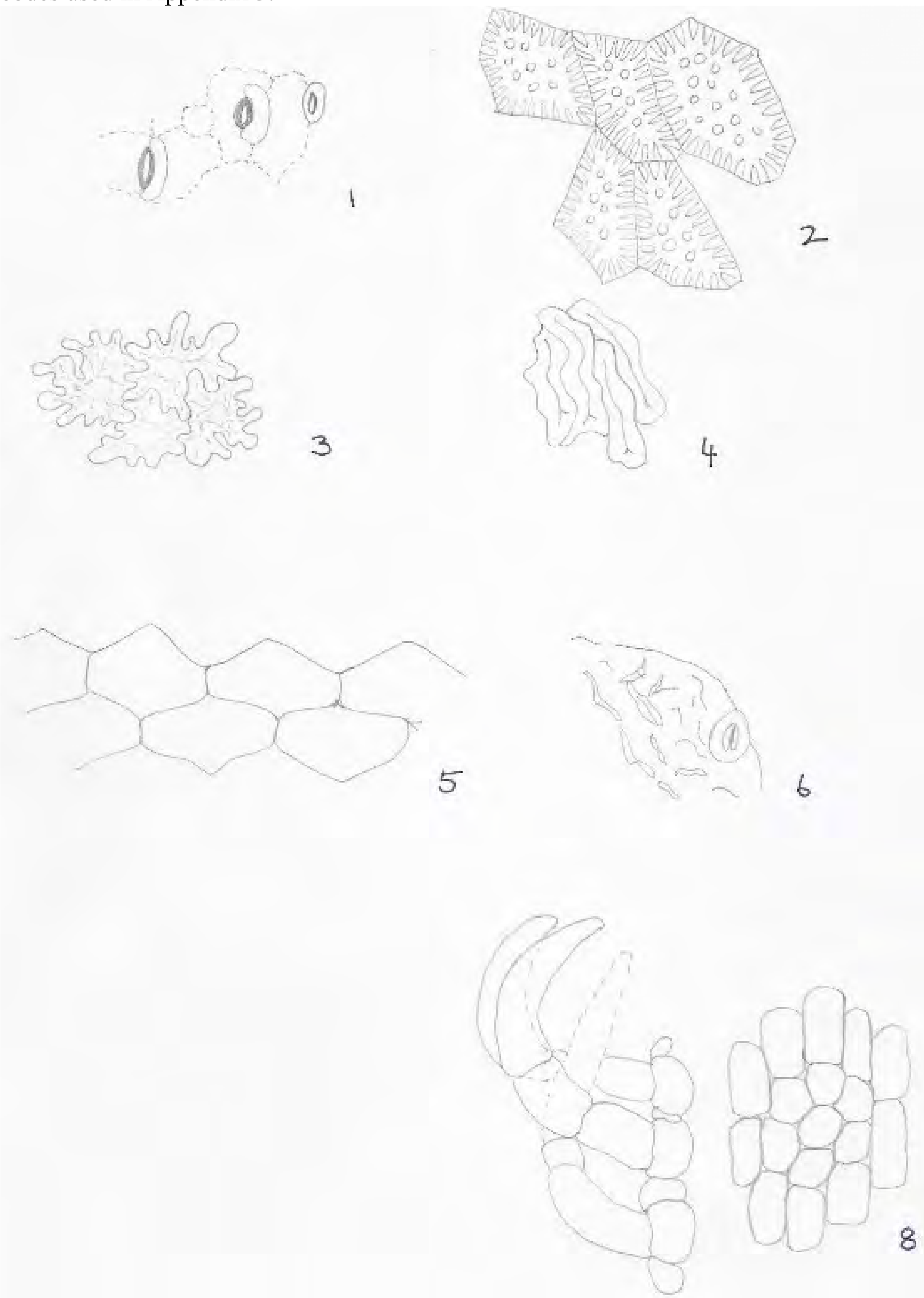
31a



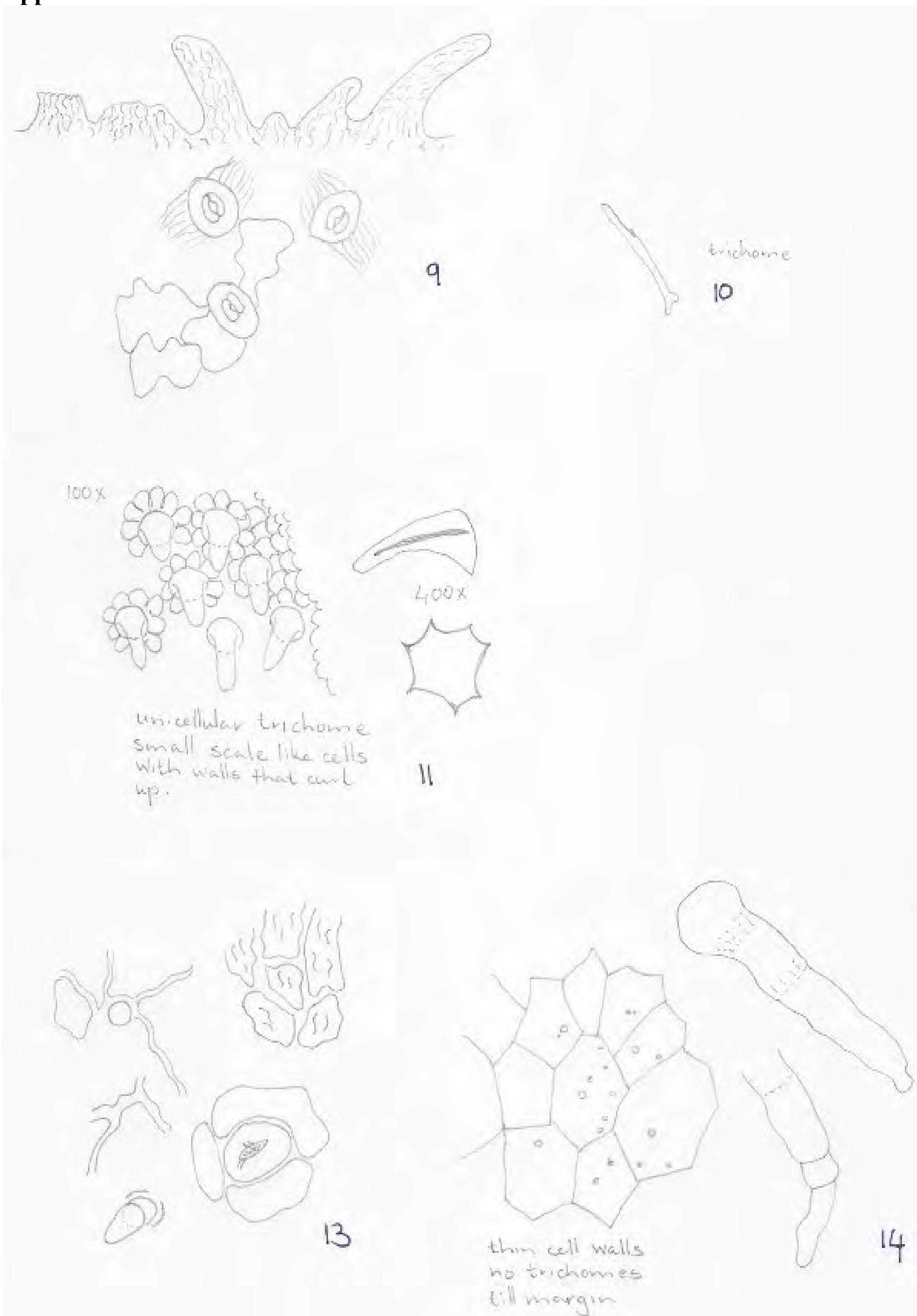
31b

Plate 12. 30a: *Tetragonia decumbens* 100x; 30b: *Tetragonia decumbens* 400x
31a*: Zygophyllum maritimum* 100x; 31b: *Zygophyllum maritimum* 400x.

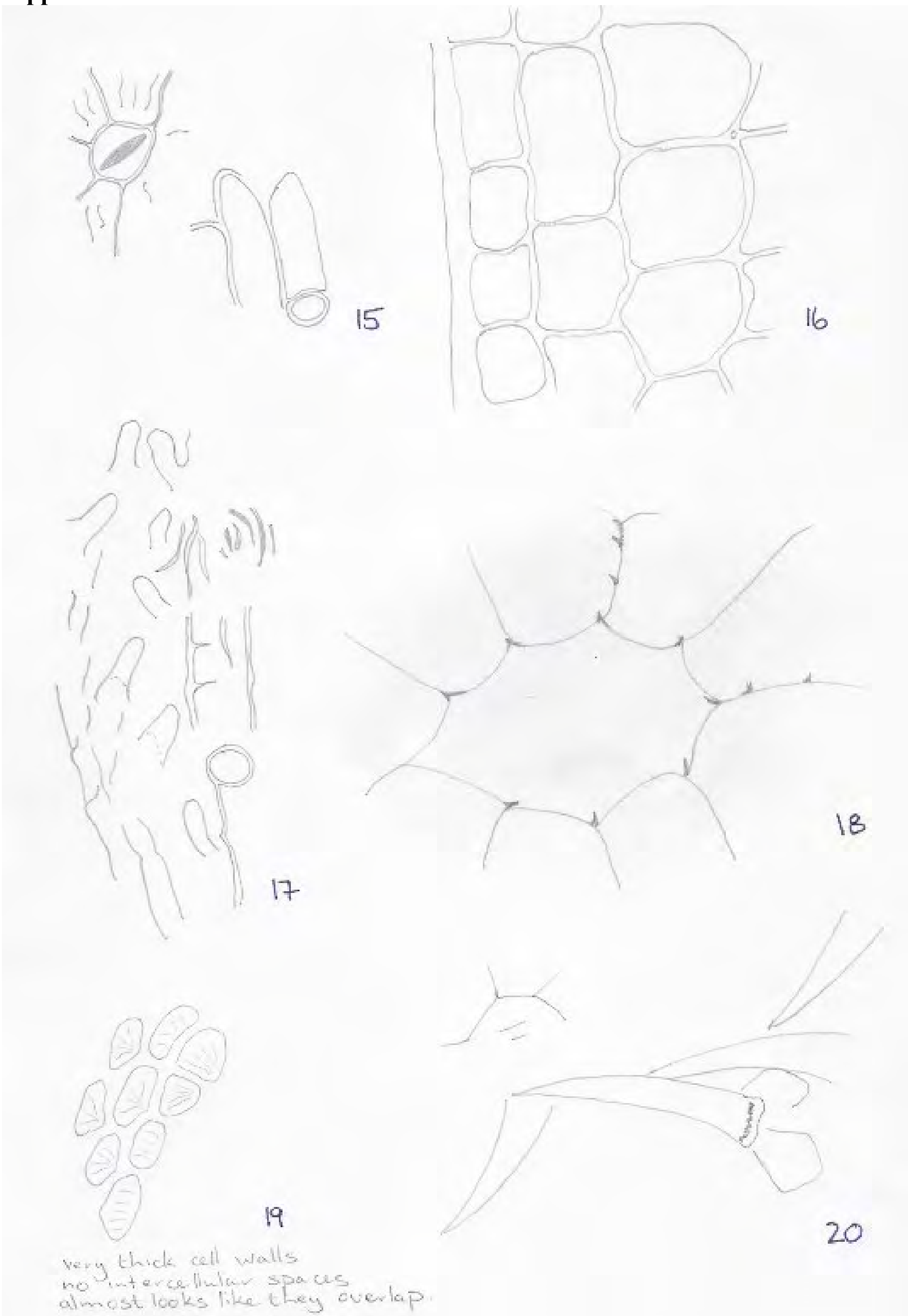
Appendix 1b- Sketches of unidentified plant fragments found in diet of Angora goats but not in the photographic reference collection. Numbers refer to the unidentified species codes used in Appendix 3.



Appendix 1b- Continued



Appendix 1b- Continued

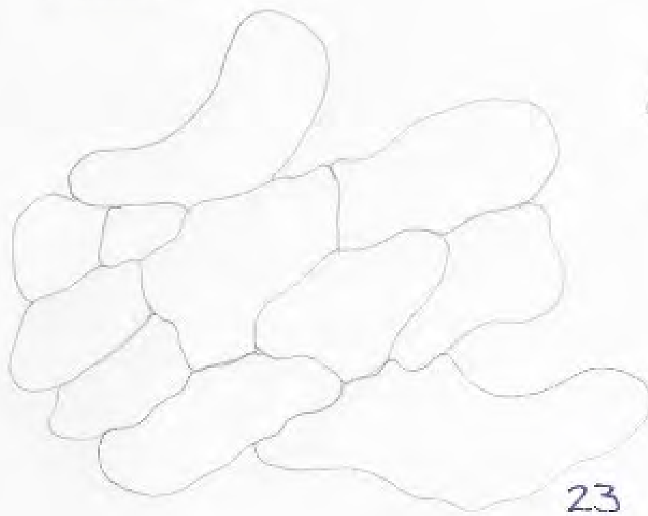


Appendix 1b- Continued

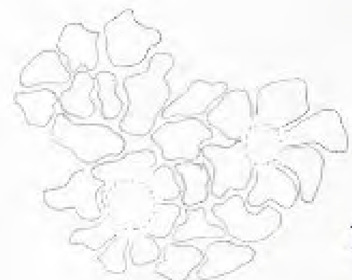
21

Very "hairy" difficult to see cells and stoma

22



23



24

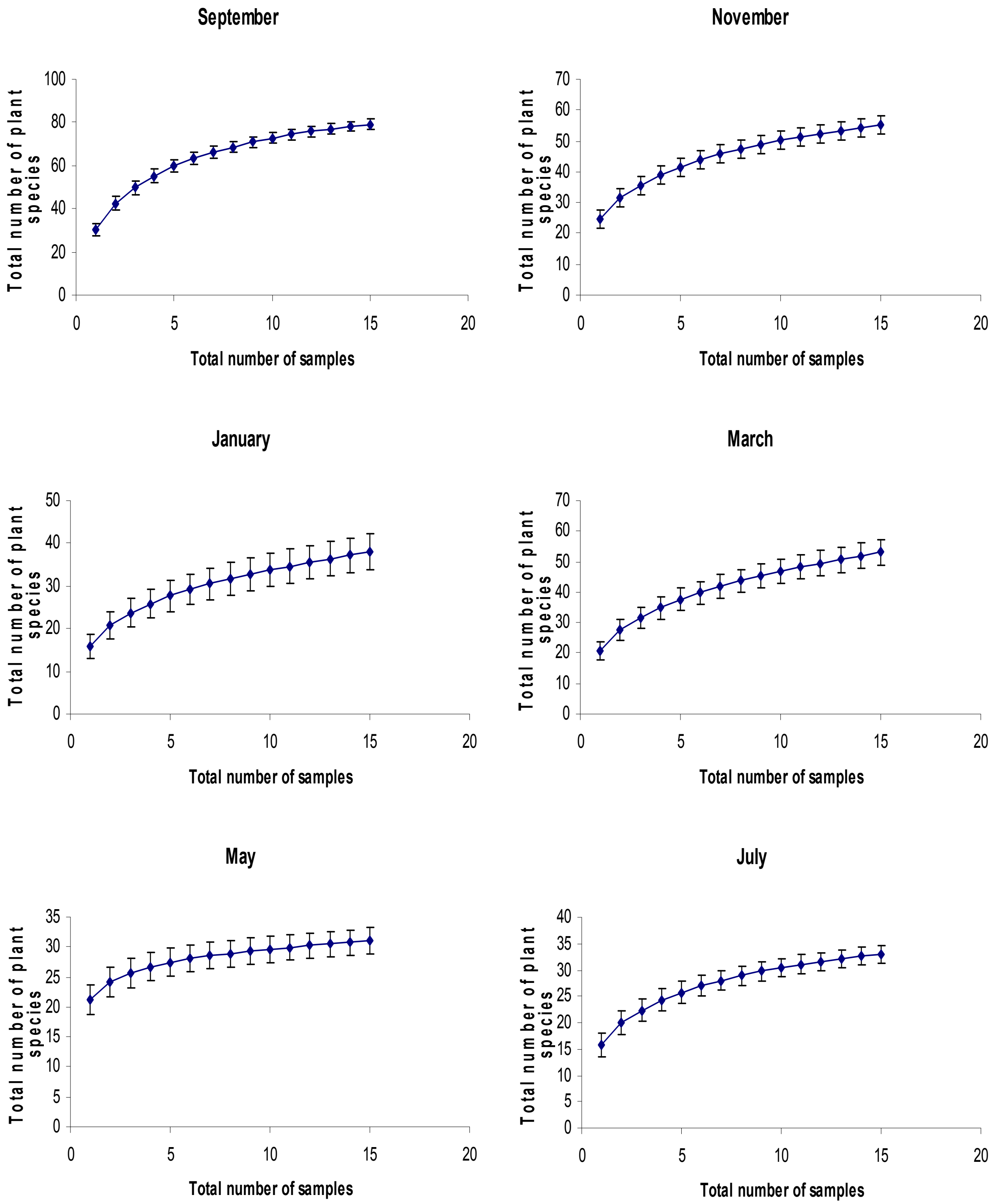
2.6

27

25

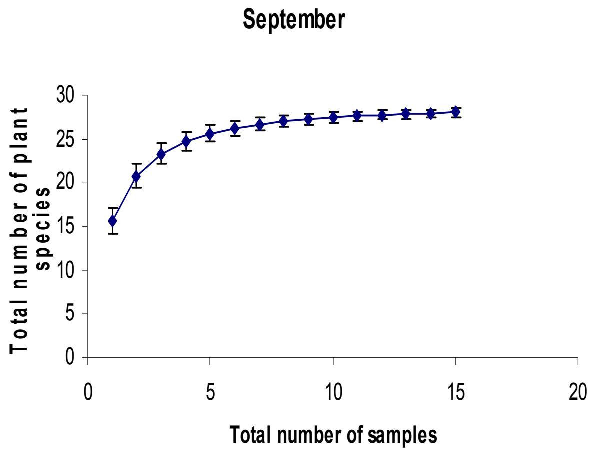
trichome

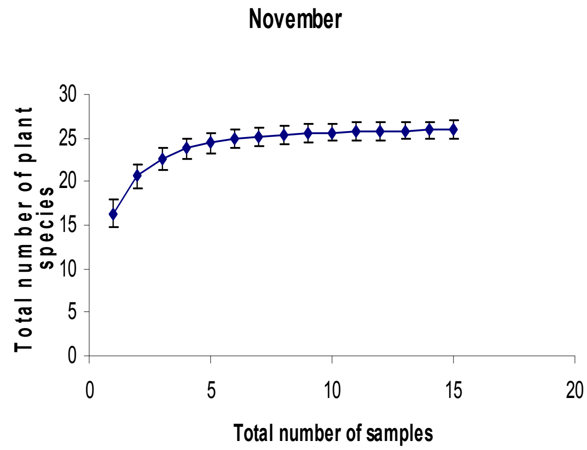
Appendix 2- Accumulation curves (mean ± SD; 50 randomised interactions) of plant species recorded per goat faecal sample a) transformed treatment b) intact treatment.

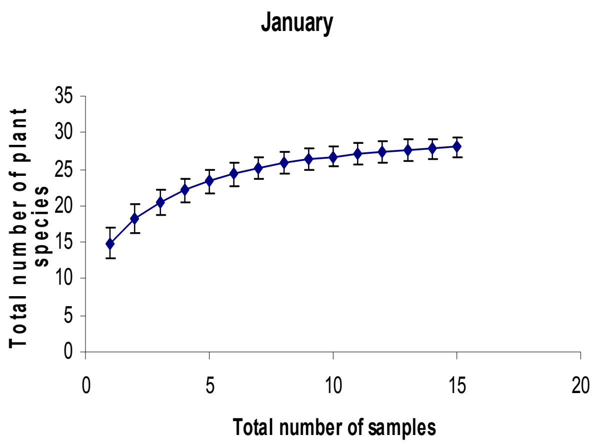


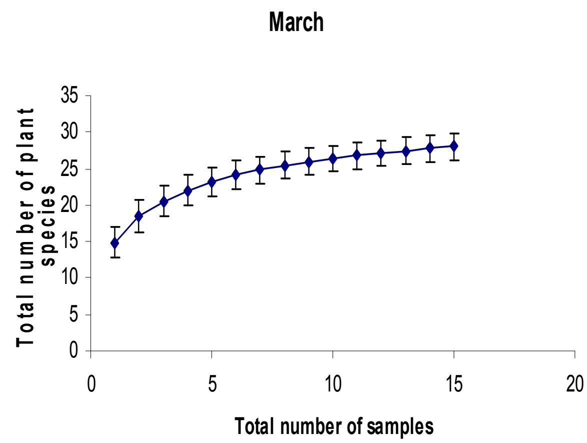
a)

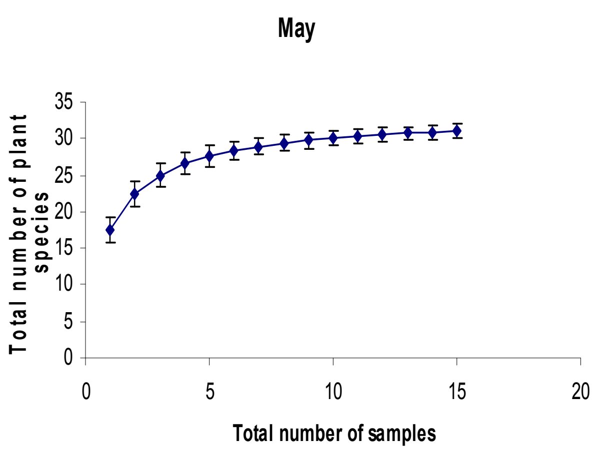
Appendix 2- Continued

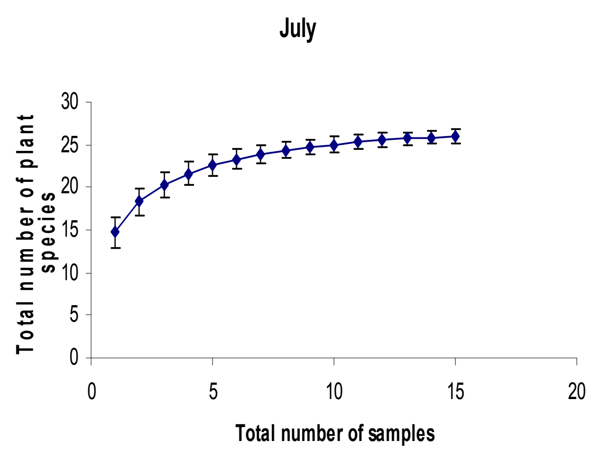












b)

Appendix 3- Percentage contribution of different plant species to the diet of Angora goats in the two treatments. Names in bold represent plant species found in goat diet in both treatments.

Family	Plant Species	% Diet Intact	% Diet Transformed
Woody Shrubs (n=33)			
Anacardiaceae	***Rhus longispina***	0.57	1.67
Anacardiaceae	***Rhus pterota***	1.87	3.61
Anacardiaceae	***Rhus refracta***	0.21	1.56
Asparagaceae	*Asparagus aethiopicus*		0.79
Asparagaceae	***Asparagus africanus***	1.46	3.59
Asparagaceae	***Asparagus crassicladus***	0.27	2.17
Asparagaceae	***Asparagus densiflorus***	0.11	3.30
Asparagaceae	***Asparagus racemosus***	0.03	0.63
Asparagaceae	***Asparagus rubicundus***	0.30	2.33
Asparagaceae	*Asparagus setaceus*		0.01
Asparagaceae	***Asparagus striatus***	1.34	4.36
Asparagaceae	*Asparagus suaveolens*		1.50
Asparagaceae	*Asparagus subulatus*		0.43
Asteraceae	*Brachylaena ilicifolia*		0.02
Bignoniaceae	***Rhigozum obovatum***	0.06	0.38
Boraginaceae	***Ehretia rigida***	0.12	1.26
Fabaceae	***Schotia afra***	1.78	2.07
Capparaceae	***Capparis sepiaria***	0.76	0.59
Capparaceae	*Maerua cafra*		0.46
Celastraceae	*Gymnosporia capitata*	1.58	
Celastraceae	*Gymnosporia polyacantha*		0.23
Chenopodiaceae	*Chenopodium album*		0.11
Ebenaceae	***Euclea undulata***	0.80	2.02
Euphorbiaceae	*Clutia affinis*	0.48	
Fabaceae	*Acacia karroo*		0.39
Lamiaceae	*Plectranthus sp*		0.06
Menispermaceae	*Cissampelos capensis*		0.01
Rhamnaceae	***Scutia myrtina***	0.07	0.03
Rutaceae	***Ptaeroxylon obliquum***	1.71	1.07
Salvadoraceae	***Azima tetracantha***	0.07	0.32
Sapindaceae	***Pappea capensis***	3.12	2.97
Solanaceae	*Solanum tomentosum*		0.01
Tiliaceae	***Grewia robusta***	9.32	5.82
Grasses (n=10)			
Poaceae	***Aristida diffusa***	0.07	0.96
Poaceae	***Cenchrus ciliaris***	2.00	1.93
Poaceae	***Cynodon dactylon***	4.67	6.19
Poaceae	*Ehrharta villosa*		0.14
Poaceae	***Eragrostis curvula***	4.53	5.88
Poaceae	***Eragrostis obtusa***	2.12	12.02
Poaceae	***Panicum deustum***	12.06	12.78
Poaceae	***Panicum maximum***	2.46	7.57
Poaceae	*Setaria sphacelata*		0.01
Poaceae	*Stipa dregeana*		0.22
Succulents (n=7)			
Asphodelaceae	*Aloe pluridens*		0.03
Asphodelaceae	*Aloe speciosa*		0.10
Apocynaceae	*Carissa bisponosa*	0.88	
Crassulaceae	*Crassula ovata*	0.80	
Crassulaceae	***Crassula perforata***	0.24	0.10
Portulacaceae	***Portulacaria afra***	41.68	3.01
Zygophyllaceae	*Zygophyllum maritimum*	0.08	

Family	Plant Species	% Diet Intact	% Diet Transformed
Forbs (n=21)			
Acanthaceae	*Hypoestes forskaolii*		0.02
Aizoaceae	*Aizoon glinoides*		0.08
Asteraceae	***Arctotheca calendula***	1.16	0.31
Asteraceae	*Cuspidia cernua*		0.09
Asteraceae	*Felicia amoena*		0.16
Asteraceae	*Felicia sp*		0.01
Asteraceae	*Pentzia incana*		0.29
Asteraceae	*Senecio ilicifolia*		0.01
Asteraceae	***Senecio linifolius***	0.04	0.03
Asteraceae	***Senecio macroglossus***	0.04	0.03
Behniaceae	*Behnia reticulata*		0.41
Brassicaceae	*Lepidium africanum*		0.10
Chenopodiaceae	*Atriplex lindleyi sub inflata*		0.11
Ebenaceae	*Diospyros lycioides*	0.41	
Fabaceae	*Indigofera sessilifolia*		0.02
Lamiaceae	*Leucas capensis*		0.06
Scrophulariaceae	*Diascia sp*		0.04
Zygophyllaceae	*Tribulus terrestris*		0.48
	Species 1		0.08
	Species 7		0.03
	Species 36		0.01
Lianas (n=2)			
Vitaceae	***Rhoicissus digitata***	0.01	0.04
Vitaceae	*Rhoicissus rhomboidea*	0.43	
Geophytes (n=2)			
Hyacinthaceae	*Albuca sp*		1.08
Dracaenaceae	***Sansevieria hyacinthoides***	0.28	0.33
Unidentifiable (n=25)			
	UnID 1		0.01
	UnID 2		0.28
	UnID 3		0.06
	UnID 4		0.18
	UnID 5		0.02
	UnID 6		0.03
	UnID 8		0.10
	UnID 9		0.18
	UnID 10		0.03
	UnID 11		0.07
	UnID 13		0.02
	UnID 14		0.02
	UnID 15		0.03
	UnID 16		0.02
	UnID 17		0.12
	UnID 18		0.03
	UnID 19		0.02
	UnID 20		0.02
	UnID 21		0.04
	UnID 22		0.11
	UnID 23		0.01
	UnID 24		0.01
	UnID 25		0.03
	UnID 26	0.02	0.03
	UnID 27	0.01	0.03