Characterisation of Determinants of Predation of Goats in Communal Production Systems

By

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DECLARATION

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Abstract

Predation is challenge in communal goat production systems. The broad objective of the study was to explore determinants of goat predation in communal production systems. A survey was conducted in 195 households in flat and mountainous terrains of Bergville local municipality in KwaZulu-Natal, using pre-tested semi-structured questionnaires to determine the effect of genotype and topography on the incidence of predation of goats. An average of eight goats was reported per household. Diseases and thefts, followed by predation were ranked as the major causes of goat losses in both areas. Jackals (*Canis aureus L.*), caracal (*Felis caracal*), wild dogs (*Lycaon pictus*) and leopards *(Panthera pardus)* were the common predators during the hot wet season. There were no leopards and caracal in the hot dry season in the flat environments. Farmers reported no leopards in the flat terrains in the cool dry season. Farmers owning non-descript goat genotypes were five times more likely to experience predation problems than farmers owning the indigenous Nguni goats. Farmers staying in mountainous environs were 2.3 times more likely to experience predation challenges than farmers in the flat land. Kids were the major class of goat targeted by predators. Predation largely occurred in the veld and drinking areas. The major finding from the survey was that the Nguni goat genotype is less likely to be lost to predators.

Assessing goat vigilance behaviour in predation risk areas is important in understanding determinants of goat predation. The second objective of the study was to assess the vigilance of free grazing Nguni goats in different flock sizes and ages in flat and mountainous terrains. Vigilance behaviour was categorized into antipredator or social vigilance and further distinguished into vigilance with or without chewing. Goats spent more time ($P < 0.05$) in antipredator vigilance than social vigilance. In the flat terrains, does in large flocks spent 2.5 times more time in antipredator vigilance with chewing than does in small flocks. A similar pattern was observed in the mountainous environments. For large flocks, does in flat terrain spent 1.9 times more time in antipredator vigilance with chewing than does in mountainous areas. For large flocks, kids in flat terrain spent 2.7times more time than in mountainous areas in antipredator vigilance with chewing. In the flat terrain, does in large flocks spent five times more time in antipredator vigilance without chewing than does in small flock sizes. In mountainous areas, does in large flocks spent twice more than the time spent by does in small flock sizes. In flat terrain, kids in large flocks spent seven times more time in antipredator vigilance without chewing than kids in small flocks. In large flocks in the flat terrain, kids spent more time in antipredator vigilance with chewing than does ($P < 0.05$). Age of goats had no effect on the vigilance behaviour. It was concluded that, in flat environments, goats exhibit more antipredator vigilance than those in mountainous areas. Goats in larger flocks spent more time in antipredator chewing vigilance behaviour.

Keywords: age, flock size, Nguni goats, genotype, predator, topography, vigilance behaviour

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Dedications

This dissertation was written to honour and express affection to….

My father, ***Jeffery Durawo;***

My mother, ***Mavis Durawo;***

My husband, ***Israel Nhimura;***

My baby girl, ***Nyasha Jo-Ann Nhimura***

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CHAPTER ONE. General Introduction

1.1 Background

Most goats are kept in communal production systems for household food security, rituals, performing ceremonial functions and risk aversion. Local goats in the Sub-Saharan region can strive the persistent droughts, extreme temperatures and high prevalence of diseases (Rumosa Gwaze *et al*., 2010). Whilst there have been extensive studies on ways to reduce goat losses to diseases, parasites, feed and water shortages, there is no data on the extent of goat predation. Predator-driven mortality is still a huge drawback to goat production (van Niekerk *et al*., 2013).

Predation is an increasing threat to livestock production. Meissner (2013) reported that predation accounts for between 0.2 and 2.6% of global livestock losses. About 2.8% of all small stock was lost due to predators in the Northern Cape Province of South Africa. Predation can be as high as 10% in mountainous and vegetation dense environments and also during the rainy season. Whilst there are a range of predators, major losses in South Africa are predominantly due to black-backed jackal (*Canis mesomelas*) and secondly to caracal (*Felis caracal*) (Blaum, 2009). Other predators of goats include snakes, eagles and wild dogs.

There have been several studies focusing on animal welfare issues, most of which dealt exclusively on behavioural responses to determine the level of stress that livestock undergo. Behavioural studies have also been used in assessing animal temperament. A few of these behavioural studies, however, have focused on the issue of predation. Understanding these behavioural responses assists in identifying goats that are most likely to be preyed upon.

1.2Justification

Although diseases, parasites, feeds and water shortages and low levels of management are the major causes of low productivity of goats, predation can lead to even the productive animals, in addition to weak ones, being lost. To reduce such losses, integrated predator management (IPM) should be considered. It requires producers to identify methods that are effective in reducing predation. The extent to which farmers are aware or employ these tactics need to be determined. Factors which need to be considered in integrated predator management include topography, age of goats, flock size and goat genotype (Meissner, 2013).Preventing predatory losses is more economical than controlling once the problem has occurred. In addition to determining farmer perceptions, detailed on-field monitoring studies and consequently using robust statistical techniques to identify factors that influence predation are required. Comprehensive studies to understand goat predation are scarce.

1.3 Objectives

The broad objective of the study was to determine determinants of goat predation in communal production systems. The specific objectives were to determine:

1. The influence of topography and genotype on goat predation in communal production systems; and,
2. The effect of topography, age and flock size on the vigilance behaviour of Nguni goats.

1.4 Hypotheses

The hypotheses tested were that:

1. Topography and genotype affect goat predation in communal production systems; and
2. Topography, age and flock size affect vigilance behaviour of Nguni goats.

1.5 References

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CHAPTER TWO: Literature Review

2.1 Introduction

Goats play an important role in rural livelihoods. They are kept for household food security, rituals, performing ceremonial functions and risk aversion (Msangi, 2014). Goat production in communal farming systems is hampered by diseases and parasites and predation. The predation challenge, although critical in goat production, has been ignored in a rush to reduce and control diseases and parasites through extensive research. As a result, most of the available literature on predation is generally not recent. Some studies that have attempted insight into predation have been done from a wildlife management perspective (Bromley and Gese, 2001a; Kluever *et al*., 2008; Blaum, 2009). Goats in communal production systems may be free to scavenge for feed, thereby encountering predators. Predators present depend on the season and geographic location. This chapter discusses the predation challenge in communal production systems and the vigilance behaviour exhibited by goats to detect the predators. Common predator control methods are also discussed.

2.2 Communal goat production systems

South Africa has over six million goats raised by either the commercial farmers or by small-scale and emerging farmers (Roets and Kirsten, 2005). About 50% of the goat population in South Africa is kept under small scale conditions (Shabalala and Mosima, 2002). The SA Boer goat, the Savanna and the Kalahari Red are the commercial goat breeds available for meat production (Casey and Webb, 2010; Department of Agriculture, Forestry and Fisheries, 2011). On the other hand, indigenous goats that represent nearly 65% of the goats found in South Africa (DAFF, 2011), are kept in communal production systems. Goats in communal areas are mainly kept under extensive systems which are characterized by low levels of management and reduced productivity. The rangelands are communally owned and managed by farmers for grazing livestock and harvesting natural products such as firewood.

The 'indigenous goat' is a collective term used to refer to all varieties of South African goat breeds. South African indigenous goats can be grouped into speckled goats, Loskop South indigenous goats, KwaZulu-Natal goats, Nguni goats and the Delfzijl goats (Roets, 2004). South African indigenous goats vary in ear length, coat colour and size. They are, however, mostly of medium size. The indigenous goats are "hardy and can thrive under local environmental conditions, utilizing available feed resources much more efficiently" (Dziba *et al*., 2003; Nyamukanza and Scogings, 2008). They are known to resist several tropical diseases and parasites and survive harsh environments.

2.2.1 Management of goats in communal production systems

Goats are usually kept in small flocks on mixed farms all over Africa. They may be allowed to graze freely on communal pastures during the day or seasonally on fallow cropland. However, the increasing population pressure is limiting goats to free graze; hence goats are sometimes tethered or housed. Feeding and fodder production is thus, becoming more important in communal production systems. Goats may be tethered close to homesteads or tethered the whole day in the grazing areas.

Goats in communal production systems are normally herded by children, while their day-to-day management and care of the young stock falls to the women. Hired labour may also be used to herd the goats. Goats are usually kraaled at night and let out to graze in the morning. Kraaling and letting out times differ with each household and season. In such a system, considerable labour and time is needed to locate the goats and return the goat flocks to a kraal each time in the evening to protect them against predators and theft. Hence, in some households, the goats are left over night in the veld and are only collected whenever time is convenient for the farmer. This results in the animals being lost, preyed upon or stolen. In some systems, kids are confined in the kraal at night and during the day for better supervision and to prevent losses. In communal production systems, no specific breeding season is followed and goats mate throughout the year.

2.2.2 Challenges to communal goat production

Numerous challenges face goat production in Southern Africa. These differ with regions or geographical locations (Kosgey, 2004). The main constraints are high prevalence of diseases and parasites (Ben Salem and Smith, 2008), low level of management and limited forage availability (Raghuvansi *et al*., 2007) and poor marketing management (Kusina and Kusina, 1999). The impact of diseases and parasites may be through mortalities, abortions or subclinical effected manifested as reduced body condition or reduced weight gain, and the financial constraints in overcoming or controlling disease effects (Mahusoon *et al*., 2004). Low levels of management include poor housing, lack of proper breeding programmes and high kid mortality. Predation has emerged as an important challenge to sustainable goat production (Meissner *et al*., 2013) resulting in enormous goat losses per year (Van Nierkerk *et al*., 2010) and one of the major causes of high kid mortality (Slayi *et al*., 2014; Table 2.1).

Table 2.1: Farmer perceptions on causes of goat kid mortality in Nkonkobe Local Municipality, South Africa

	Percent
Diseases	
Foot rot	60
Gall sickness	89
Heart water	65
Endoparasites and ecto- parasites	
Worms	75
Mites	58
Ticks	68
Environmental factors	
Cold	7.5
Heavy rainfall	26
Extremely high temperatures	27.5
Predators	
Jackals	63
Hunting dogs	37

Source: Slayi et al. (2014)

2.3The predation challenge in South Africa

Predators such as the wild dog, caracal and jackal are important in natural ecosystems or reserves to remove sick, wounded animals, old or decaying carcasses. Livestock in the vicinity, however, are easy targets resulting in huge losses. A study in the Western Cape reported losses of about R105 million in terms of direct losses through predation (Van Nierkerk *et al*., 2010). Other reports have shown a loss of about R1.3 billion due to small stock predation in five provinces in South Africa (RPO News, 2012).

Predation remains a huge challenge to goat production under extensive systems (van Niekerk *et al.,* 2013). Due to its increasing threat to goat production, predation has recently been given attention by livestock farming organisations as a challenge to livestock production. For example, in South Africa, the growing concerns over goat losses to predation triggered major organizations such as the National Wool Growers' Association of South Africa, South African Mohair Growers' Association, Red Meat Producers Organization and Wildlife Ranching South Africa to form the predation management forum in 2009. These organizations, however, mainly focus on commercial goat production and little is known about the extent predation affects communal goat production systems.

Some of the methods which might be effective to reduce or control predation are expensive and the resource-limited communal farmers might not have the ability to deal with the problem- causing predator animals. A farmer, therefore, must decide what level of predation is acceptable and what predator control method would be effective and sufficient, such that the cost does not outweigh the benefits. Management of goats in communal production systems may, therefore, depend on the types of predators that are common in the area.

2.4 Common predators in South Africa

There are a wide range of predators that exist in Africa. The most common livestock predators in Southern Africa, however, are mostly due to the black backed jackal and the caracal (Blaum, 2009). These predators are mostly found in the more open semi- arid grassland habitats. The black-backed jackal is known to be a generalistic feeder feeding mostly on small to medium sized animals, rodents, insects, fruits and carrion (Karmer *et al*., 2013). They also commonly prey on small carnivores and prey (Bagniewska *et al.,* 2013). The caracal, on the other hand, generally feeds on hyrax, rodents, birds and small antelope and occasionally on small stock (Nowell and Jackson, 1996; Marker *et al*., 2005). Whilst most carnivores do not have livestock in their home ranges, predation on livestock can arise when carnivores begin to have a home range which overlaps with domestic animals (Linnel, 1999). In times of low prey availability, caracals may move to the borders of their existing and dominant ranges, crossing onto agricultural land to prey on small livestock (Melville *et al.,* 2006). Goats are major of predators especially when they exist within unfenced boundaries of communal farms (Samuels, 2013).

2.5 Predator control methods

Control methods used by goat farmers differ with the household. The general predator control practices fall into two distinct groups which are the lethal and the non-lethal methods. Non-lethal predator control methods are the most widely used and trusted for reducing goat losses. These practices include physical separations such as fencing and night penning; cultural practices such as herding and habitat management and predator determent such as fright practices and guard dogs. The lethal approach includes predator thinning by trapping, hunting and use of toxicants. All these methods provide some form of direct physical harm to the predator. No one method of control will completely reduce predation of the goat flock, therefore, the need for farmers to implement an Integrated Predator Management (IPM) strategy.

2.5.1 Non-lethal predator control methods

Non-lethal methods are sometimes used in controlling predation. These methods, however, do not provide permanent relief from predators. Very little information exists on their effect and efficiency. No one method will completely control the predation challenge, hence the need to use more than one strategy simultaneously. These methods may be expensive with no guarantee that the chosen method will work effectively (Van Deventer, 2008; De Waal, 2009).

2.5.1.1 Fencing

Fencing can be electric or jackal-proof fencing. Predator proof enclosure protects animals all the time, providing there is no predator within the enclosed area. Jackal-proof and electrical fencing is an expensive capital investment. When the fences have to be medium-sized predator-proof, the labour cost usually doubles. This is due to the process of having to attend to and blocking all possible entry spots for the animals. For these fences to be efficient, maintenance is critical. Porcupine and warthog can easily dig under such fences thereby cause the fence to be ineffective. This means that fences must be checked frequently, this is however, very expensive and time consuming (Snow, 2006).

Fencing may be expensive for resource-limited smallholder communal farmers. There is, therefore, need for government subsidies especially in areas in which predation poses a huge challenge. During the previous century, farmers received official subsidies to assist in enclosing large tracts of farmland with jackal-proof fences to protect their sheep and goats.

Most of these original jackal-proof fences have exceeded their effective lifespan and unless they have been maintained or replaced since at the farmers' own expense, these fences are not effective anymore.

2.5.1.2 Use of livestock guarding animals

Several forms of livestock guard animals have been tried with varying degrees of success. These include donkeys, zebras, ostriches and Anatolian dogs. The use of guard dogs to protect sheep has become popular in the last decade. In the USA, guard dogs have been successful in about two-thirds of the trials where they have been tested for their ability to protect sheep from predators in fenced or open range grazing conditions. The use of Anatolian Shepherd livestock guard dogs is a proven technique across the world and is gaining popularity in some parts of South Africa (Leijenaar *et al*., 2015). Predator problems are usually associated with young animals that are still suckling; this is where guard dogs can provide great relief (Herselman, 2005). These guard dogs are, however, not totally effective everywhere. The presence of guardian dogs may, in some cases, increase the probability of chronic predator attacks in sheep (Mattiello *et al*., 2012), especially when dogs are introduced after repeated attacks (Espuno *et al*., 2004). They are not the industry-wide solution to the predator problem as Green *et al.* (1984) stated. Unfortunately, there are a few disadvantages, the cost of guard animals is high and the method might reduce losses, but may not prevent them entirely (Snow, 2006). In spite of the setbacks, the presence of well trained dogs has proven successful for reducing sheep predation in other areas (Landry *et al*., 2005; Marker *et al*., 2005; Berzi, 2010).

Benefits of using guarding animals may include a decrease or elimination of predation, reduced labour to confine animals at night, more efficient use of pastures for grazing, reduced dependence on other predator control techniques.

2.5.1.3 Use of collars

King collars, bell collars and scent collars are sometimes used in predation control. King collars are plastic PVC fitted to the neck of goats to prevent predators to attack the goats on the neck. These are simple, inexpensive and adjustable. Over time, predators may, however, learn to attack the goats from behind therefore rendering them useless. Maggots may also accumulate under the collar during rainy seasons so the collars cannot be fitted permanently. Bell collars and scent collars work by confusing and discouraging predators because of the unnatural sound they make; or the human-associated scent they project; provided they are used inconsistently and in conjunction with other methods. It is important, however, to only use these collars in times when predation is at its highest, such as during kidding seasons, so that the predators do not get used to them making them unafraid.

2.5.2 Lethal predator control methods

Lethal methods cause direct physical harm to the predator. These include; hunting at night with rifles, poisoning, traps and snares, and hunting with dogs. Using these methods usually brings great successes; however, most of these strategies provide a non- selective way controlling predators (Van Deventer, 2008; De Waal, 2009). There have been ongoing debates in South Africa's Predator Forum Management about using these methods to protect livestock in an environmentally and economically sustainable way.

2.5.2.1 Hunting for predators

Hunting damage-causing animals is one of the most effective ways to reduce the predation. Hunting has been used since the early 1870's in South Africa by settlers to protect their livestock against predators (Beinart, 1996). This method is also used in other countries to reduce predation on livestock (Goldberg, 1996). Aerial hunting is commonly used by agriculture agencies in the USA (Wagner *et al.,* 1999); whereas in Australia and the United Kingdom (UK) shooting predators is frequently used to reduce fox populations (Gentle, 2006). This is most often done at night with the aid of a spotlight and calling equipment. Shooting at night can be very selective and solve problems within a short timeframe and with little ecological effects (De Waal, 2009).

2.5.2.2 Poisoning

Poisoning is another method often used to kill problem-causing animals out of the predator populations. In Australia, the introduced red fox (*Vulpes vulpes)* represents a continuing threat to livestock farmers. These problems are, however, managed by setting ground-level baits impregnated with poison such as compound 1080 (sodium monofluoroacetate). The effectiveness of control programmes lies in a proper managed management program to achieve long term goals. In South Africa, only three toxins or poisons may be used; sodium cyanide, strychnine and sodium monofluoroacetate may be used in meat baits and then only with a permit. The method has been used by farmers to poison carcasses or in poisoned baits to kill predators, the reason this method is so frequently used, is because it is cheap and very effective. The only drawback is that non-targeted animals might also get killed (Snow, 2006).

2.5.2.3 Trapping

Trapping is a simple and cost effective way of controlling predators. The only factor influencing trapping is the potential to cause some injury or distress to the target and non-target animals without killing it and thereby causing suffering and pain to these animals. Gin traps, jaw-traps or "slagysters" may be effective, if they are correctly sited and set. Steel-jawed gin-traps without padding between the jaws are mostly used in South Africa, but cause severe injury to the animal. Cage traps are usually preferred in certain areas, since non-target animals can be released easily. Gin-traps are mostly used and are more effective for black-backed jackal, while cage traps are preferred for caracal (Snow, 2006).

2.6 Factors affecting predation

Factors affecting predation are categorized in terms of management factors, animal factors and environmental factors.

2.6.1Management factors of predation

2.6.1.1 Management practices

Very few studies have done on factors affecting predation in South Africa. Van Nierkerk *et al.* (2013) outlined some factors affecting small stock predation in the Western Cape province of South Africa. It was reported that higher levels of management on farm resulted in lower levels of predation. Higher levels of management will be difficult when farmers are diversified and need to manage all the farming enterprise. Kraaling of small stock at night was found to significantly increase predation levels. This might be because the predators adapt themselves to infiltrate in closed areas and cause major losses, especially where fences are not up to standard. A high level of success was reported when non-lethal methods are used in combination or in rotation with one another.

2.6.1.2 Flock size

Animals commonly forage together as more cohesive groups which are better at detecting predators. Flocking behaviour is often driven by the fear of predators (King *et al.,* 2012). There are two contrasting theories on the potential reaction to predator threats; the "Many Eyes Theory" and the "Selfish- Herd Theory". The "Many Eyes Theory" suggests that larger groups staying together may be safer whilst the "Selfish-Herd Theory" suggests that individuals in a large herd may benefit spatially, provided they can move freely (King *et al*., 2012). Goats commonly follow the "Many Eyes Theory" which is further reinforced by herding. This flocking behaviour, therefore, deters predators. Similarly, Davies (1999) suggested that herding may be the best way to reduce livestock losses to predators. In certain circumstances, however, individuals may stray especially during the kidding season. A larger herd is more difficult to manage. Hence Davies (1999) suggested an existing threshold of average herd size in which individuals are safe.

2.6.1.3. Goat genotype

Some goat breeds such as mountain goats tend to avoid predators by escaping to elevated terrain (Gillard *et al*., 1998). Most confined sheep and goats may lack such unique anti-predator instincts. These anti- predatory behaviours may be further lost through breeding programmes which elevate the need for larger body frame sizes and early maturing animals. Certain studies on welfare and handling in goats have reported that exotic goat genotypes such as the Boer and their crossbreds were easier to handle than the South African indigenous goat genotypes (Ali *et al*., 2006; Jackson and Hackett, 2007; Ndou *et al*., 2010). The ease of handling may mean calmer animals which are more prone to predator attacks. Investigations on how improved goat breeds respond to predation should be conducted.

2.6.2 Animal factors of predation

2.6.2.1 Goat age and condition

Goat age and condition are likely to affect their predation. Naturally, the young and the weak are mostly susceptible to predators because of their vulnerability and lack of experience. Female animals may also be vulnerable to predators because they will be trying to protect their kids, consequently exposing them to predators as well. Males may, however, be more vulnerable than females because females are more sensitive to predation risk because of their young. Lutchminarayan (2014), as highlighted in Table 2.2, reported the greatest number of predation in the weaner age group, followed by kids of less than four months old. These two age groups are the most vulnerable to predators because they lack experience in defending themselves against predators and therefore, become easy prey for predators. As a result, some communal production systems are keep kids near the homestead and given supplementary feeding whilst adult goats are released to free- range in the vast communal rangelands. Weak, wounded and sick animals are also vulnerable and may be considered easy prey by the predators (Mech, 1970; Pimlott, 1967; Kruuk, 1972). Meier *et al*. (2012) suggested special care in form of herding for sick and animals in bad condition as they become prime targets for predators.

Table 2.2 Median and Inter Quartile Range (IQR) of the total number of goats of different age classes reported lost to predators in Paulshoek (South Africa) each year for the period 1998- 2013

Kids (<4months)	Weaner (>4months)	Does	Withers	Bucks
10.5 (14.8)	14.0 (17.0)	5.5 (10.3)	1.0 (1.3)	0 (0)

Source: Lutchminarayan (2014)

2.6.3 Environmental factors of predation

Environmental factors will be defined in terms of the surrounding in which the goats are kept.

2.6.3.1 Vegetation type and topography

Different types of predators have different preferred habitats. The black-backed jackal is found in a wide range of habitats in South Africa (Cillie, 1997). These areas include arid savannah, open savannah, woodland savannah mosaics. Generally, black-backed jackals show a preference for open habitats, thus tending to avoid dense vegetation. In KwaZulu-Natal, they are recorded from sea level to more than 3 000 m above sea level in the Drakensberg and in localities receiving more than 2 000 mm of rainfall. The trend is for black-backed jackal to use either the open grassland or wooded savannah (Loveridge and Nel, 2004). This shows that the black-backed jackal has preferred areas, but can adapt to most of the areas in South Africa.

Caracals, on the other hand, are found in dry savannah and woodland areas, scrubland and rugged terrain in mountainous regions even as high as 3 000 m above sea level (Cillie, 1997). Like other cats that are found in dry, arid or semi- dessert locations, the caracal can survive for long periods without water by obtaining its requirement from the metabolic moisture of its prey.

2.6.3.2 Seasonal effects

Predators are often more likely to attack livestock at specific times to the year. These times often coincide with predators own specific needs. For example, the killing of lambs by coyotes coincides with the need to provide for their pulps (Till and Knowlton, 1983; Bromley and Gese, 2001a). If livestock are bred earlier in the season, lambs may be less vulnerable to predators. A study in the USA by Robel et al. (1981) confirmed that fall lambing reduces sheep losses. A study in South Africa by Kamler *et al*. (2012) reported an increase in the incidence of sheep predation during lambing season as sheep are the main source of food for jackals. Furthermore, Kaunda et al. (2003, Botswana) suggested an expansion of jackals ranges due to an increase in territory maintenance by mated pairs during the jackal mating season (late May to August) resulting in livestock vulnerability during this time (Macdonald and Moehlman, 1983; Skinner and Smithers, 1990). For the caracal, seasonal decrease in rodents and other natural prey, in periods when caracal energy needs are high, results in an increase in predation of small stock (Avenant *et al*., 2008). Altering kidding seasons may only be achievable in commercial goat production systems. Goat production in communal farming systems is often resource- limited and strict breeding practices are not followed.

Vigilance is an important behavioural strategy in goats that shows the alertness of an animal relative to its surroundings.

2.7 Vigilance behaviour in goats

The survival of the prey animal depends on its ability to detect predator, defend itself or flee the predator. The primary importance of vigilance is detection and avoidance of predators (Quenette, 1990; Hunter and Skinner, 1998; Boland, 2003).

Several studies on native ungulates have shown that predators have important impacts on prey behaviour (Hunter and Skinner 1998; Laundre´ et al., 2001; Lung and Childress, 2006). As to date, very few studies have reported the behavioural impacts of predation on goats. Several studies have shown behavioural responses to predation in livestock in pens (Terlouw et al., 1998; Hansen et al., 2001; Welp et al., 2004).Little is known on whether predation influences the behaviour of goats in the grazing areas, and if so, whether the change in behaviour has consequences on the farmer. Many studies that focus on indirect impacts of predation on ungulates focus on scanning behaviour, or vigilance (Cameron and Du Toit, 2005; DuLung and Childress, 2006).

2.7.1 Types of vigilance

Although vigilance behaviour is crucial for livestock to increase their safety, this activity may also serve for the acquisition of social information in most gregarious species (Beauchamp, 2001). Vigilance may also reduce the time an individual engages in some activities such as food acquisition and thus may reduce energy gains, especially when the prey have strong time constraints on foraging (McNamara and Houston, 1992) gregarious livestock should, therefore manage their use of vigilance to balance the need for safety, social information and food acquisition. Two types of vigilance have been reported; social vigilance and antipredator vigilance.

2.7.1.1Social vigilance

Social vigilance is vigilance towards other group members. Social vigilance has been used in various contexts, including, monitoring competitors, searching for mates, protecting the young and indirectly monitoring predators (Caro, 2005; Ellard and Byers, 2005). Social vigilance may also allow social foragers to locate and access the quality of food patches discovered by others (Stears *et al*., 2014). This behaviour has been explained in producer-scrounger models which suggest that an individual may find their own food (produce) or join other individuals at a food patch (scrounge). Social vigilance has been described as when an animal raises its head to look at other group members (Favreau *et al*., 2015).

2.7.1.2 Antipredator vigilance

Antipredator vigilance has been described as the main form of vigilance used by foragers for direct detection of predators. It has been described as when an animal raises its head above its shoulders to scan its surroundings (Favreau *et al*., 2010; 2015).

2.7.2 Intensity of vigilance

Although vigilance is thought to reduce feed intake, the cost of foraging vigilance may be reduced in cases where scanning and feeding are not compatible (Spalinger and Hobbs, 1992; Illius and FitzGibbon, 1994; Cowlishaw *et al*., 2004). In fact, most mammals and birds are able to continue ingesting their food by handling or chewing their food during vigilant periods (Baker *et al*., 2011; Norris, 2011; Pays *et al*., 2012). It is, therefore, possible to distinguish the level of intensity of vigilance.

2.7.2.1 Vigilance with chewing

Vigilance with chewing is a lower intensity form of vigilance in which the animal is vigilant while handling or processing food (Meer *et al*., 2012; Robinson and Merrill, 2013; Favreau *et al*., 2015). Carrying multiple tasks may, however, reduce an animal's attention to predator detection efficiency (Dukas, 2002). Vigilance with food handling might reduce the chance of detecting a predator because of the increased noise of the sound of the mastication process (Fortin *et al*., 2004; Blanchard and Fritz, 2007).

2.7.2.2 Vigilance without chewing

Vigilance without chewing is a more intense form of vigilance in which the animal stops all activities and raises its head to scan its surroundings. The investment of social foragers in these two intensities of vigilance has been shown to vary with predation risk, food resource characteristics, group size and distance between foragers (Meer *et al*., 2012, Pays *et al*., 2012; Periquet *et al*., 2012).

Vigilance behaviour varies with group size, reproductive status, topography and ageof animal.

2.7.3Factors affecting vigilance

2.7.3.1 Flock size

Foraging in groups may improve predator detection but individuals in a flock may have increased competition for food. A decrease in vigilance by individuals as group size increases has been a widely-reported effect explained in terms of an increase in likelihood of predator detection (Many-Eyes Theory) or a decrease in perceived predator threat (dilution effect) (Elgar, 1989; Quennette, 1990). Similarly, in some gregarious ungulates, vigilance behaviour of individual animals decreased as the flock size increased (Lung and Childress, 2006, Kluever *et al*., 2008; Favreau *et al*., 2015). Vigilance, however, has many functions besides predator detection, including; searching for food patches (Barbosa, 2002) and maintaining social information (in domestic sheep, Dumont and Boissy, 2002). These two activities both require the animal to be in a head up posture to visually scan the environment. Predator detection may also be possible in a head down posture, although less effective (in dark eyed juncos, Juncos hyemalis, Lima and Bednekoff, 1999). If food is widely dispersed in patches, individuals may spend more time in a head-up posture to locate the food. In large flock sizes, there is more opportunity to locate food by watching other group members and therefore, individuals may spend more time on vigilance, even in little predation risk (Beauchamp, 2001). Hence some studies, have reported that group sizes increase the vigilance behaviour of animals (Molvar and Bowyer, 1994; Cameron and Du Toit, 2005).

2.7.3.2 Reproductive status

Lactating cows have shown to increase their vigilance rates than those not lactating (Kluever et al., 2008). This is despite the fact that lactating cows have more nutritional requirements than non- lactating cows. Similarly, studies on wild ungulates have also shown that lactating animals are more vigilant than non- lactating animals (Burger and Gochfield, 1994; Lung and Childress, 2006). However, lactation status does not always influence vigilance behaviour in all ungulate species (Ruckstuhl *et al*., 2003; Cameron and Du Toit, 2005). The vigilance rates of lactating female mammals decrease as the age of their young increases (Caro, 2005). Although this trend has not been studied in goats, a similar trend is also expected. Generally, the susceptibility of ungulates to predation decreases as age increases, up to a certain point, and decreases as body size increases (Underwood, 1982).

2.7.3.3 Effect of vegetation cover and topography

Goats are domesticated ungulates. Goats in communal production systems may graze freely in vast communal rangelands. Goats however, prefer grazing and browsing in mountainous and hilly environments were bushes and woody shrubs are readily available. Trees and shrubs or bushes can hamper ungulates ability to scan their environment hence increasing their vigilance.

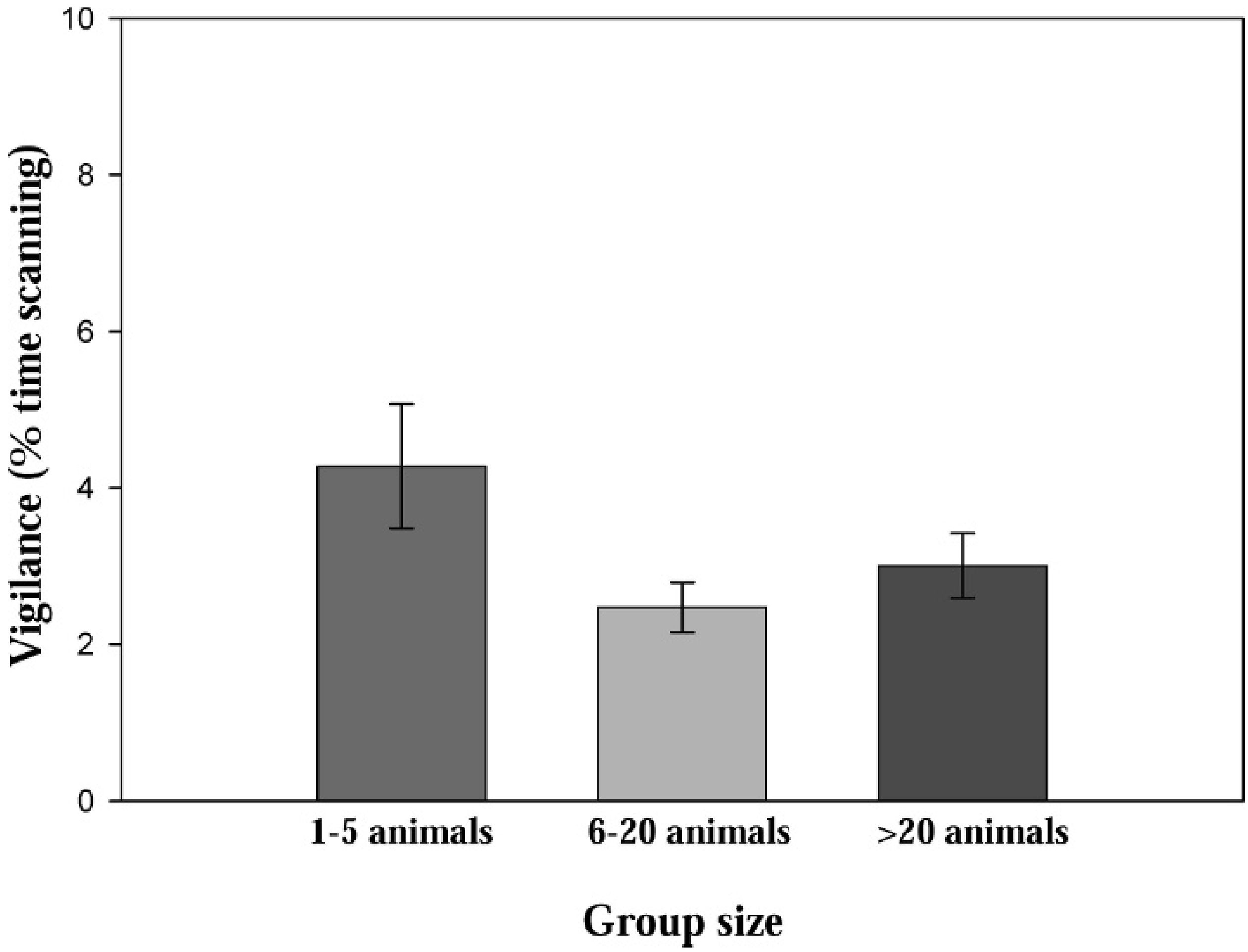

Figure 2.1 Percent of time ($\bar{x}$ ± SE) adult female cattle exhibited vigilance during peak foraging hours in relation to group size. Group sizes were 1–5 animals (n = 32), 6–20 animals (n = 98), or > 20 animals (n = 84).

Source: Kluever *et al*. (2008)

For example, the mule deer were more vigilant in wooded areas rather than in open areas (Hernandez *et al*., 2005) and were more vigilant in forest edges, an area that mountain lion predators may frequent than within open and forest areas (Altendorf *et al*., 2001). Conversely, initial studies have shown varying results on the effect of habitat on vigilance behaviour of ungulates (Underwood, 1982; Schall and Ropartz, 1985; Lagory, 1986). Preferred grazing areas may however change with perceived predation risk (Kotler *et al*., 1991; Ripple and Beschta, 2003). Landscape features have shown to influence the likelihood of detecting predators in time and the prospect of escape (Lima and Dill, 1990). As a result, prey alter their preferred foraging environments (Ripple and Beschta, 2003). For example, some Israeli desert rodents spend more time foraging under bushes in the presence of owls (Kotler *et al*., 1991, 1993a). When owls are replaced with snakes, the rodents change their foraging sites to open spaces to avoid ambushes (Kotler *et al*., 1993b). Similarly, the mule deer (*Odocoileus hemionus)* forages less intensively and is more vigilant in woody vegetation than in open spaces (Altendorf *et al*., 2001). This is because their common predator, the mountain lion (*Puma concolor*) prefers to hunt in woodlands. A study done in areas where free ranging domesticated goats were exposed to the caracal predator showed that the goats preferred grazing in open spaces and avoided the hillside where the caracal can easily ambush those (Shrader *et al*., 2008).

2.7.3.4 Effect of age

The vulnerability of kids to predators may be because of their inexperience in detecting predators. Although predator detection is an important early warning sign, kids may not benefit from it because they cannot outrun a predator. Information on vigilance behaviour of kids is scarce. Some studies, however, have reported an increase in vigilance of mothers with young. This may be a natural mothering instinct. Kluever *et al*. (2008) reported that mother cows whose calves had been killed or attacked by predators increased their vigilance and decreased their foraging times. There is need to further expand on the information on whether or how kids exhibit vigilance behaviour.

2.8 Summary

Predation poses a challenge to goat production in communal farming systems. Predator control methods used by farmers may be lethal or non- lethal. These methods have varying degrees of success. Factors which predispose goats to predators include goat genotype, vegetation or topography, goat age and seasonal effects. Goats exhibit vigilance behaviour by scanning the environment to detect predators. Vigilance behaviour is affected by flock size, topography or landscape features, perceived predator threat and availability of food. There is need to determine factors which influence goat predation in communal production systems and vigilance behaviour of goats in predation risk environments.

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CHAPTER THREE: Influence of genotype and topography on the goat predation challenge under communal production systems

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Abstract

The objective of the current study was to compare incidence of predation of goats in flat lands and mountainous areas. It was hypothesized that the predation challenge is affected by the genotype of goats and the topography in which they are kept. Data were collected from 195 goat- owning households using structured questionnaires;100 households from the mountainous areas and 95 households from the flat areas. Each household had an average of eight goats. Diseases and thefts, followed by predation were ranked as the major causes of goat losses in both areas. Jackals (*Canis aureus L.*), caracal (*Felis caracal*), wild dogs (*Lycaonpictus*) and leopards*(Panthera pardus)*were the common predators during the hot wet season. There were no leopards and caracal in the hot dry season in the flat areas. Farmers reported no leopards in the flat area in the cool dry season. Farmers owning non- descript goat genotypes were five times more likely to experience predation problems than farmers owning the indigenous Nguni goats. Farmers staying in mountainous areas were 2.3 times more likely to experience predation challenges than farmers in the flat land. Kids were the major class of goat targeted by predators. Predation largely occurred in the veld and drinking areas. The use of the Nguni genotype in mountainous areas would likely result in less predation challenges.

Key words: Flat lands; Predation; Mountainous areas; Nguni goats; Non-descript goats

3.1 Introduction

Goats play an important role in household food security worldwide. Due to their grazing habits, and adaptability to varying climates and nutritional regimes, they are able to strive in harsh environmental conditions. Of the 200 million goats in the Sub-Saharan Africa, about 65 % are kept in communal production systems under semi-arid conditions (Department of Agriculture, Fisheries and Forestry, 2011). These goats are owned by resource-poor communal farmers, mainlyfor household food security, rituals, ceremonial functions and risk aversion (Msangi, 2014).In the developed parts of the world such as Central America and Asia goat production also constitute an integral part of the livestock industry where they are mainly kept for meat, milk, skin, fibre and manure production (Dubeuf *et al*., 2004).

Despite their adaptability and abundance, optimum productivity is hampered by large losses from mortality. Kid mortality in extensive goat production systems often exceeds 50 % (Pandey *et al*., 1994). Major causes of goat mortality include persistent droughts, extreme temperatures, high prevalence of diseases and predation. There have been several efforts to solve these challenges. Indigenous goats in the Sub-Saharan region can strive the persistent droughts, extreme temperatures, high prevalence of diseases (Rumosa Gwaze *et al*., 2010).Whilst there have been extensive studies on ways to reduce goat losses to diseases, parasites, feed and water shortages, there is no data on the extent of goat predation. Predator-driven mortality is still a huge drawback to goat production (van Niekerk*et al*., 2013).

Due to its increasing threat to goat production, predation has recently been given attention as a challenge to livestock production. For example, in South Africa, the growing concerns over goat losses to predation triggered major organizations such as the National Wool Growers' Association of South Africa, the South African Mohair Growers' Association, the RedMeat

Producers Organization and Wildlife Ranching South Africa to form the predation management forum in 2009. Meissner (2013) reported that predation accounts for between 2 and 6% of livestock losses. About 3% of sheep and goat losses in the Northern Cape Province of South Africa are due to predation (van Niekerk *et al*., 2013).Predation can lead to animals that are in good condition being lost. As high as 10 % of goat populations in mountainous environments can be lost due to predation (van Niekerk *et al*., 2013).Types of livestock predators vary with geographical location. For example, coyotes *(Canis latrans*) and bobby cats (*Lynx rufus*) are the prominent small stock predators in parts of the USA and Canada (Windberg, 1997; Conner *et al.*, 1998) whilst in Nepal the snow leopard (*Panthera uncia*) is the most common predator for goats (Jackson *et al*., 1996).In the Sub-Saharan Africa, major losses are predominantly due to black-backed jackal (*Canismesomelas*) and secondly to caracal (*Felis caracal*) (Blaum *et al*., 2009).

Despite its threat to goat production, there is little information on preventing goat losses through predation. Studies on predation shed new light on an important aspect that has received very little attention from stakeholders and a basis from which practical applications can be derived. No one method of control will completely reduce predation of the goat flock, therefore, the need for farmers to implement an Integrated Predator Management (IPM) strategy. The first step is to identify common goat predators and strategies communal farmers put in place to control predation.

Goat production in communal areas is generally characterized by free ranging and herding (Rumosa Gwaze *et al*., 2009; Hossain *et al*., 2015). Goats are herded during the day and penned at night in enclosures usually made with tree branches, a mud wall or other fencing (Sebei *et al*., 2004). Free ranging is usually practiced during the post-harvest season and goats are penned only at night. As a result, goats might travel long distances in search of better feed sources. In the communal production systems of Southern Africa, different breeds are mixed together as one flock, with flock sizes ranging from 7 to 20 goats (Mahanjana and Cronjé 2000;Rumosa Gwaze *et al.*, 2009). Flocks from different households usually graze as one unit in cases where grazing area is limiting, or may graze separately in areas where there are vast tracts of grazing land.

Most livestock development policies in Sub-Saharan Africa encourage farmers to keep the exotic or mixed goat genotypes which are fast growing and large-framed compared to the indigenous genotypes. The mixed genotypes are non- descript crossbreds from mating the exotic Boer, Kalahari Red or the Savannah goat genotypes with indigenous genotypes. These recommendations should, however, have been followed by investigations on how well these fast-growing goat genotypes would be adapted to the new environment. It is important to understand that most of the communal farmers occupy the less arable mountainous areas whilst the flat lands are mostly used in commercial farming systems. Occupation of mountainous areas has historical origins, where farmers were displaced from flat fertile lands during colonization. Consequently, rapid population growth rates have forced people to occupy mountainous areas, thus exposing them to predators.

The objective of the study was to determine the challenge of predation on goats in flat and mountainous terrains. The hypothesis was that topography and goat genotype influence goat predation challenge in communal production systems.

3.2. Materials and methods

3.2.1Study site

The study was conducted in Bergville local municipality in KwaZulu-Natal province, South Africa. Bergville local municipality is situated inUThukela district (28°44′S 29°22′E). The area is situated on the foothills of the Drakensburg Mountains. The southern part of Bergville is fairly flat with scattered kopjes and hills. The area experiences a sub-humid climate with hot-dry and cool-wet seasons. Annual rainfall averages 550 mm. The vegetation type is mainly dense bush veld and foothill wooded grasslands (Nel and Sumner, 2006).The area was chosen based on its distinct differences in topography and the numbers of goats kept. About 65% of the area is mountainous and 35% is flat land. Key informant interviews had indicated high predator challenge in the area.

3.2.2. Sampling of households

A total of 195 households that owned goats were interviewed; 100 households from the mountainous area and 95 households from the flat area. The respondents were selected and identified with the assistance of local leadership and key informants. Farmers who owned at least three goats for at least a period of three years were selected.

3.2.3 Data collection

Farmers were interviewed at their homesteads using a pre-tested structured questionnaire. The interviews were conducted in the Zulu vernacular by five trained enumerators. Data collected included household demographics, number and type of livestock kept, goat flock composition and the genotype of goats kept. The Nguni goat genotype was identified using the phenotypic characteristics described by Epistein (1971).The indigenous Nguni goats are multi-coloured goats with a small frame size and small to medium semi- pendulous ears.

Goats which did not show distinct phenotypic characteristics as the Nguni, the Savanna or the Boer goats were classified as non-descript. Each farmer was asked to rank grazing area of goats in each season, causes of goat losses, known predators and season they usually attack, classes of goats usually targeted by the predators and strategies used to control goat predators.

3.2.4 Statistical analyses

All data were analyzed using SAS (2008). Mean rank scores for causes of goat losses, areas where predation normally occurs and predators common in each season for each area (flat land or mountainous) were determined using PROC MEANS of SAS (2008).To determine the predictors to predation challenges, an ordinal logistic regression (PROC LOGISTIC) was used to estimate the probability of a household experiencing predator problem.The logit model fitted predictors, area (mountain versus flat), penning frequency (occasionally versus every day) and genotype of goats (non-descript versus Nguni).The logit model was:

$$\text{Ln}\ [P/1\text{-}P] = \beta_0 + \beta_1 X_1 + \beta_2 X_2 \ldots + \beta_t X_t + \varepsilon$$

Where:

P = probability of household experiencing predator challenges

[P/1-P] = odds of household experiencing predator challenges

β_0 = intercept;

$\beta_1 X_{1 \ldots} \beta_t X_t$= regression coefficients of predictors

ε = random residual error

When computed for each predictor (β_1... βt), the odds ratio was interpreted as the proportion of households experiencing predator challenges versus those that did not experience any predator challenges

3.3. Results

3.3.1 Livestock species kept

Mean herd/flock sizes of livestock species kept by households and goat flock composition are shown in Table 3.1.In addition to goats, the households kept cattle, sheep, pigs and chickens. The average herd size of cattle, and flock size of sheep were the same in both areas ($P > 0.05$). Flat lands had larger pig herds, goat and chicken flocks than mountainous areas ($P < 0.05$).There were more bucks in mountainous areas than in flat lands ($P < 0.05$)

3.3.2 Causes of goat losses

Ranking of causes of goat losses was the same in mountainous areas and flat lands (Table 3.2; $P < 0.05$). Diseases and thefts were perceived as the major causes of goat losses, with thefts ranked highest in both areas, followed by diseases. Predation was ranked third, followed by gastro intestinal parasites then accidents. External parasites and harsh weather were ranked as the least causes of goat losses.

3.3.3 Occurrence and extent of predation

The mean ranks of classes of goats targeted by predators in flat and mountainous areas are shown in Table 3.2.There was no significant difference in ranking of classes mostly lost to predators in flat and mountainous areas. Female kids were mostly lost to predators followed by male kids, does then bucks. Predation mainly occurred in the veld followed by pensthen drinking areas in both flat lands and mountainous areas. Veld and drinking areas were ranked higher in flat lands ($P < 0.05$).

Table 3.1 Mean herd/flock sizes (± SE) of livestock species and goat flock composition

Class	Flat	Mountainous
Livestock species		
Cattle	8.3 ± 1.15	6.8 ± 0.75
Sheep	4.8 ± 1.03	5.1 ± 0.59
Pigs	5.7 ± 1.18[a]	2.4 ± 0.73[b]
Goats	10.2 ± 0.69[a]	7.1 ± 0.51[b]
Chickens	12.9 ± 1.45[a]	9.0 ± 1.00[b]
Goat flock composition		
Bucks	1.6 ± 0.32[a]	2.4 ± 0.19[b]
Does	3.3 ±0.94	5.5 ± 0.66
Kids	2.5 ±0.4	3.0 ± 0.24

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

SE: standard error

Table 3.2 Mean rank scores of causes of goat losses, classes of goats targeted by predators and predators prevalent in flat lands and mountainous areas

Class	#Mean rank score	
	Flat	Mountainous
Cause of goat losses		
Diseases	1.88± 0.23	2.03± 0.11
Internal parasites	2.5± 0.37	2.69±0.14
External parasites	3.0± 0.41	2.66± 0.14
Predation	2.89± 0.44	2.57± 0.15
Theft	1.76± 0.27	2.15± 0.14
Accidents	2.5± 0.87	2.67± 0.71
Harsh weather	2.87± 0.35	2.98± 0.2
Class of goats targeted by predators		
Bucks	3.32± 0.58	3.50±0.41
Does	1.96±0.35	2.14± 0.25
Male kids	1.50± 0.41	1.95± 0.19
Female kids	1.25± 0.50	1.76± 0.14
Where predation normally occurs		
Veld	1.00± 0.20 [a]	1.33± 0.10 [b]
Pen	1.50± 0.42	1.57± 0.12
Drinking areas	1.33± 0.60 [a]	2.33± 0.46 [b]

 # The lower the mean rank, the higher the cause of loss was ranked.
[ab]*Values with different superscripts, within a row, are different ($P<0.05$).*

The odds ratios of a particular household experiencing predation problems are shown in Table 3.3.Households in mountainous areas were 2.3 times more likely to experience goat predator problems than households in the flat lands. Households owning non-descript breeds were 5.2 times more likely to experience goat predator problems than households with Nguni goats. There were no significant differences in likelihood of losing goats to predators between households who penned their goat flocks occasionally and those who penned every day. Households who let their goats graze with their kids where 1.3 times more likely to lose their goats to predators that those who did not let the kids go to the grazing areas.

3.3.4 Common predators

Households ranked dominant predators in each of the two areas (Table 3.4). Wild dogs (*Lycaon pictus*) were ranked highest followed by caracals then jackals (*Canis aureus L.*) in mountainous areas. Jackals were the most problematic in flat lands followed by vultures (*Aegypius monachus*) then wild dogs. Caracals were least ranked in flat lands. Mean rank scores of predators during cool-dry season and hot-wet season in flat lands and mountainous areas are shown in Table 3.4. In flat lands, wild dogs were ranked highest in both seasons. There were no differences in rankings of wild dogs and jackals between seasons. There was a perceived non-existence of leopards *(Panthera pardus)* and caracals during the cool-dry season. In mountainous areas, caracals were perceived to be more problematic during the hot-wet season ($P > 0.05$). As was the case in flat lands, leopards did not kill goats during the cool-dry season.

Table 3.3 Odds ratio estimates, lower and upper confidence interval (CI) of a household experiencing predator challenges

Predictor	Odds ratio	Lower CI	Upper CI
Area (mountain vs. flat)	2.3	0.19	0.98^{*}
Age of head (old ≥50 years vs. young < 50years)	1.1	0.45	1.9^{NS}
Genotype (Non-descript vs. Nguni)	5.2	0.77	0.48^{*}
Adult goats and kids graze together (yes vs. no)	1.3	1.36	1.7^{*}
Kraaling frequency (occasionally vs. every day)	1.6	0.51	4.8^{NS}

P < 0.05; NS – not significant

Table 3.4 Mean rank scores of topographical areas where predation normally occurs, predators reported in the hot wet seasons, predators reported in cool dry seasons and predator control strategies in flat and mountainous areas

	Flat	**Mountain**
Prevalent predators		
Wild dogs (*Lycaonpictus*)	1.98 ± 0.23	1.44 ± 0.18
Jackals (*Canisaureus L.*)	1.58 ± 0.18	1.81 ± 0.29
Leopards *(Pantherapardus)*	2.66 ± 1.87	2.38 ± 0.44
Caracal *(Felis caracal*)	3.00 ± 0.29	1.69 ± 0.84
Vultures (*Aegypiusmonachus***)**	1.84 ± 0.21	2.25 ± 0.48
Snakes *(Serpentes)*	2.33 ± 0.11	2.79 ± 0.76
Predators in hot wet season		
wild dogs (*Lycaonpictus*)	2 ± 0.16	1.46 ± 0.11
Jackals (*Canisaureus L.*)	2.00 ± 0.29	1.66 ± 0.90
Leopards *(Pantherapardus)*	2.00 ± 0.83	2.24 ± 0.15
Caracal *(Felis caracal*)	3.00 ± 0.85	1.5 ± 0.13
Predators in cool dry season		
Wild dogs (*Lycaonpictus*)	1.70 ± 0.48	3.97 ± 1.78
Jackals (*Canisaureus L.*)	1.44 ± 0.38	1.98 ± 0.17
Leopards *(Pantherapardus)*	_	2.05 ± 0.23
Caracal *(Felis caracal*)	3.00 ± 0.88	1.57 ± 0.15
Predator control methods		
Trapping	1.67 ± 0.45	1.83 ± 0.18
Chemicals	6.00 ± 1.16	2.34 ± 0.16
Guard dogs	1.45 ± 0.24	1.94 ± 0.12
Night penning	1.40± 0.39[a]	2.41± 0.16[b]
Herding	2.83 ± 0.58	2.58 ± 0.21
Hunting	1.63 ± 0.20	1.97 ± 0.13

#The lower the mean rank, the higher the cause of loss was ranked

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

3.3.5Predator control methods

Ranking of strategies used to control predators is shown in Table 3.4. Night penning was the most preferred way of controlling predators in flat lands whilst households in mountainous areas ranked trapping first. Guard dogs were ranked second in both areas ($P > 0.05$). Use of chemicals to kill predators was the least ranked in both areas.

3.4. Discussion

Many studies on goat production have focused on nutrition, health and disease, and breeding (Webb and Mamabolo, 2004; Githiori *et al*., 2006; Ben Salem and Smith, 2008). Despite its threat to goat production, there is little information on preventing goat losses through predation. Predation can lead to animals in good condition being lost, thus threatening the breeding stock for the next generation of goats. Efforts of improving nutrition of goats will be fruitless if the goats will be lost to predators.

Predation has been the cause of large losses of healthy small stock in both communal and commercial systems (van Niekerk *et al*., 2013). The finding that predation was ranked third to diseases and theft was comparable to reports by Webb and Mamabolo (2004) who reported that the major losses of goats in semi-arid areas were due to theft, predation and disease. Although predation was not ranked first herein, it remains a huge concern. Disease prevalence and theft have received considerable attention with various strategies to counter them already in place (Webb and Mamabolo, 2004). Mahanjana and Cronjé (2000) highlighted that causes of goat losses varied with production systems and management practices. Pneumonia was reported to be the most prevalent disease for kids under extensive goat production with diarrhoea being ranked second (Ershaduzzaman *et al*., 2007). Snyman (2010) indicated that predation was more problematic than diseases. Diseases can be controlled and treated whilst effective predator control is still a challenge. Predator prevention methods which are currently being used by farmers are not effective (Mattiello *et al*., 2012).

The finding that predation was twice likely to be experienced by farmers living in mountainous areas than in flat areas could have been confirmed by the large flocks in flat lands than mountainous areas. Atickem *et al*. (2010) also reported that predator prevalence is one of the major challenges with raising livestock in mountains. Shrader *et al*. (2008) reported that, due to high predation risk in hilly areas, goats prefer grazing in open grounds. The terrain and rocky nature of mountainous areas is likely to provide suitable habitat and cover for most of predators. The bushy and rocky nature of mountains allows predators to pounce on prey from trees or rocks with ease as compared to open prairies were the can be easily spotted by hunt dogs, herders and/or the prey itself. It is also difficult for goats to escape predators in bushy and rocky areas. Once cornered, the ability of an animal to rebuff a predator is compromised and is usually depended on the animal's physical ability and health status (Martín *et al*., 2006). Health-depended vulnerability of goats to predators needs to be investigated.

Predation was high in the veld and around drinking areas than in pens maybe because wild animals prefer habitats which are rocky, dense and far from human settlements. Wild animals, including predators, usually avoid areas human habitation (Hebblewhite and Merrill, 2009). Mattiello *et al*. (2012) reported that for sheep, presence of farmers on a farm resulted reduction in numbers lost to predators. Human settlements are usually concentrated in flat areas (Coleman et al., 2008).Pens are usually built near homesteads. Penning has been used as a traditional measure to control predation by both commercial and communal farmers (van

Niekerk *et al*., 2013). Thus, it was unexpected that households who pen their goats occasionally were more likely to lose their goats to predators than those who penned them every day. The findings that the average herd size of cattle and flock size of sheep in mountainous areas were the same as in flatlands could indicate that cattle and sheep are less prone to predators as compared to goats. Ability to fight and escape from predators differs with livestock species (Collinge, 2008).

Likelihood of households who let their goats graze with their kids losing their goats to predators can be attributed to vulnerability of kids to predators. Kids are at risk because they are small and lack life experience. They have a tendency of sleeping when their mothers are grazing and, thus, can easily be attacked by predators. The kids cannot also run fast, fight or negotiate gullies, bushes and stones hence they are easily caught. This could also explain the finding that, in both mountainous and flat lands, kids were ranked the class which is mostly lost to predators. Does were ranked second to kids as the class which is mostly lost to predators. Allowing does to go graze together with kids can also make them more vulnerable to predators since they will be trying to fight for their kids. The observation that bucks were ranked as the least class which is lost to predators can explain the higher number of bucks in mountainous areas. As also suggested earlier (Atickem *et al*., 2010), it is advisable for households located in mountainous areas to have more bucks in their flocks.

Households with Nguni goats were five times less likely to face predator challenges compared to the Non-descript genotype. Nguni genotypes are native to the study area. The breed, thus, may have developed survival characteristics against common predators in the region. Nguni goats have a very pronounced herd instinct, making them well suited for bushy areas (Campbell, 2003). They always stay together during browsing and this could facilitate collective defending or alerting each other against predators. The goats are also well known for good mothering ability and, thus, can protect the kids from predators such as vultures. The Nguni breed has strong long legs and developed camouflage patterns with spots and speckles over years (Campbell, 2003).Maybe the camouflage patterns with spots and speckles allow them to hide from predators. Long and strong legs probably enable them to run long distances and jump across gullies and stones and, thus, escaping from predators. The Non- descript goat genotypes have been developed from mating the indigenous Nguni and the meat type fast growing genotypes to develop an intermediate genotype which is faster growing than the Nguni. This selection however, may have resulted in more tame animals which predispose them to predators.

Similar to our findings, van Niekerk*et al*. (2013) reported that wild dogs, caracals and jackals were the most common predators for small stock in the Western Cape Province of South Africa. In the Bale Mountains of Ethiopia, Atickem *et al*. (2010) observed that hyenas were the most problematic predators for goats. This shows that predators vary with region. Differences in rankings of prominent predators between mountainous and flat areas can be an indication that, although the same predators can be found in a wide variety of habitats, they have different preferred hunting grounds depending on topography and vegetation type. Wild dogs, which were ranked first in mountainous areas, have been reported to prefer rocky and densely vegetated areas as their habitat (van Niekerk *et al*., 2013). Jackals, which we found to be the most prominent predator in flat lands, generally prefer open areas with cover nearby (Kalmer *et al*., 2012). The finding that caracals were least ranked as a problem in flat lands whilst highly prominent in mountainous areas was expected. Caracals are typically found in thickets and rocky hills (Marker and Dickman, 2005).

Most predators were prominent during the hot-wet season. Seasonal changes have been reported to directly affect predators and their behaviour (Stenseth *et al*., 2002). During the hot-wet season vegetation dense, providing cover for predators. Smell and sounds of goat kids possibly attracts predators. The hot-wet season is usually the kidding season when there is maximal pasture growth and does will be at peak lactation (Marume *et al*., 2013). The dormancy of predators during cold-dry season maybe due to low prey availability and unfavorable environments. Kalmer *et al*. (2012) reported that, for sheep, high predation is found during lambing seasons. Seasonal changes in prevalence of goat predators can also be attributed to seasonal changes in availability of other prey for the predators. Predation of small stock by the caracal usually happen during the seasonal decrease in rodents and other natural prey and critical periods when caracal energy needs are high (Avenant *et al*., 2008).

The finding that night penning ranked as the most used predator control method in flat lands agrees with Mattiello *et al*. (2012) who reported that most goat farms use fences as a way to fight predators. Jackals, predators which were found to be more prominent in flat lands, are nocturnal (Kalmer *et al*., 2012). In flat lands, predators may prefer attacking at night to avoid human beings and guard dogs. In mountainous areas predators have dense vegetation and rocks to hide and, thus can attack even during the day. In similar findings to the current study, Mattiello *et al*. (2012) reported that the use of guard dogs to curb predation is a common practice among sheep farmers. Guard dogs are cheap to purchase and maintain, easy to train have instinctual behaviour towards predators (Andelt and Hopper, 2000). Limited use of chemicals as a predator control method could be because farmers are aware of the potential risks of chemicals to human safety and other animals.

3.5. Conclusions

Predation is the third major cause of goat losses, after diseases and theft. Predation was highly likely to occur in mountainous than in flat areas. There are more predators in the hot wet season compared to the other seasons. Imported and non-descript goats are more susceptible to predation than indigenous Nguni goats. Night penning and guard dogs are the commonly used predator control methods in both mountainous and flat lands. The use of the indigenous Nguni goat genotype in mountainous terrains may reduce predation challenges.

3.6 Ethics

The study was granted ethical clearance certificate (HSS/1861/015M) by the University of KwaZulu-Natal's Research Ethics Committee and has, therefore, been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. All persons interviewed gave their informed consent prior to their inclusion in this study.

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CHAPTER FOUR: Effect of topography, age and flock size on the vigilance behaviour of free-grazing Nguni goats

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Abstract

Vigilance behaviour is important in free- ranging goats to guard against predators. The objective of the study was to determine effect of topography, age and flock size on vigilance behaviour exhibited by free grazing goats. Kids and does were investigated in small and large flock sizes in flat and mountainous areas. Vigilance behaviour was categorized into antipredator or social vigilance and further distinguished into vigilance with or without chewing. Goats spent more time (P< 0.05) in antipredator vigilance than social vigilance. In flat terrain, does in large flocks spent 2.5 times more time in antipredator vigilance with chewing than does in small flocks. A similar pattern was observed in the mountainous area. For large flocks, does in flat terrain spent 1.9 times more time in antipredator vigilance with chewing than does in mountainous areas. For large flocks, kids in flat terrain spent 2.7times more time than in mountainous areas in antipredator vigilance with chewing. In flat terrain, does in large flocks spent five times more time in antipredator vigilance without chewing than does in small flock sizes. In mountainous areas, does in large flocks spent twice more than the time spent by does in small flock sizes. In flat terrain, kids in large flocks spent seven times more time in antipredator vigilance without chewing than kids in small flocks. In the large flock in flat terrain, kids spent more time in antipredator vigilance with chewing than does (P< 0.05). Age of goats had no effect on the vigilance behaviour. It can be concluded that goats in flat areas exhibit more antipredator vigilance than goats in

mountainous areas. Goats in larger flocks spent more time in antipredator chewing vigilance behaviour.

Keywords: antipredator vigilance, predation, mountainous areas, social vigilance

4.1. Introduction

Goats play an important role in household food security, rituals, ceremonial functions and risk aversion (Msangi, 2014) in resource- limited households in developing countries. Due to their grazing habits and ability to be selective feeders, they are able to strive in harsh environmental conditions. Of the 200 million goats in the Sub-Saharan Africa, about 65 % are indigenous goats which are kept in communal production systems under semi-arid conditions (Department of Agriculture, Fisheries and Forestry, 2011 Goat production, however, is faced by many challenges. These include persistent droughts, extreme temperatures, high prevalence of parasites, diseases and predation.

Goats prefer grazing in mountainous or rocky areas which are habitats for predators.Predation can lead to goats that are in good condition and productive animals being lost. As high as 10 % of goat populations in mountainous environments can be lost due to predation (van Niekerk *et al*., 2013).Predator control is such a huge challenge because most of the predator control methods focus on the predator itself instead of the prey. Killing or catching the predators is being condemned. Assessing prey behaviour may be a more suitable option. Prey behaviour in response to predators has been investigated on ungulates (Hunter and Skinner 1988; Laundre´ *et al*., 2001; Lung and Childress, 2006). Some behavioural traits can show alertness or ability to fight predators. Selection for such behavioural traits in goats can help to curb predator effects.

Prey species have developed behavioural traits that enable them to detect, avoid and defend themselves against predators (Brown, 1999; Laundré *et al*., 2001; Apfelbach *et al*., 2005).One such behaviour is vigilance. Vigilance behaviour assesses the alertness of an animal to its surroundings to increase awareness of predator presence. In gregarious species, vigilance also serves in acquiring social information (Favreau *et al*., 2015, Beauchamp, 2014). Social vigilance may serve to indirectly detect predators in gregarious species (Caro, 2005; Ellard and Byers, 2005), where individuals monitor group members. Antipredator vigilance is directly scouting the surroundings to detect predators. Many foraging animals are able to continue feed ingestion during periods of vigilance (Baker *et al*., 2011; Pays *et al*., 2012). High intensity vigilance occurs when an animal raises its head and stops all activities ("vigilance without chewing") and is distinguished from a lower intensity of vigilance, when the animal continues to chew feed ("vigilance with chewing") (Pays *et al*., 2012; Robinson and Merrill, 2013; Favreau *et al*., 2015).

Investigating vigilance behaviour in free ranging goats therefore provide insight in adaptation of these goats to predators in different topographical areas. This may provide an alternative tool in understanding and dealing with goat predation. A decrease in vigilance behaviour as group size increases has been widely reported, suggesting an increase in likelihood of predator detection or a decrease in the perceived threat ('comfort in numbers') (Elgar, 1989; Quenette, 1990).The objective of the current study, therefore, was to determine the effect of flock size, age and topography on the vigilance behaviour of free ranging Nguni goats. The hypothesis was that flock size, topography and age affect the vigilance behaviour exhibited by free-ranging goats.

4.2. Materials and methods

4.2.1Description of study site

The study was conducted in Bergville municipality in KwaZulu-Natal province, South Africa. Bergville local municipality is situated in UThukela district (28°44′S 29°22′E). The site is situated on the foothills of the Drakensburg Mountains. The southern part of Bergville is fairly flat (slope of less than 5º) with scattered kopjes and hills. The area experiences a sub-humid climate with hot-dry and cool-wet seasons. Annual rainfall averages 550 mm. The vegetation type in the mountainous areas is mainly dense bush veld and foothill wooded grasslands. The flatland vegetation is classified as grassland biome, but *Aloe ferox* and *Acacia sieberiana* have encroached into eroded areas. The study was conducted at the end of winter (mid- August) when grass is tall (about 1m) and very fibrous.

The area was chosen based on its distinct differences in topography and the numbers of goats kept. About 65% of the area is mountainous and 35% is flat land. Key informant interviews with community leaders had indicated high predator challenge in the area. Goats in this area forage during the day in the vast communal rangelands without herders and may travel long distances in search for feed resources. They return on their own to their pens in the late afternoon where they are housed overnight.

4.2.2 Experimental design

A total of 16 goat flocks from four villages were selected for the study (Table 4.1). Two goats (one doe and one kid) from each flock were then selected for observation. The selection criterion was based on the goats being of the Nguni genotype. Nguni goats were identified as having small erect ears with a small body frame. Flocks selected had to have at least one doe and one kid (less than two months of age).Goat flocks were further categorized into small flock size (<8 goats) and large flock size (>8 goats).

4.2.3 Data collection

A preliminary observation session was conducted at the beginning of the study with four trained observers to conduct data collection. One doe and one kid from each flock were randomly selected as focal animals and painted on the flank for easy identification. Each observer monitored one flock in their usual grazing area. Data recording started once the goats were grazing normally.

Behavioural data were recorded on recording sheets. Goat flocks were allowed to graze freely on the rangeland whilst being accompanied by observers. Selected goats in a flock were observed for 10 minutes between 0900 to 1200h. Interviews with goat farmers in the area indicated that goats are released from the pen in the morning and travel long distances in search for feed. Goats herd back to the pen around 1400h each day and some goats may be missing. It was, therefore, assumed that predation risk is high during this period. Each goat was observed sequentially for 10 min using stop watches. The activities recorded were social vigilance with chewing, social vigilance without chewing, antipredator vigilance with chewing and antipredator vigilance without chewing.

4.2.4 Statistical analyses

The data were analyzed using the PROC GLM procedure of SAS (2003). The model used was as follows:

$$Y_{ijklm} = \mu + A_i + B_j + C_k + (A \times B)_{ij} + (A \times C)_{ik} + (B \times C)_{jk} + (A \times B \times C)_{ijk} + e_{ijklm}$$

Table 4.1 Characteristics of the villages selected

Village name	Topography	Number of goat flocks
Potshini	Mountainous	4
Nokupela	Mountainous	4
Mlimeleni	Flat	4
Okhombe	Flat	4

Where;

Y_{ijklm} = time spent on each activity;

μ overall mean response;

A_i= effect of topography (i= mountainous, flat)

B_j= effect of flock size (j= small flock, large flock)

C_k= effect of age (k= does, kids)

$(A \times B)_{ij}$= interaction of topography and flock size

$(A \times C)_{ik}$= interaction of topography and age

$(B \times C)_{jk}$= flock size and age interaction

$(A \times B \times C)_{ijk}$= topography, flock size and age interactions

E_{ijklm}= residual error

Comparison of means was done using the PDIFF option of SAS.

4.3 Results

4.3.1 Levels of significance of age of goats, flock size and topography on vigilance behaviour

The level of significance of age of goats, flock size, topography and their interactions to vigilance behaviour exhibited by goats are shown in Table 4.2. The social with chewing and antipredator with chewing behaviour exhibited by goats were affected by topography. Flock size affected antipredator with chewing and antipredator without chewing. There was an interaction between topography and flock size on antipredator vigilance with chewing ($P < 0.05$).

Table 4.2 Significance level ($P < 0.05$) of factors of vigilance behaviours tested

	Variables					
	A	**B**	**C**	**A × B**	**B × C**	**A × B × C**
Vigilance behaviour						
Social with chewing	*	NS	NS	NS	NS	NS
Social without chewing	NS	NS	NS	NS	NS	NS
Antipredator with chewing	*	*	NS	*	NS	NS
Antipredator without chewing	NS	*	NS	NS	NS	NS

NS- not significant; *significant   A= topography; B= flock size; C= age of goat

4.3.2 Percentage time spent in vigilance by does

The percentage of time spent by does in vigilance is shown in Figure 4.1. Does in flat lands in small flocks spent most of their vigilant time exhibiting antipredator with chewing vigilance. Does in flat lands in large flocks did not show any social vigilance. Only does in mountainous areas in small flocks exhibited social without chewing vigilance. Does in mountainous areas spent a greater percentage of their vigilant time on antipredator without chewing vigilance.

4.3.3 Percentage time spent by kids

The percentage of time spent by kids in vigilance is shown in Figure 4.2. Kids in flat terrain in small flocks spent a greater percentage of their vigilant time in antipredator with chewing vigilance. Kids in mountainous areas in large flocks spent a greater percentage of their vigilant time in antipredator without chewing vigilance. Kids in flat terrain in large flocks did not show any social with chewing vigilance.

4.3.4 Time spent in vigilance in flat and mountainous areas

The vigilance duration observed in flat and mountainous areas is shown in Figure 4.3. Social vigilance was lower than antipredator vigilance in both flat and mountainous areas ($P < 0.05$). Antipredator vigilance with chewing was higher in flat areas than in mountainous areas ($P < 0.05$). Antipredator vigilance without chewing, however, was higher in mountainous areas than in flat areas ($P < 0.05$).

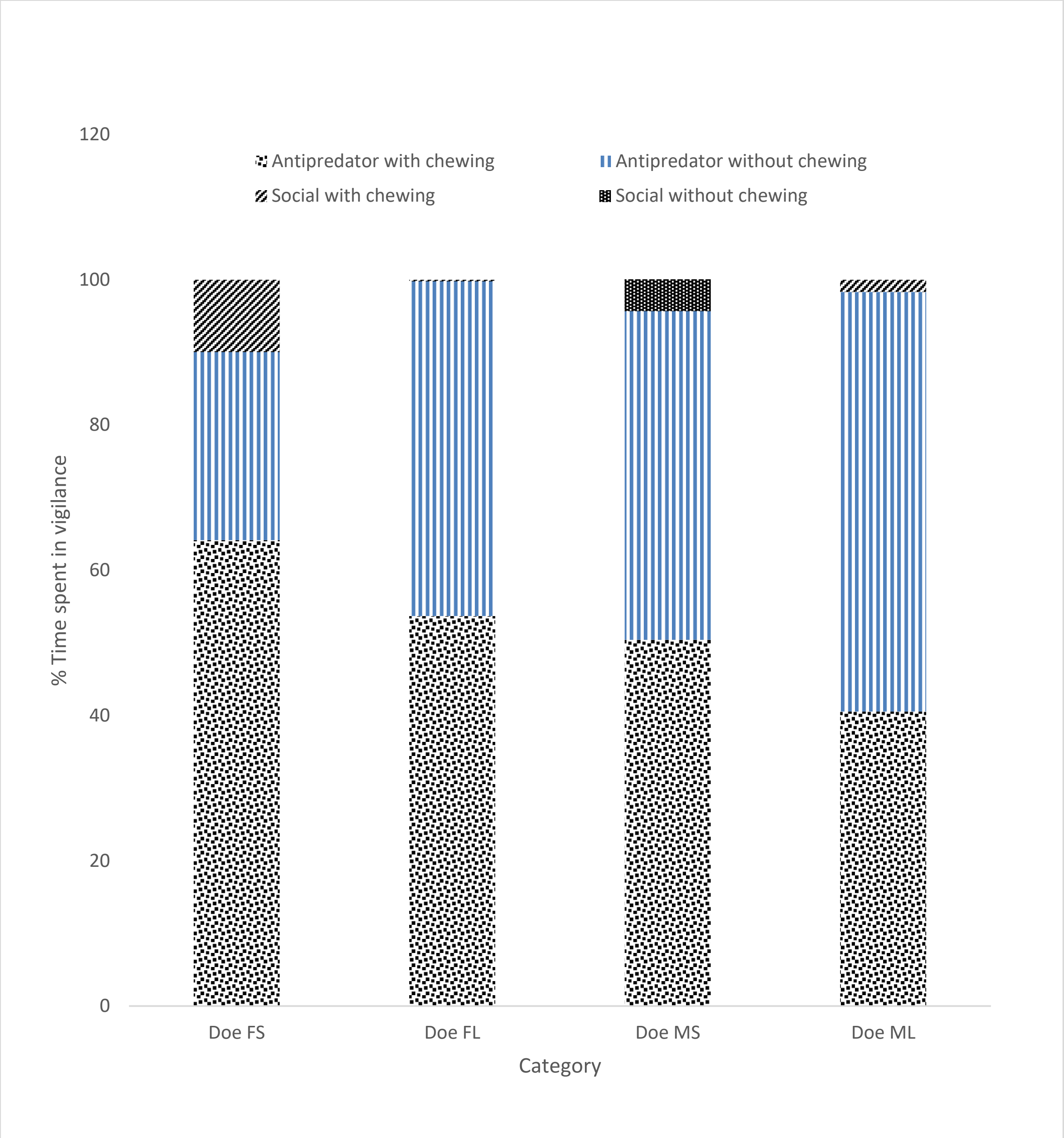

Figure 4.1 Percentage of time spent in vigilance by does

FS- flat terrain, small flock **FL**- flat terrain, large flock **MS**- mountainous, small flock **ML**- mountainous, large flock

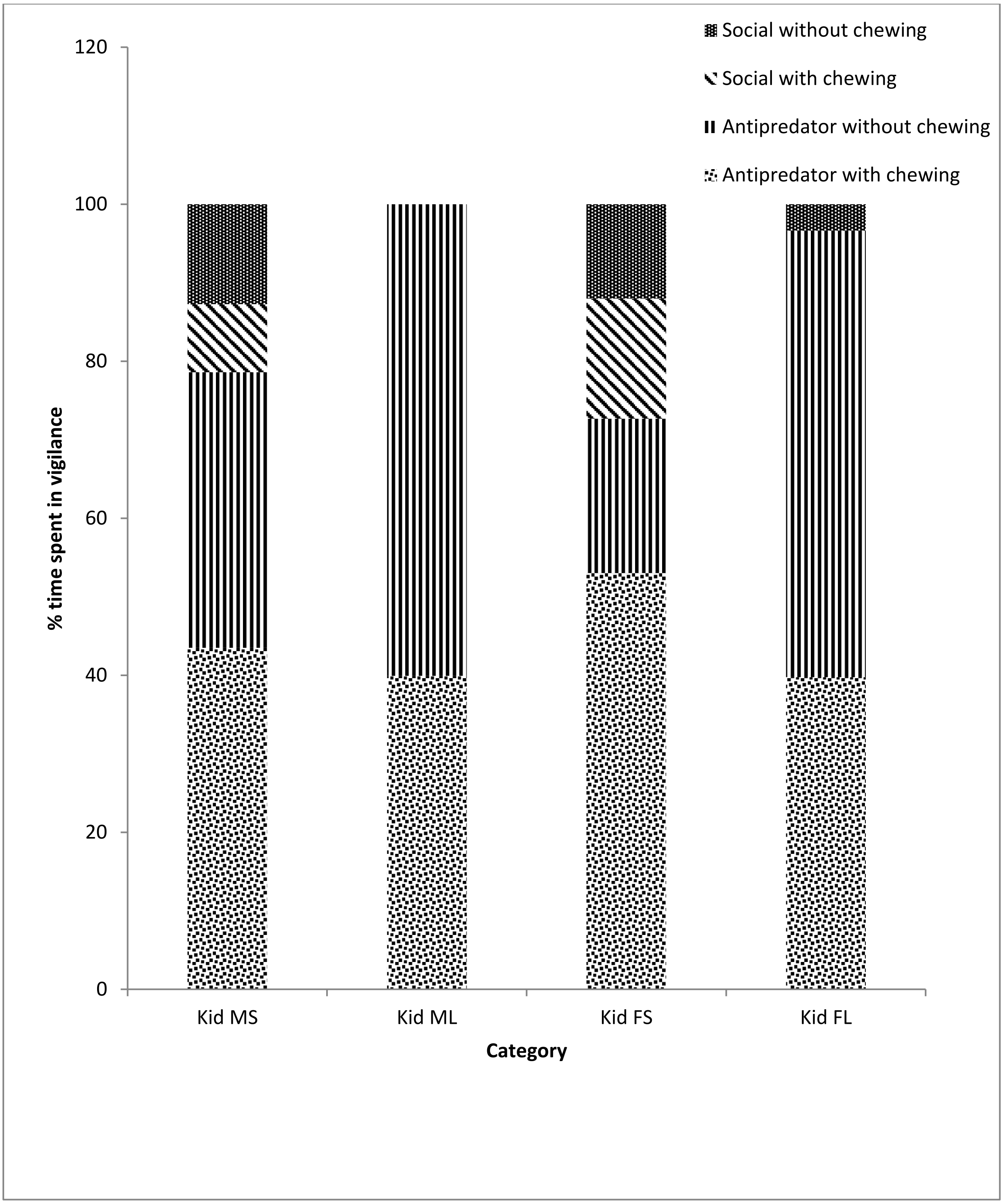

Figure 4.2 Percentage of time spent in vigilance by kids

FS- flat terrain, small flock **FL**- flat terrain, large flock **MS**- mountainous, small flock **ML**- mountainous, large flock

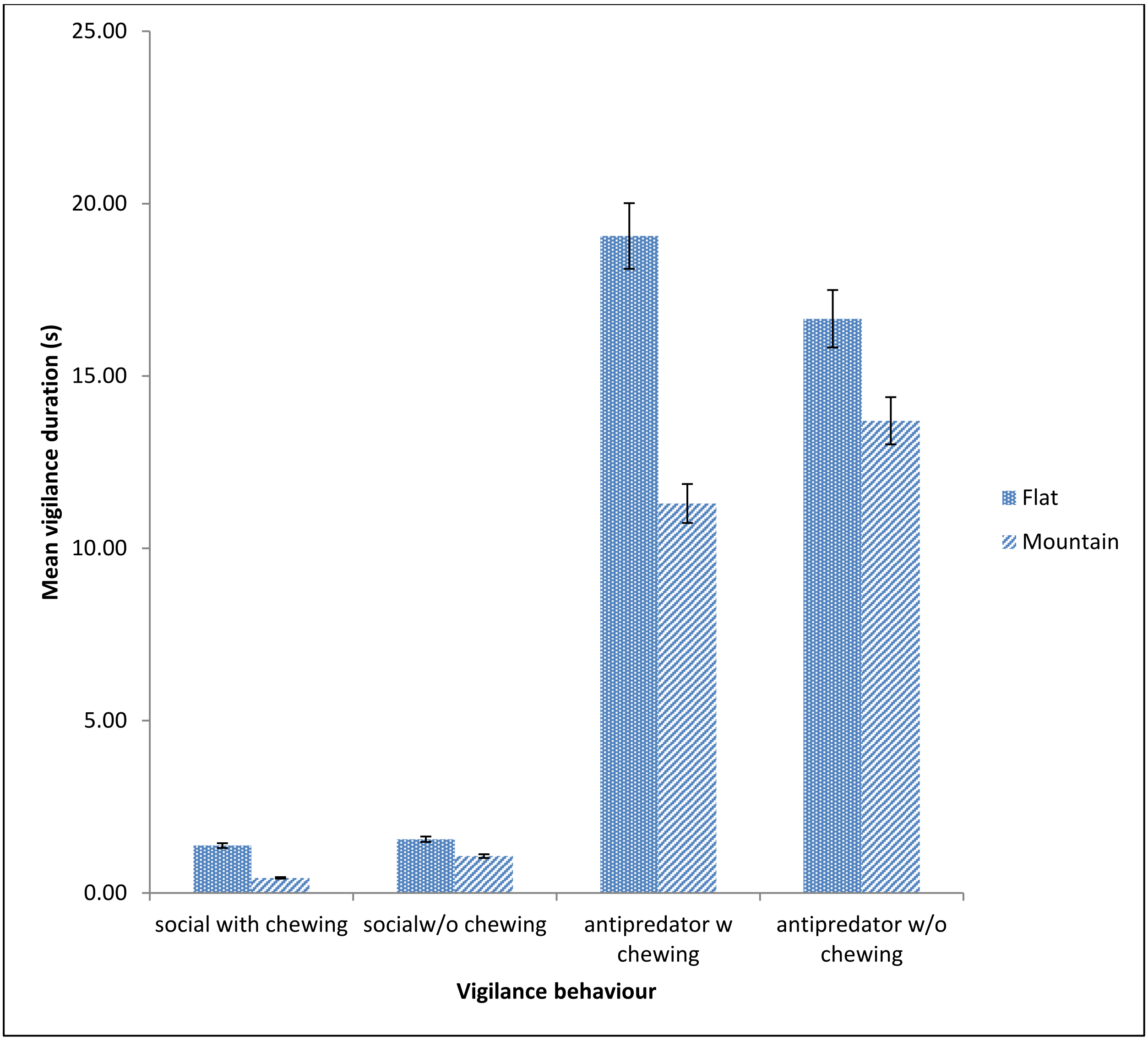

Figure 4.3 Least square mean vigilance duration of goats in flat and mountainous lands

4.3.5 Time spent on social with chewing behaviour

Interactions of topography, flock size and age group of goats on time spent on social vigilance with chewing are shown in Table 4.3. In flat areas, kids in small flocks exhibited 1.9 times more social vigilance with chewing than does in large flocks ($P < 0.05$). In both flat and mountainous terrain, does in large and small flocks spent the same amount time in social vigilance ($P > 0.05$).There were no significant differences between times spent in social vigilance with chewing of does in small and large flocks. In mountainous terrain, does spent no time on social vigilance with chewing. For small flock sizes, kids in flat lands exhibited two times more social with chewing vigilance than those in mountainous areas ($P < 0.05$). Kids in large flocks in both mountainous and flat areas did not show any social vigilance with chewing.

4.3.6 Time spent on social vigilance without chewing behaviour

Table 4.3 also shows the time spent by goats in social vigilance without chewing. In flat terrain, does in small and large flocks did not exhibit any social without chewing vigilance. Similarly, kids in mountainous areas in large flocks did not exhibit any social without chewing vigilance.

Table 4.3 Least square means (±SE) of time spent (seconds) in social vigilance with and without chewing

Social vigilance with chewing			
Topography	**Flock size**	**Doe**	**Kids**
Flat	Small	1.88 ± 0.97[a]	3.50 ± 0.97[b]
	Large	0.13 ± 0.12[a]	0
Mountain	Small	0	1.75 ± 0.97[a]
	Large	0	0
Social vigilance without chewing			
Flat	Small	0	2.75 ± 0.79
	Large	0	1.88 ± 0.79
Mountain	Small	1.06 ± 0.77	2.56 ± 0.77
	Large	0.67 ± 0.39	0

[a, b] *For each type of social vigilance, values with different superscripts differ (P<0.05)*

4.3.7 Time spent on antipredator with chewing behaviour

Topography, flock size and age interactions on time spent in antipredator vigilance with chewing are shown in Table 4.4. In flat terrain, does in large flocks spent 2.5 times more time in antipredator vigilance with chewing than does in small flocks. A similar pattern was observed in the mountainous environment. For large flocks, does in flat terrain spent 1.9 times more time in antipredator vigilance with chewing than does in mountainous areas. For large flocks, kids in flat terrain spent 2.7 times more time than in mountainous areas in antipredator vigilance with chewing. For large flocks in mountainous areas, does spent twice more time in antipredator with chewing vigilance than kids. There was an interaction between topography and flock size on antipredator vigilance with chewing.

4.3.8 Time spent on antipredator without chewing behaviour

Time spent by goats in antipredator vigilance without chewing is also shown in Table 4.4. In the flat terrain, does in large flocks spent five times more time in antipredator vigilance without chewing than does in small flock sizes. In the mountainous region, does in large flocks spent twice more than the time spent by does in small flock sizes. In the flat terrain, kids in large flocks spent seven times more time in antipredator vigilance without chewing than kids in small flocks. In the large flock in flat terrain, kids spent more time in antipredator vigilance with chewing than does ($P < 0.05$).

Table 4.4 Least square means (±SE) of time spent (seconds) in antipredator vigilance with and without chewing

Antipredator vigilance with chewing			
Topography	**Flock size**	**Doe**	**Kids**
Flat	Small	12.13 ± 4.08^{ab}	12.13 ± 4.08^{ab}
	Large	29.88 ± 4.08^{c}	22.13 ± 4.08^{bc}
Mountain	Small	12.25 ± 2.88^{a}	8.75 ± 2.88^{a}
	Large	16.08 ± 3.33^{b}	8.13 ± 4.08^{a}
Antipredator vigilance without chewing			
Flat	Small	4.88 ± 5.89^{a}	4.50 ± 5.89^{a}
	Large	25.63 ± 5.89^{c}	31.63 ± 5.89^{d}
Mountain	Small	10.99 ± 4.17^{ab}	7.06 ± 4.17^{a}
	Large	22.91 ± 4.81^{c}	13.88 ± 4.81^{bc}

^{abcd}*For each type of antipredator vigilance, values with different superscripts differ(P< 0.05)*

4.4. Discussion

The study investigated the effect of topography, age and flock size on the vigilance behaviour exhibited by free ranging Nguni goats. Goats in communal production system are sometimes herded, especially during crop- growing season to prevent them from destroying crops. Goats in the area are therefore, familiar with close human presence. The vast grazing communal rangelands are shared with other livestock species such as cattle and sheep, and, although these species may be in close proximity, they do not mix as one flock.

Vigilance behaviour is important in livestock to guard against predators and to monitor other group members. Social vigilance serves many purposes in goats and enables goats to better detect of predators and to successfully defend neonates (Jarman, 1974; Hunter and Skinner, 1998; Estevez *et al*., 2007). The amount of time goats devote to vigilance behaviour may be affected by the perceived predator threat, the number of individuals in a group, nutritional requirements and the distribution and availability of food. We reported that goats generally invested more time in antipredator vigilance than social vigilance. A similar pattern was observed in female kangaroos (Favreau *et al*., 2010; Favreau *et al*., 2015). This may have been because the study area was reported to have a high predation risk; hence the goats spent more time in antipredator vigilance. Where predation risk is high, goats reduce their feeding efforts (Shrader *et al*., 2008) and this might be because of increased time spent in antipredator vigilance.

The current study reported an increase in, antipredator with chewing and antipredator without chewing vigilance behaviour as flock size increased. It was expected that vigilance behaviour decreases in larger flocks. Molvar and Bowyer, 1994; Cameron and Du Toit, 2005 also reported an increase in vigilance with increased group size in wild ungulates. Conversely, Kluever *et al*. (2008) reported an increase in vigilance behaviour of cattle in small group sizes. Favreau *et al*. (2015) reported that the probability of female kangaroos engaging in vigilance increased with group size. Some studies on wild ungulates have suggested that individual animal benefit from the collective scanning of group members (Pulliam, 1973; Elgar, 1989; Quenette, 1990; Lima and Dill, 1990; Lung and Childress, 2006). Goats are herbivorous ungulates, hence the comparison of goats to other ungulates such as sheep, cattle, kangaroos and giraffes. The increase in vigilance behaviour of goats in larger flocks could be explained by the increased competition for food from group members in larger flocks. Goats in larger flocks may scan the environment more to track suitable food patches (Roberts, 1996). The study was conducted at the end of winter when grass and herbage quality was very fibrous. In flat terrain, an increase in antipredator with chewing vigilance by does in larger flocks than does in smaller flocks. The increase might be because mothers in larger flocks might elevate their vigilance to track their kids and other flock mates (Beauchamp, 2001).

There are distinct differences in vegetation type and cover in flat areas and in mountainous areas. The current study reported an increase in antipredator with chewing behaviour in flat than in mountainous areas. Antipredator vigilance is scanning the surroundings for any possible danger. It was expected that antipredator behaviour increases with increased vegetation cover. The study, however, reported that for larger flocks in mountainous areas, does spent twice more time spent with kids in antipredator with chewing vigilance behaviour. The mountainous area was mostly dominated by rocks and thick bushes in which predators can easily hide. Does in mountainous environments may have spent more time in antipredator vigilance to keep track of their kids. Goat losses to predation are high in mountainous environments (van Niekerk *et al.,* 2013), therefore, the need for goats to exhibit a more intense form of vigilance in mountainous areas than in flat areas. The presence of woody vegetation in mountainous areas also increases the vigilance behaviour of goats because the ability to detect predators would be hampered by woody vegetation. The findings that goats exhibited more antipredator vigilance in flat terrain than in mountainous areas may be because of the ease of chase and catch by predators in plain flat terrain than in mountainous areas (Li *et al*., 2005). Goats in mountainous areas may be able to hide in the bushes and behind rocks in mountainous areas, which may not be present in flat terrain.

There was no effect of age on any of the vigilance behaviour tested on goats. This was unexpected since animal juveniles are expected to be less vigilant because they need time and experience to learn certain aspects of behaviour, their smaller size and stature might mean predators are difficult to detect them hence may not need to be as vigilant as adults. Kids are also expected to invest more time in food acquisition since their energy and nutritional requirements are higher than adults for growth, hence invest less time in vigilance. The lack of age differences on the vigilance behaviour may be because goat kids would mimic and follow after what their mother was doing. There is need, however, for further research on this area.

4.5. Conclusions

Nguni goats spent more time in antipredator vigilance than social vigilance. The social with chewing, antipredator with chewing and antipredator vigilance without chewing vigilance behaviour were higher in large flocks than in small flocks. Goats in flat terrain and larger flocks spent more time on antipredator with chewing behaviour than goats in mountainous environment and smaller flocks. Goats in larger flock sizes spent more time on antipredator without chewing than goats in smaller flocks. Age of goats had no effect on any of the vigilance behaviour tested.

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CHAPTER 5. General discussions, conclusions and recommendations

5.1 General discussion

Most communal goat farmers occupy marginal mountainous environments which are not arable. The flat terrain is mostly used for commercial farming systems. The mountainous environments are preferred habitats for predators. Predation results in productive animals being lost, in addition to the weak counterparts in the flock. Goat predation in communal production systems is poorly understood.

A survey was conducted (Chapter 3) to determine the effects of genotype and topography on the predation challenge in communal goat production systems. It was hypothesized that topography and goat genotype affect the extent to which predation of goats occurs in communal production systems. The study revealed that households in mountainous environments were more likely to experience predation challenges than households in flat lands. The common predators were the caracal, jackal, wild dogs and leopards. The Nguni goat genotype was less likely to experience predator challenges than the non-descript genotype. The Nguni genotype was, therefore, more adapted to its environment. Farmers who let adult goats and kids graze together were more likely to experience predator challenges. There were more predators in the hot-wet season than in the cool-dry season. The study provided enough evidence to suggest that imported and crossbred genotypes are more susceptible to predators than Nguni goats. The hypothesis that mountainous regions are more likely to suffer predation of goats was also not rejected. During the dry season, when most grasses are dry and vegetation is scarce, most goats and other livestock species go to the mountains where bushes and shrubs retain their green pigmentation and protein quality and quantity. The influence of genotype and topography on goat predation in communal production systems should, therefore, not be ignored when designing integrated predator management systems. Assessing goat vigilance behaviour in predation risk areas is important in understanding determinants of goat predation.

In Chapter 4, the effects of topography, flock size and age on the vigilance behaviour of free-ranging Nguni goats were studied. Vigilance assesses the extent to which goats are alert to their environments. It was hypothesized that topography, age and flock size affect vigilance behaviour of goats. The study showed that in flat terrain, does in large flocks spent more time in antipredator vigilance with chewing than does in small flocks. For large flocks, does in flat terrain spent more time in antipredator vigilance with chewing than does in mountainous areas. In flat terrain, does in large flocks exhibited more antipredator without chewing than does in small flocks. The goats' exhibit of more antipredator vigilance in large flocks in flat terrain by does in large flocks may have been in search for better food patches because of competition for food in larger flocks. Does in large flocks in mountainous areas may have exhibited more antipredator with chewing vigilance to keep track of their kids. The mountainous terrain provides vegetation cover and woody bushes were predators can easily hide hence the findings that households in mountainous environments experienced more predator challenges. The findings that does in flat terrain were more vigilant than does in the mountainous areas may provide an explanation to the findings that predation was less likely to occur in the flat lands (Chapter 3). Does were reported to be more vigilance in flat areas in larger flocks to keep track of their kids, and consequently making them also prone to predator attacks. The study provided enough evidence to suggest that flock size and topography affect goat vigilance behaviour. There was not enough evidence to suggest that age affects goat vigilance behaviour.

5.2 Conclusions

Predation is more likely to occur in mountainous areas than in flat lands. There were more predators in the hot-wet season in both flat and mountainous areas. The Nguni goat genotype is less likely to experience predation challenges. Does large flocks exhibit more antipredator vigilance in flat terrain than does in small flocks. In large flocks, does in mountainous areas exhibited more antipredator with chewing than does in flat terrain. There was no age effect on antipredator vigilance in free-ranging Nguni goats.

5.3 Recommendations and further research

Households rearing goats in areas which are prone to predator attacks should rear the Nguni goat genotypes. Letting kids stay in the pen when adult goats go to graze may also reduce predation attacks. Feed supplementation will therefore be needed for the goat kids.

To reduce goat losses, an effective integrated predator management (IPM) is recommended. No one method will completely manage goat predation. By combining many predator control methods, goat predation can be reduced. There is, therefore, a need to conduct a collaborative and co-operative research projects involving government, non-government organizations, farmers and other stakeholders for effective integrated predator control methods in communal production systems.In addition, detailed on-field monitoring studies and consequently using robust statistical techniques to identify factors that influence predation are required.The studies should be conducted with active engagement and participation of communities involved. The information should be dissipated using local newspapers, radio stations and magazines.Goat selection programmes and breeding schemes should also incorporate vigilance as a trait of economic importance.

Aspects that need further research include:

- The effect of season on the vigilance behaviour of free- ranging Nguni goats
- The effect of genotype on the vigilance behaviour of goats
- Assessing the role of different time of day on the vigilance behaviour of goats
- Determining the effect of flock composition and sex on the vigilance behaviour of goats
- Determining effective integrated predation management in different environments
- The effect of presence other livestock species on the vigilance behaviour exhibited by goats
- Determining the feeding behaviour of goats in predation risk areas.

APPENDIX 1: Survey Questionnaire

SECTION A: DEMOGRAPHIC AND SOCIO-ECONOMIC STATUS OF THE HOUSEHOLD

A1. Age of head of household *(Iminyaka)*………………..
A2. Relationship *(Ubudlelwane)*? 1. Head *(Inhloko)*……. 2.Spouse *(UNkosikazi or Umkhwenyana)*……. 3.Child *(Ingane)*…….
A3. Highest education level (*Izinga lemfundo*)? 1. Primary (*Amazinga aphansi*)………. 2.Secondary (*Amazingaaphakathi)*……….. 3. Tertiary (*Amazinga aphakeme*)……….
A4. Number of adults in the household (*Inani labantu abakhulile ekhaya*) (>13 yrs)…………….
A5. Number of children in the household *(Inani Labantwana ekhaya*) (<13 yrs)………….
A6. Major source of income? 1. Employed *(Uyasebenza*)……. Unemployed (*Awusebenzi)*…….
A7. Which livestock do you keep (*Hlobo luni lwemfuyo enilugcinayo?*

Species	**Cattle (*Inkomo)***	**Sheep *(Imvu)***	**Pigs*(In gulube)***	**Goats *(Imbuzi)***	**Chickens *(Inkukhu*)**	**Other (*okunye*)**
Tick (*Khetha*)						
Number (*Inani)*						

SECTION B: GOAT FLOCK COMPOSITION AND GENDER ROLES (Ukuhlukana kwezimbuzi nane nxele edlalwa ubulili)

B1. What is the composition of your goat flock? (Uwuhlukanisa kanjani umhlambi wakho)

Class	**Bucks (*Impongo)***	**Does *(Nsikazi*)**	**Kids (*Zinyane)***	**Lactating *(Insikazi*)**
Tick (*Khetha)*				
Number *(Inani)*				

B2. Who is the owner of your goats (*Umani umnikazi wezimbuzi*)? 1. Mother *(Umama*)………..
2. Father *(Ubaba*)……… 3.Children *(Ingane*)…….4. Other (*Omunye*) (specify)………….
B3. Why do you keep goats *(Nizigcinelani izimbuzi*) (tick one or more) (*Khetha okukodwanoma okungaphezulu)* (Rank 1 as the most common use)

Use	Meat *(Inyama*)	Milk *(Ubisi)*	Sales *(Ukudayisa*)	Manure (*Imfucuza)*	Dowry (*kumalobolo*)	Ceremonies (*Imicimbi*)	Skin (*Isikhumba)*
Tick *(khetha)*							
Rank *(Hlela)*							

B4. What role (s) does each household member play in goat production? (Iyiphi inxenye edlala umuntu ngamunye ekukhiqizeni kwezimbuzi) Tick one or more (Khetha okukodwa noma okungaphezulu)

Role	**Adult males (Osekhulile wesilisa)**	**Adult females (*osekhulile wesifazane*)**	**Boys (*Umfana)***	**Girls (*Amantombazane)***
Herding(*ukulusa*)				
Kraal construction *(Ukwakha isibaya*)				
Purchasing *(Ukuthenga*)				
Slaughtering *(Ukuhlinza*)				
Other (specify) *(Okunye*)				

B5. Which age group of children herd goats (*Iliphi izinga leminyaka yezingane ezilusa imbuzi)?* 4-6 years………. 7-9 years…….. 10-13 years………...
B6. What breed of goats do you keep (*Hlobo luni lwezimbuzi enizifuyayo*)? 1. Nguni………. 2.Boer……….. 3. Mixed *(Zixubile*)………….

SECTION C: GOAT FEEDING AND MANAGEMENT PRACTICES (*Indlela ezidlangayo imbuzinanokunakekelwa kwazo)*

C1. What type of feeding system do you use (*Iyiphi indlela enizipha ngayo ukudla*)? 1. Herding (*Ukwelusa*)………. 2.Paddock (Amadlelo ahlukanisiwe) ……… 3.Stalling*(Isibaya esincane*)………. 4.Free grazing (Emadlelweni)……… 5.Tethering *(Ziyaboshwa*)………. 6.Other (*Okunye*) (specify)……………………………………………..

C2. If you tether your goats, where do you tether (*Uma uzibopha ziboshelwa kuphi)?* 1. Near the homestead *(Eduze* nasekhaya)……2. In the grazing areas *(Emadlelweni*)……….. 3. Anywhere (*Noma yikephi*)…… 4. Other (specify) *(Kwenye indawo*)……………
C3. Do you provide supplementary feeding for your goats (*Ngabe uyazinikeza okunye ukudla ngaphezulu*) 1.Yes *(Yebo*)…… 2.No *(Cha*)……
C4. If yes, what feed do you use to supplement your goats *(Uma uzinikeza ukudla okungaphezulu luhlobo lunilokudla ezikudlayo*)? …….. 1. Pasture/Veld (*emadlelweni)*……..2.Crop residues *(Izitsalelazezitshalo*)……..3.Conserved feed (Ukudla okugciniwe)……..4.Bought-in feed (*Ukudla okuthengiwe*)………. 5.Other *(Okunye*)……………..
C5. Which class of goats do you supplement (*Hlobo luni lwezimbuzi enilunika ukudla okungaphezulu*)?

Class of goat	Does *(iMbuzi yesifazane*)	Bucks *(Imbuzi yesilisa*)	Kids (*Amazinyane)*
Tick			

C6. In which season do you supplement *(Iyiphi inkathi enizinika ngayo ukudla okuphezulu*)? 1. Hot wet(*Ntwasahlobo)* ……2.Cool dry*(ebusika)* ……3. Hot dry*(Inkwindla*)…….
C7. Why do you supplement your goats (*Yingani nizinika lokudla okuphezulu*)? (Tick one or more & Rank)

Does (iMbuzi yesifazane)			**Kids** (Amazinyane)		
Reason (*Isizathu)*	**Tick (*Imkhaza)***	**Rank *(Hlela)***	**Reason *(Isizathu)***	**Tick (*Khetha*)**	**Rank (*Hlela*)**
For lactation *(Ngexa yokuphuma kobisi*)			For improved growth		
To improve body condition *(Ukuthuthukisa umzimba wazo*)			To improve body condition (*Ukuthuthukisa umzimba wazo)*		
To prevent predation *(Ukuzivikela kumaketshane*)			To prevent predation (*Ukuzivikela kumaketshane*)		
To improve fertility (*Ukuthuthukisa izinga lokukhiqiza*)					
Other (specify) *(Okunye*)			Other (specify) *(Okunye)*		

C8. How often do you kraal your goats (*Uzifaka isikhathi esingakanani esibayeni Imbuzi zakho)?* 1. Every day (*Njalo)*…..2. Once a week *(Kanye ngesonto*)……3. Any day we want (*Ngasosonke iskhathi umaufuna)*……. 4.Other (specify)…………
C9. Rank where do your goats usually graze in each season. *(Ngabe zidlaphi izimbuzi zakho ngokushitshakwenkathi)*

	Season (Inkathi)					
Grazing area	Hot wet (*Ntwasahlobo*)	Rank *(Hlela*)	Hot dry *(Inkwindla*)	Rank *(Hlela)*	Cooldry *(ebusika)*	Rank *(Hlela*)
Mountains & hills (*Entabeni nase maqgumeni*)						
Dense vegetation						
Along water sources (*Eduze nemifula)*						
Open spaces (*Endaweni evulekile)*						

C10. What time do you open the kraal for the goats to go graze *(Sikhathi sini enivulela ngaso izimbuzi*)? 1. Early morning (*Ekuseni)* 2.Mid-morning (*Ntatha kusa*).…… 3.Noon *(Phakathi nemini)*.…... 4.Afternoon *(Ntambama*)…….5. Other *(Okunye*) (specify)……….
C11. What time do you close them in the kraal (*Nizivalela nini esibayeni*)? 1. Sunset *(Ukushonakwelanga*)…….. 2. After sunset *(Ngale kokushona kwelanga*)…….
C12. In which season does kidding occur *(Ngabe iyiphi inkathi lapho ezi zala khona*)? 1. Hot wet……2.Cool dry……3. Hot dry…….
C13. Where do your goats give birth *(Zizalela kuphi imbuzi*)? 1. Around homestead *(Eduze nasekhaya*)……… 2.In the veld *(Emadlelweni*)…………….
C14. How often do you count your goat flock *(Uzibala kangaki izimbuzi zakho*)? 1. Everyday *(Njalo*)……2. After every two days *(Udlulisa izinsuku ezimbili*)………3.Once a week *(Kanye ngesento*)……..4. Other (*Okunye)* (specify)………

C15. Do adult goats and kids graze together (*Ngabe ezidala namazinyane kudla ndawonye*)? 1. Yes *(Yebo*)……..2.No (*Cha)*……
C16. If no to **C15**, why do they not graze together *(Yini zingadli ndawonye)?* (Tick as many as possible & Rank)

Reason *(Isizathu*)	**Tick *(Amakhizane*)**	**Rank *(Hlela)***
They will be lost *(Zizolahleka*)		
They can't walk long distances *(Azikwazi ukuhamba indawo ende)*		
To avoid predation (*Ukuzivikela kumakentshane)*		
Other (specify)		

C17. What do you do to kids when goats are grazing (*Nenzani kumazinyane uma izimbuzi zidla)?* 1. They graze alone *(Zidla zodwa*)…….2.They are housed *(Ziyavalelwa*)…….
C18. If they graze alone, where do they go to graze (*Uma zidla zodwa zidlela ngakephi*)? 1. Near the homestead *(Eduzane nasekhaya*)……2. Anywhere *(Noma yikephi*)………3. Other (*Kwenye indawo*)………………….
C19. At what age do you allow kids to go together with the adults *(Ngabe inini lapho enivuma khona ukuthiamazinyane ahambe nezimbuzi ezidala*)? 1. 0-2 months……. 2. 3-4 months………4. 5-6 months………5. >6 months………….
C20. How many and which class of goats were lost in the last 12 months?*(Ngabe zingaki, naluphi uhlobo oluke* lalahleka ezinyangeni ezidlule)

Class of goat	Does (*Isifazane*)	Bucks *(Isilisa)*	Male kids (*Ingane yesilisa)*	Female kids (*Ingane yesifazane*)
Number				

C21. What were the causes of losses? (Yini imbangela yokulahlekelwa) (Tick one or more & Rank)

Cause of loss	**Tick (*Amakhizane)***	**Rank *(Hlela)***
Diseases (*Izifo)*		
Worms (*Iminyundu)*		
External parasites (*Amakhizane*)		
Predation (*Amakentshane*)		
Theft (*Ziyetshiwa)*		
Accidents (*Izingozi)*		
Harsh weather (*Isimo seZulu*)		
Do not know (*Awazi)*		

C22. Where does predation normally occur? (*Ikephi lapho amakentshane adla khona izimbuzi*)

	Veld (*Emadlelweni)*	Kraal *(Esibayeni*)	Drinking areas (*Endaweni yokuphuzela*)	Other (specify)
Rank *(Hlela)*				

C. Is the kraal raised or on ground *(Ngabe isibaya siphatsi or phezulu*) 1.Raised (*Phezulu*)……. 2. On ground *(Phansi*)…….
C23. How did you know that your goats had been attacked by predators (*Waze kanjani ukthi izimbuzi zakho zidliweamaketshane*)? 1. Saw animal remains *(Izitsalela zezilwane*)........ 2. Animals were wounded *(Izilwanebezinezibazi)*………. 3.Couldn't account for all the goats (Asikwazanga ukuchaza ukthi kwenzakalani kwezinye izimbuzi)…………. 4.Heard goat cry from attack at night (*Ngezazikhala izimbuzi ebusuku*)………….. 5. Other (*Okunye)*……………
C24. Which goat predators do you know of in your area and in which seasons do they usually attack?(Tick one or more & Rank) (*Iyaphi amaketshane eniwaziyo endaweni futhi ingayiphi inkathi lapho khona zihlasela*)

	Season (Inkathi)					
Predator	Hot wet (*Ntwasahlobo)*	Rank *(Hlela*)	Hot dry *(Inkwindla*)	Rank *(Hlela*)	Cooldry *(ebusika*)	Rank *(Hlela)*
Wild dogs *(Zinja zasedle)*						
Jackals (*Ojakalase)*						
Wild leopards (*Igwe yasemaphandleni*)						
Caracal						

Birds/ vultures (*Amaqe)*						
Snakes (*Izinyoka)*						
Other (specify)						

C25. Which class of goats is usually targeted by the predators you named above? (*Yiluphi uhlobo lwezimbuzi olujwayele ukudliwa amakentshane)*

Class of goat (*Uhlobo lwezimbuzi)*	Bucks *(Impongo*)	Does *(Nsikazi)*	Male kids (*Ijongosi)*	Female kids
Tick *(Khetha)*				
Rank (*Hlela)*				

C26. Which traits are important for goats to reduce predator effects (*Iziphi izindlela ezisetshenziswa izimbuzi ukuvikela ukungadliwa ama kentsane)?*

Trait	Mothering ability (*Zivikelwa omama bazo*)	Aggressiveness (*Ngabe ziyazilwela*)	Body size (*Zisebenzisa ububanzi bomzimba wazo)*	Other (*Okunye)*
Tick *(Khetha*)				
Rank *(Hlela)*				

C27. What strategies do you use to control predation of goats? (Tick as many as possible and rank most important) *(Iziphi izidlela enizisebenzisayo sokumelana namakentshane)*

Control method	Trapping (*Ukusebenzisa uzoxaka*)	Hunting (*Ukuzingela)*	Use of chemical toxicants *(Ukusetshenziswa kwezinto sodokotela)*	Herding (*Ukuzixosha)*	Night penning *(Ukuzibiyela ebsuku*)	Guard dogs (Ukusebenzisa *izinja)*	Other
Tick (Khetha)							
Rank (Hlela)							

C28. What did you do after the attack *(Wenza najni emva kokuthi zidliwe amakentshane izimbuzi zakho*)? 1. Change husbandry practices *(Washitsha indlela enizigcina ngayo*)………..2. Nothing (*akukho*)………….3. Other *(Okunye*)……

C29. Is predation a huge challenge for you (*Yingabe amakentshane aletha inking enkulu*)? 1. Yes *(Yebo)…………….* 2.No *(Cha*)…………

C30. Which of your livestock species are more susceptible to predation (*Iziphi izilwane zakho ezidliwaamakentshane)?*

Livestock species	**Tick (*Khetha)***	**Rank (*Hlela)***
Goats (*Izimbuzi)*		
Cattle *(Inkomo)*		
Sheep *(Izimvu)*		
Chickens *(Izinkukhu*)		
Donkeys (*Izimbongolo*)		

C31. What are the factors that increases vulnerability of kids to predation (*Yiziphi izinto ezikhuphula izinga lokuthiamakentsane adle amazinyane*)

Factor	Gender (*Ubulili*)	Breed (*Uhlobo*)	Age *(Iminyaka*)	Season *(Inkathi)*	BCS (*Iziga lomzimba*)	Health status *(Impilo)*	Other (*Okunye*)
Tick *(Khetha*)							
Rank *(Hlela)*							

Thank you! (*Siyabonga*)

APPENDIX 2: Approved Ethics Clearance

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

28 January 2016

Ms Charity Durawo 211543953
School of Agriculture, Earth and Environmental Sciences
Pietermaritzburg Campus

Dear Ms Durawo

Protocol reference number: HSS/1861/015M
Project title: Characterization of determinants of predation of goats among smallholder farmers

Full Approval – Expedited Application

In response to your application received 17 December 2015, the Humanities & Social Sciences Research Ethics Committee has considered the abovementioned application and the protocol has been granted **FULL APPROVAL.**

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment /modification prior to its implementation. In case you have further queries, please quote the above reference number.

PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.

The ethical clearance certificate is only valid for a period of 3 years from the date of issue. Thereafter Recertification must be applied for on an annual basis.

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

Yours faithfully

....

Dr Shenuka Singh (Chair)
Humanitities & Social Scinces Research Ethics Committee

/pm

Cc Supervisor: Prof m Chimonyo
Cc Academic Leader Research: Professor Onisimo Mutanga
Cc School Administrator: Ms Marsha Manjoo

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