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Wild herbivore vigilance and grass regrowth under livestock grazing in Ngorongoro, Tanzania

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WILD HERBIVORE VIGILANCE AND GRASS REGROWTH UNDER LIVESTOCK GRAZING IN NGORONGORO, TANZANIA

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A Dissertation Submitted in Partial Fulfilment of the Requirements for the Degree of Master's in Life Sciences of the Nelson Mandela African Institution of Science and Technology

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ABSTRACT

Pastoralists consider wildlife the biggest competitors over resources for livestock while little is known about the potentially positive or negative behavioural effects that livestock can have on wildlife when foraging together. In the Ngorongoro Conservation Area (NCA), wildlife has been grazing together with livestock for centuries but knowledge on how this impacts wildlife feeding behaviour or grazing intensity on grass regrowth is scarce. Behavioural observations of wildlife and livestock species were conducted from a vehicle driving along transects within NCA. Four groups of wild herbivore species including plains Zebra *(Equus burchelli)*, Thomson's gazelle (*Gazella thomsonii)*, Grant's gazelle (*Gazella granti)* and Wildebeest (*Connochaetes taurinus)* were observed, grazing either with or without livestock species, i.e., cattle (*Bos taurus)*, goats (*Capra aegagrus hircus*) and sheep (*Ovis aries)*, over two different seasons. Out of 158 groups in total, on average 48 herds without and 31 herds mixed with livestock were recorded. Moving cages were used to assess the effect of different wildlife and livestock grazing pressure on grass regrowth (height and coverage). Results show that wildlife decreased their foraging time while they increased vigilance behaviour when grazing together with livestock, particularly when herders were present, compared to grazing without livestock. The grass regrowth potential decreased with increasing grazing intensity. Therefore, in contrast to foraging facilitation theory we conclude that the presence of livestock does not seem to be beneficial for wild herbivores and that wildlife protection area, in which pastoralists cannot lead their cattle, are important for a sustainable management of the NCA.

DECLARATION

I, Angelamercy Baltazary do hereby declare to the senate of Nelson Mandela African Institution of Science and Technology that this dissertation is my own original work and that it has neither been submitted nor being concurrently submitted for degree award in any other institution.

.... 23.4.2019 ....

Angelamercy Baltazary **Date**

Name and signature of Candidate

The above declaration is confirmed by

.... 23/4/19 ....

Prof. Anna C. Treydte **Date**

Name and signature of supervisor

.... 23/4/2019 ....

Prof. Eivin Røskaft **Date**

Name and signature of supervisor

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CERTIFICATION

The undersigned certify that they have read the dissertation titled "Wild Herbivores Vigilance and Grass Regrowth Under Livestock Grazing in Ngorongoro, Tanzania" and recommended for examination in fulfillment of the requirement for the degree of Master's in Life Sciences of the Nelson Mandela African Institution of Science and Technology (NM-AIST).

Treydte .... 23/4/19 ....

Prof. Anna C. Treydte **Date**

Name and signature of supervisor

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Prof. Eivin Røskaft **Date**

Name and signature of supervisor

DEDICATION

This work is dedicated to my loving husband Mr. Bashange, my daughter Charity, my sons, Ethan and Ian and my parents, Mr. and Mrs. Baruti. Thank you for your support and patience during my absence.

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First of all I would like to thank the almighty God for His guidance toward the accomplishment of this work, without Him this work would have not been possible.

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May Almighty God Bless you abundantly!

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LIST OF ABBREVIATIONS AND SYMBOLS

%	-	Percentage
cm	-	Centimeter
GPS	-	Global Positioning System
LGMP	-	Livestock Grazing Management Plan
m	-	Meter
Masl	-	Meter above Sea Level
NCAA	-	Ngorongoro Conservation Area Authority
NCA	-	Ngorongoro Conservation Area
PRA	-	Participatory Rural Appraisal
SE	-	Standard Error
UNESCO	-	United Nations Educational, Scientific and Cultural

CHAPTER ONE

INTRODUCTION

1.1 Background

Rangelands across the world have been a home to millions of pastoral people with their livestock interacting with wildlife over the last centuries (Prins, 2000; Sitters *et al.,* 2009; Atickem and Loe, 2013; Ogutu, 2016; Tyrrell *et al.*, 2017). Today, more than 90% of the mammal biomass on earth consists of humans and their livestock, and this proportion is still increasing (Thornton, 2010; Bar-on *et al.,* 2018). Rangelands have created a complex set of conservation challenges, for example in African savannahs, wild herbivores are commonly interacting with livestock (Ogutu *et al*., 2011; Riginos, 2012; Lind, 2013 and Veblen, 2016).

The presence of livestock in rangelands can affect native wild ungulate use of the grasses when the two groups of ungulates are using the same forage (Ruckstuhl, 2006). Furthermore, overlap it the use of forage can lead to behavioural changes in wildlife by altering their activity budgets (Kie, 1995; Ruckstuhl, 2006). Also, wild herbivores have often been regarded as competitors to livestock by altering their behaviours, and reducing their productivity (Zimmermann, 2009; Atickem, 2010; Riginos, 2012) and foraging success (Chaikina and Ruckstuhl, 2006).

Wildlife livestock interaction is a complex phenomenon that results into competition for grazing areas and water (Prins, 2000; Atickem and Loe, 2013; Ogutu, 2016). However, pastoralists whose main goal is to maximize livestock production often see wild herbivores as direct competitors (Bourn, 1999), while wildlife managers blame livestock for the large declines of wildlife population hence management decisions are often made based on this assumption, and usually livestock excluded for the benefit of wildlife though, the tradeoff between the two is more complex (Vavra, 2005). Yet, wild herbivores and livestock depend on the same grazing resources, thus need to be properly managed to ensure they coexist in a sustainable and profitable manner (Lyons and Wright, 2000; Sitters, 2009).

The spatial foraging decisions by herbivores are strongly influenced by dietary preferences, which result in suppression of preferred species when grazing pressure is high (Bailey, 1996). Furthermore, according to Augustine and McNaughton (1998), grazing may change the relative quantities of grasses and forbs available for wildlife, depending on the livestock species used. Despite of negative effects grazing may have, it can also improve quality of grass by eliminating old forage and stimulating new growth and livestock can increase wildlife's access to forage resources (Odadi, 2011; Butt and Turner, 2012; Rubenstein, 2016; Hancock, 2017). Also study by Scheiband and Cody (2003) found that the presence of other species can reduce vigilant behaviour sensu the 'many eyes effect' and dilution. Hence, we expected that the presence of livestock in rangelands together with wild herbivores may reduce the time that wild herbivores spends to be vigilant instead increase time of foraging.

Many studies have been conducted on the vigilance behaviour that is in response to the presence of predators on foraging grounds. While most studies investigated foraging competition between wild and domestic herbivores (Atickem and Loe, 2013; Patton *et al.,* 2007; Leeuw, 2001) only few scientists have investigated how the presence of livestock affects vigilance when foraging together with wild herbivores. In the context of grazing, grass productivity may be high at a low or moderate level of grazing than with either grazing exclusion or high grazing. Hence, grazing can stimulate productivity, with the maximum stimulation at intermediate grazing intensities.

Also studies on grass regrowth in response to grazing have been studied in other areas (Holechek, 1998; Lyons and Wright, 2000; Atickem and Loe, 2013) but in Ngorongoro rangelands, there has been no study that determined grass regrowth under different grazing intensities. Therefore, study on the grazing intensity on grass regrowth addressed the gap that exist, particularly on development of a livestock grazing management plan, which will help to reduce the extreme grazing in the rangelands.

1.2 Problem statement

Livestock herds are increasing in numbers, particularly in eastern Africa while many wildlife species are in decline, also in Tanzania (Ogutu, 2016). Consecutively, livestock herds increasingly graze directly adjacent to protected areas (Butt and Turner, 2012) and, therefore, overlap with wildlife. This can lead to competition as a result of the physical presence of livestock on shared rangelands, or indirectly through changes they stimulate in the vegetation (Prins, 2000; Odadi, 2012). However, many studies have been conducted on the vigilance behaviour that is in response to predators present on foraging grounds, but few scientists have included the presence of livestock and how this affects vigilance when foraging together with wild herbivores. As Ngorongoro Conservation Area is an example of wild and livestock grazing together, this phenomenon must be understood to achieve a sustainable land use management plan in the long run in Ngorongoro conservation area and in other protected areas.

Therefore, this study provides information whether wild herbivores change their behavioural activities (grazing, vigilance) when livestock are present on their foraging grounds. Also in the Ngorongoro Conservation Area (NCA), Tanzania, where wildlife interacts with livestock and people, there has been limited information known on the influence of livestock on grass regeneration. While the livestock numbers are still rising (Thornton, 2010; Alkemade, 2013; Ogutu, 2016) in this area, limited information is known how this increasing pressure affect wildlife species that jointly use resources with livestock in this area. Therefore, studying the effect of grazing intensity on grass regrowth gave information on development of a livestock grazing management plan, which is needed in NCA and other protected areas in Tanzania.

1.3 Objectives

1.3.1 General objective

The main objective of this study was to understand whether wildlife benefits from foraging in association with livestock in terms of time devoted to feeding. Further, we aimed at identifying an optimal grazing frequency under which the herbaceous layer is most productive.

1.3.2 Specific objectives

(i) To assess whether four selected wildlife species are more or less vigilant when grazing together with or in the vicinity of livestock

(ii) To asses grass regrowth under different grazing intensities in Ngorongoro rangelands

1.4 Research hypotheses

Hypothes 1: The time wildlife spend being vigilant will be higher when foraging without livestock than in the vicinity of livestock.

Hypothes 2: Grass regrowth is higher in moderately grazed areas than in highly grazed areas.

1.5 Significance of the study

Wildlife populations in eastern Africa generally are in decline due to decreasing forage resources (Ogutu, 2016). Often wildlife and livestock overlap which lead to competition

(Prins, 2000). Some wildlife species are generally observed together with livestock such as Grevy's zebra (*Equus grevyi*), plains Zebra (*Equus burchelli*), Eland (*Tragelaphus oryx*), Wildebeest (*Connochaetes taurinus*) African buffalo (*Syncerus caffer*), Hartebeest (*Acelaphus buselaphus*), Oryx (Oryx gazelle), Grant's gazelle (*Gazella granti*), Thomson's gazelle (*Gazella thomsonii*) as well as megaherbivores such as giraffe (*Giraffa Camelopardalis*) and African elephant (*Loxodonta africana*) (Odadi, 2012).

As overgrazing in communal lands by livestock is a large problem across eastern Africa (Dregne, 1991; Homewood and Rodgers, 1991) knowing the impact livestock grazing has on the vegetation as well as on wildlife communities will contribute to both wildlife and livestock production as well as wellbeing in NCA, where humans and wildlife have lived together for centuries. Baseline data obtained during the study will be used to develop a proper livestock grazing management plan (LGMP) to improve livestock production, sustainable grazing, and wildlife habitat enhancement in the Ngorongoro rangelands.

CHAPTER TWO

LITERATURE REVIEW

2.1 Wildlife-livestock Interaction

Wildlife interacts with livestock in various ways (Young *et al.*, 2005). Often, transhumance pastoralists share resources with wildlife species in rangelands, many of which are close to protected areas (Osofsky, 2005). The value and nature of interaction is influenced by several interacting factors such as occupation and education of the local communities (Dickman, 2010). However, one of the most common and major problems that protected areas are facing is wildlife-livestock interaction, in terms of predation and foraging (Maleko, 2012).

In African savannahs and many other rangelands around the world, wild herbivores are replaced by increasing livestock populations (Riginos, 2012). The positive effect of livestock - wildlife interactions can be in terms of facilitation of forage accessibility and improvement of quality or facilitation through habitat modification (Prins, 2000; Augustine, 2009). In Ngorongoro, there has been no study that determined whether the livestock grazing could enhance forage production under optimal conditions. A sound livestock management grazing plan is needed to use livestock grazing for maintaining good wildlife habitat in Ngorongoro rangelands.

In addition, the study by Ogutu (2016) shows that forage availability and vegetation cover is clearly higher with increasingly lower levels of livestock grazing. Furthermore, wildlife has often been regarded as competitors to livestock by reducing livestock productivity and altering livestock behaviours (Riginos, 2012). However, livestock may also change the behaviour of wildlife, particularly herbivores. This study aims at quantifying the effect of livestock on wildlife species, especially on wildlife feeding behaviour. The information obtained will fill the knowledge gap on whether livestock may change the foraging behaviour as well as vigilance behaviour of wildlife, when foraging together.

2.2 Vigilance and foraging behaviour

Vigilance behaviour of wild ungulates generally decreases time available for foraging (Pe´riquet, 2010). In this study, the animal was considered vigilant when the head is raised above shoulder level and when it appeared appears to be looking around (Pe´riquet, 2010). Although group foraging can be beneficial, it is not known yet whether the time spent for vigilance by wildlife decrease when foraging together with livestock and wildlife when forage together the time spent for vigilance by wildlife decrease.

According to Owen-smith (2002), the proportion of time spent feeding during foraging among wild ungulates can last up to one hour or more, typically in 80–90% of the cases for grazers, and 65–80% for browsers. About 5–15% of foraging time is diverted into standing vigilant or other non-foraging activities, leaving 7–20% of their time moving between foraging sites (Owen-smith, 2002). Therefore, we expected that the time spent for vigilance should be less compared to the time spent on foraging and the former would increase when foraging without livestock. The aim of this study was to examine the presence of livestock on vigilance behaviour of wildlife association and whether grazing intensity had effect on grass regrowth.

2.3 Grass regrowth

Grazing intensities have effects on grass productivity, i.e., high grazing intensity decreases but low grazing intensity increases grass regrowth in rangelands. Grass that is harvested often has more photosynthetic tissue removed and little opportunity for regrowth (Trlica, 1992). These grasses may enter a period when soil moisture, temperature and growth stage limit regrowth and little leaf area remains for photosynthesis (Trlica, 1992; Skinner, 1999). Thus, their ability to replace reserves or produce additional new tillers is restricted (Jewiss, 1972). If grazing removes grass, regrowth rate is slowed and root growth affected by heavy defoliation (Ferraro and Oesterheld, 2002), which makes grass roots not penetrate to depths where adequate moisture exists (Mulholland and Fullen, 1991). Therefore, high livestock grazing affect regrowth of grasses. In order to increase forage production in Ngorongoro rangelands livestock grazing should be low or moderate according to intermediate theory (Wilkinson, 1999).

Grazing by livestock also improves quality of vegetation by eliminating old forage and stimulating new growth by providing manure through defecation (Rubenstein, 2016; Hancock, 2017). However, livestock grazing increases herbaceous diversity during rainy season but have no benefit during drought (Lyons and Wright, 2000). The competition caused by drought or extreme grazing can be reduced with a proper livestock grazing management plan that allows each pasture to rest during the growing season at least once over a period of several years (Baxter, 2009), and stocking rate should be used to manage wildlife habitat.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study area description

This study was conducted in the Ngorongoro Conservation Area (NCA) in northern Tanzania (3°14'29.56"S and 35°29'16"E (Fig. 1). Ngorongoro Conservation Area was selected for this study due to the fact that it is a multiple land use area for wildlife, people and their livestock and a UNESCO World Heritage Site (Melita, 2014). The presence of pastoralists in NCA, who have coexisted with wildlife in this area for more than 200 years, has led to year-long interactions between humans, wildlife and livestock (Homewood and Rodgers, 1991).

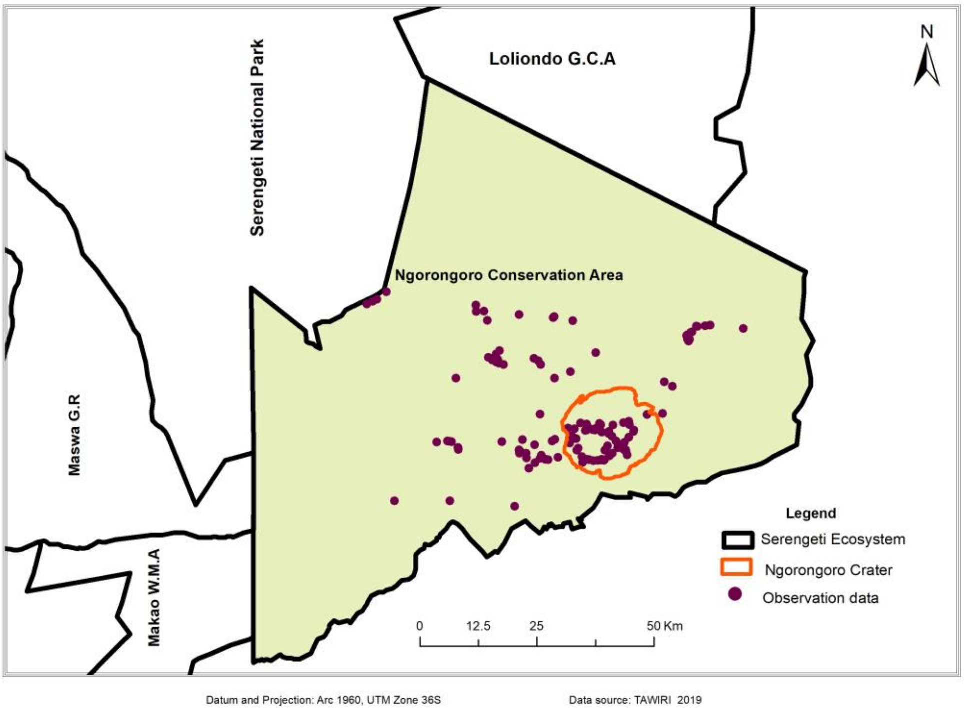

Figure 1: Study area map. Purple circles indicate locations of observations. The red circled area indicates the crater area, which is protected for wildlife only and does not allow any human activity except for tourism.

The main economic activities in the Ngorongoro Conservation Area are livestock keeping and tourism (Melita, 2014). The livestock species include cattle (*Bos taurus)*, goat (*Capra* aegagrus *hircus)*, sheep (*Ovis aries)* and donkeys (*Equus asinus)*. Dominant wildlife species present in NCA include plains Zebra (*Equus burchelli*), Eland (*Tragelaphus oryx*), Wildebeest (*Connochaetes taurinus*), African buffalo (*Syncerus caffer*), Grant's gazelle (*Gazella granti*), Thomson's gazelle (*Gazella thomsonii*), as well as megaherbivores such as giraffe (*Giraffa* *camelopardalis*) and African elephant (*Loxodonta africana*) (Odadi, 2012). All of these species have been observed to sometimes associate with livestock in Kenyan rangelands (Odadi, 2012). The Ngorongoro Crater hosts the world's largest volcanic caldera and is 260 km^2 large, ranging between 1700 masl and 2235 masl (Gaidzik, 2011). The climatic zones vary from semi-arid to montane forests, and annual precipitation ranges from 500 mm to 1700 mm, which leads to temperature fluctuations between 2°C and 35°C (Masao *et al.,* 2015). Average annual temperatures vary between 14°C to 25°C, the crater floor part has higher temperatures compared to the rim (Masao, 2015). Also the presence of grassland and water (lakes and rivers) used by wild herbivores has made the area very latent.

3.2 Research design

The research design of this study was cross-sectional whereby data were collected at two seasons. It included direct observation on wildlife and livestock groupings, establishing and monitoring moving cages for vegetation assessment under varying grazing treatments. Participatory Rural Appraisal (PRA) was also applied.

3.3 Data collection methods

3.3.1 Assessment of vigilance behaviour

Behavioural observations of wild and domestic mammalian herbivore species were conducted from a vehicle driving along transects within NCA. Transects were driven using a four-wheel drive vehicle at 10 km/h (Tyrrell, 2017). Occasionally, the observer was sitting on the roof of the car scanning for animals. Once a wildlife or wildlife with livestock group was sighted the vehicle was stopped and sighting information was recorded. We recorded species and number of animals in the group, and whether livestock was observed or not with the wild animals. Groups were recorded between May to August 2018, i.e., the end of the wet until the middle of the dry season to cover potential differences in behaviour across seasons.

During direct observations, binoculars and camera-recordings were used as well as a stop watch. Distance was recorded using a laser rangefinder (Leica) and coordinates taken by a hand held GPS (eTrex). In order to avoid pseudo-replication we avoided recording similar groups and species in the vicinity of the first recorded group (Buckland, 2001). Any group (> 5 individuals) of wild herbivores, either together with or without the presences of livestock, was observed and their behaviour recorded. Behaviour was classified as (1) foraging, (2) grooming, (3) resting, (4) ruminating, (5) grooming, (6) moving, (7) looking with head up (vigilance) (Hariohay *et al.*, 2018). However, in the further analyses we tested only vigilance and foraging behaviour. The focal animal sampling method was used (Altmann, 1974).

Four species of wild herbivores, that have been reported elsewhere to be seen frequently together with livestock (Odadi, 2011), were selected for observations. These included plains Zebra, Thomson's gazelle, Grant's gazelle and Wildebeest, while the livestock species included cattle, goats and sheep. Only adult individuals were observed and females with calves and juveniles were avoided because they might be more vigilant by default (Shorrocks and Cokayne, 2005). The distances from the observer to a group ranged from 50 m to 100 m, which was according to recommendations by Kluever (2008) and Robinette and Ha (2001). However, in the Ngorongoro crater, i.e., the core protection zones with wildlife species only, these distances were less than 50 m. Whenever a group was encountered, the car stopped, GPS point was taken, 3 minutes was given for habituation and then the recording started.

Wild herbivore or joint livestock or wild herbivore groups were defined as aggregation of animals at a nearest neighbour distance of 100 m from a randomly selected focal animal (Kluever, 2008). Therefore, individuals were supposed to be within 100 m from the focal animal to be considered as a member of a group. Only adults were observed, sex (male, female) group type (with or without livestock) and presence or absence of herders. An animal was considered vigilant when the head was raised above the shoulder level and it appeared to be looking around (Shorrocks and Cokayne, 2005; Pe´riquet, 2010). Observations were taken over a minimum of a 5 minutes period, during which the focal animal's behaviour within a group was recorded every 1 minute (Kluever, 2008), i.e. normally 5 times. The observation periods fell between 0800 and 1800 hours over two months during the wet season and two months during the dry season.

3.3.2 Quantifying grass regrowth

Grass productivity was measured by using the movable-cage method (McNaughton *et al.*, 1996). Sixteen moveable cages were placed in seven villages from four wards. The sites were selected based on grazing intensity, i.e., high grazing and low grazing (Kakinuma and Takatsuki, 2012). Participatory Rural Appraisal method (PRA) was used for identifying locations of different grazing intensities. The resource mapping and trend calendar was used as a tool for PRA (Regm, 2010) in order to acquire more resource information of the area, which helped identify suitable areas for moveable cage setting.

Participatory Rural Appraisal (PRA) was conducted in four wards including Endulen, Nainokanoka, Olbalbal and Ngorongoro. Only villages that were less than 5 km from the crater rim were selected as study sites for cage setup in order to be near the control group (wildlife only). Four cages with a size of 1 m × 1 m were placed on each ward, i.e., two on high grazing intensity and two on low grazing intensity. In close proximity, at 1 m adjacent to each cage, a plot of 1 m x 1 m was left unprotected and allowed to be grazed. Cages were moved after every month over duration of five months from April to August. Regrowth was measured as grass height and cover (Kakinuma and Takatsuki, 2012). For both caged and uncaged plots the height of grass was measured by using a scale ruler while the relative grass cover was visually estimated (Stewart, 2001). The control plots were marked by a metal marker and the coordinates of the area were taken by using GPS.

Participatory Rural Appraisal (PRA) was used to identify locations of different grazing intensity through resource mapping jointly with the Maasai pastoralists. Mapping was done in the presence of pastoralists and different types and locations of grazing areas used were located in two areas of different grazing pressure (high and low grazing pressure, according to Maasai pastoralists guided by a facilitator). About 10-13 elder pastoralists were involved from each ward. In order to avoid bias the names of pastoralists were selected from a village register book but requirement was that the person should have lived in that ward over ten years. Seasons were classified by months, i.e., from March to May was wet season and from June to August was dry season. The highly grazed area was defined as being most preferred by pastoralists during that season for grazing while the area with low grazing pressure was less preferred on that season. At each area, we conducted the grass regrowth study (see above).

3.3.3 Data analysis

The average time spent for vigilance or foraging between the mixed group (wildlife and livestock) and without livestock (wildlife alone) was compared using Kruskal Wallis tests. Grass height and cover in caged and uncaged plots in areas differing in grazing intensity also were analysed using Kruskal Wallis tests. In addition to our analyses on with or without livestock, linear regression analysis was used to analyze the foraging and vigilant time of the four focus wildlife species (Zebra, Wildebeest, Grant Gazelle and Thomson's gazelle) in relation to herder as well as livestock presence in combination with season. Vigilance and foraging time were the dependent variables and then the presence of herder males and herder females was included as independent variables, as well as group type (with or without livestock) and season.We performed statistical data analyses using PAST software and R software 3.3.3 version. Statistical significance was set at $P < 0.05$.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Assessment of vigilance and foraging behaviour

Out of 158 groups recorded, 47 non-mixed groups (without livestock) and 30 mixed groups (with livestock) were observed in the dry season, while, during wet season 49 non -mixed groups and 32 mixed groups were observed. Average group size of wild herbivores with livestock was 41 individuals during the wet and 24 during the dry season. Average group size of livestock was 55 individuals during the wet and 46 during the dry season. The number of focal wild herbivores recorded in groups without livestock was 112 during wet and 81 during the dry season. Wild herbivores recorded in groups with livestock during wet season were 42 focal wild herbivores, while during dry season were 37 focal wild herbivores.

4.1.1 Mean foraging and vigilance time

Outside crater, i.e., outside the protected areas, there were only seven mono-specific wildlife groups observed and, therefore, these herds were not included in statistical analysis. Generally, the mean foraging time was significantly almost twice as high in herds without livestock compared to those with livestock during the wet season (X^2 = 32.53, n = 112, P < 0.001; Fig. 2) while it was only by one-quarter higher in groups without livestock than with livestock during the dry season (X^2 = 26.06, n = 81, P < 0.001; Fig. 2). The mean vigilance time was about twice as high in groups with livestock compared to those without livestock during wet seasons (X^2 = 24.58 n = 112, P < 0.001; Fig. 3) while it was only by one-quarter higher in the crater than outside during dry season (X^2 = 17.62, n = 81, P < 0.001; Fig. 3).

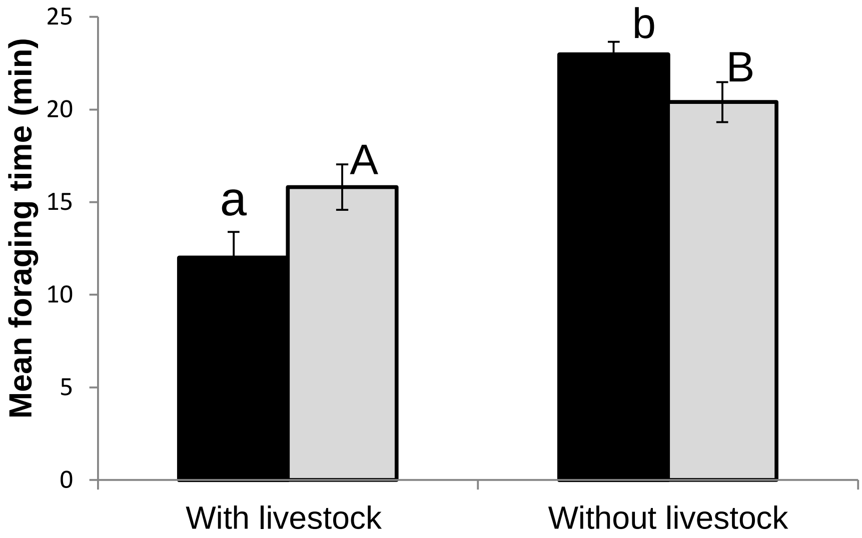

Figure 2: Mean (±SE) foraging time outside and inside the crater, i.e., in mixed herds with livestock and herds without livestock, respectively, during the dry (N=81, grey bars) and wet (N=112, black bars) season.

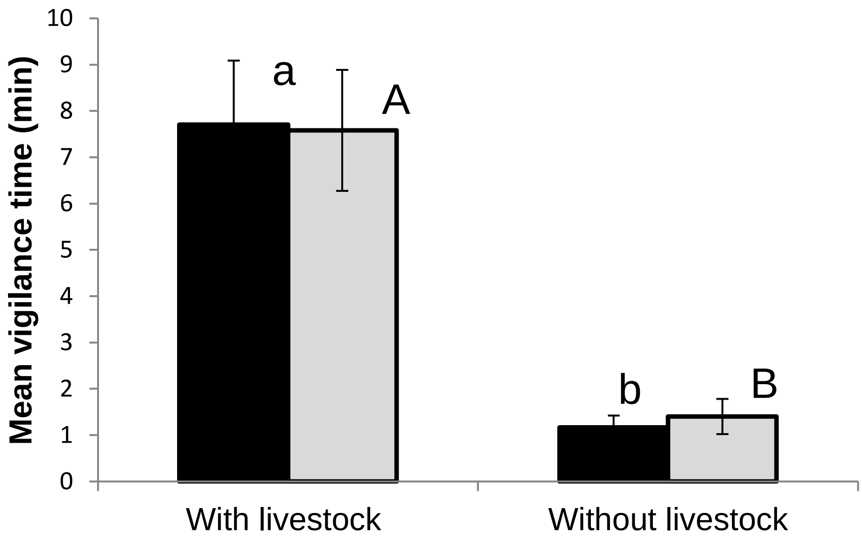

Figure 3: Mean (±SE) vigilance time outside and inside the crater, i.e., in mixed herds with livestock and herds without livestock, respectively, during dry (N=81 grey bar) and wet (N=112 black bars) season.

During the wet and dry season, the proportional foraging time of wild herbivores increased strongly when foraging without livestock but decreased when foraging with livestock, which was also found by Young *et al.* (2005). We also found that foraging and vigilance behaviour differed between species across the areas of different protection status and across season as supported by Dunham (1982). Also, animal species may differ in their time spent foraging or vigilance and other behaviour depending on their nutritional needs and level of perceived risk from predation (Houston, 1993). Many studies have reported changes in vigilance behavior due to variations in cover and interpret this change as an adaptation to an increase in perceived predation risk (Cresswell, 1994; Lazarus and Symonds, 1992; Underwood, 1982). Thus, individuals inhabiting areas where the threat of predation is perceived to be high will likely decrease their foraging time (Lima, 1998). The expectation of this study was that the foraging time would increase when foraging together with livestock because the presence of other species can reduce vigilant behavior *sensu* the 'many eyes effect' and dilution (Scheiband and Cody, 2003). However, our results showed the opposite, highlighting how important protection status of wildlife is for their wellbeing.

4.1.2 Activity budget across seasons in groups with or without livestock

Foraging was a dominant activity during both the wet and dry season when the wild herbivores were not associated with livestock (X^2 = 10.06, P < 0.0001 (Fig. 4c and Fig. 4d). However, when wildlife was associated with livestock the dominant activity was vigilance (X^2 = 12.36, P < 0.0001) (Fig. 4a and Fig. 4b).

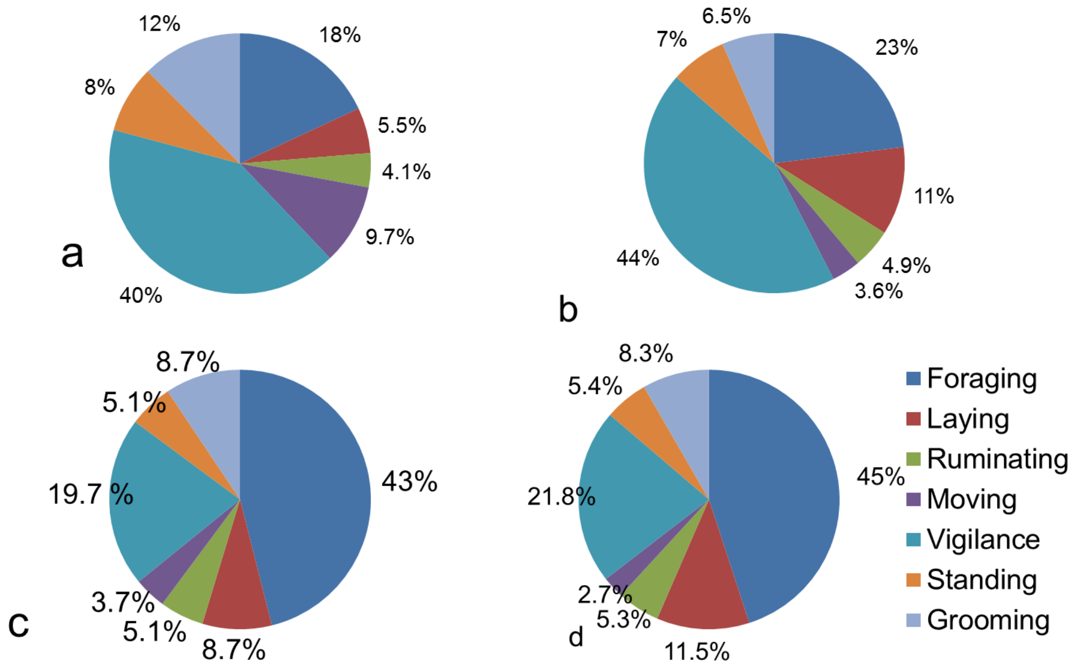

Figure 4: Activity budget in the wet and dry season of herds with livestock (a: wet, b: dry) and without livestock (c: wet, d: dry)

Food acquisition is a primary need for animals to survive, grow and reproduce (Illius, 2002). Our study also found that the dominant activity was foraging in groups without livestock in both seasons in NCA. Other activities including laying down, moving, grooming and standing were minimized during this time. Owen-Smith (2010) also found that the most dominant activity of herbivores was generally feeding. This may have been influenced by the availability of forage and absence of livestock in the crater where the groups without livestock were studied.

Herbivores face daily compromises as to how much time should be spent in each activity, and they should adjust their activity budget according to their individual requirements (Illius, 2002). In our study, the association of wild herbivores and livestock increased the wildlife vigilance behavior in both seasons. This indicates that the presence of livestock may have had a strong influence on how wild herbivores arrange their activity budget (Schieltz and Rubenstein, 2016).

4.1.3 Foraging and vigilance time in groups with or without livestock across seasons.

(i) Wildebeest

Foraging time of wildebeest was significantly higher in groups without livestock than in groups with livestock species during both the wet and dry season (X^2 = 0.559, n = 42, P = 0.01 and X^2 = 5.979, n = 23, P = 0.01, respectively; Fig. 5). While vigilance time of wildebeest was significantly higher in mixed groups with livestock species than in groups without livestock during the wet season (X^2 = 1.684, n = 42, P = 0.01) it was not significantly different during the dry season (X^2 = 0.53, n = 23, P = 0.2; Fig. 6)

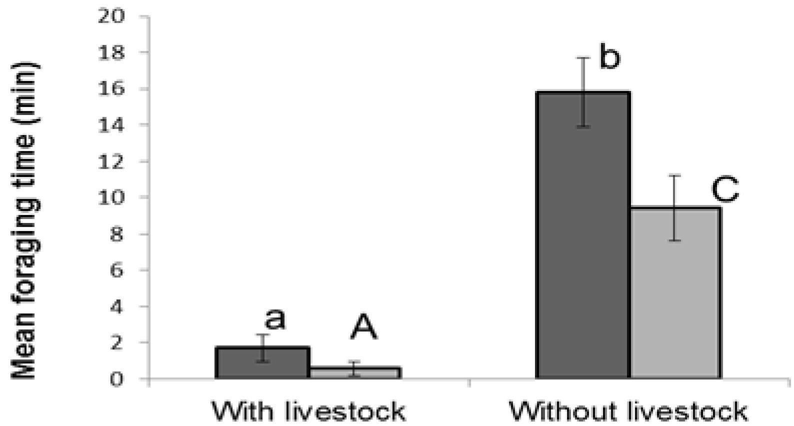

Figure 5: Mean (±SE) foraging time in wildebeest herds with livestock and herds without livestock, respectively, during dry (N=23 grey bars) and wet (N=42 solid grey bars) season.

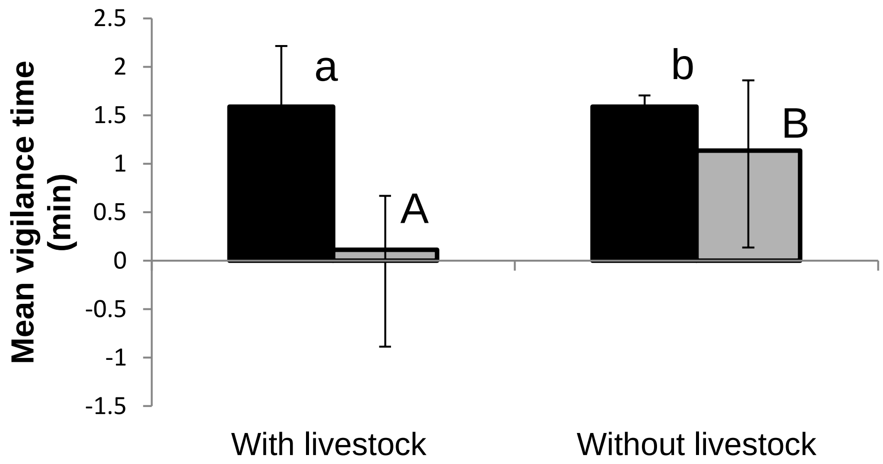

Figure 6: Mean (±SE) vigilance time in wildebeest herds with livestock and herds without livestock, respectively, during dry (N=23 grey bars) and wet (N=42 black bars) season.

(ii) Zebra

Foraging time of Zebra was significantly higher in groups without livestock than in groups including livestock species during the wet season (X^2 = 6.963, n = 53, P < 0.0001) but there was no difference during the dry season (X^2 = 0.827, n = 35, P = 0.344; Fig. 7). Vigilance time of Zebra was slightly higher in groups with livestock than in group without livestock during the wet season (X^2 = 2.842, n = 35, P = 0.028), vigilance time of Zebra did not differ during the dry season (X^2 = 0.9235, n = 53, P = 0.0635; Fig. 8).

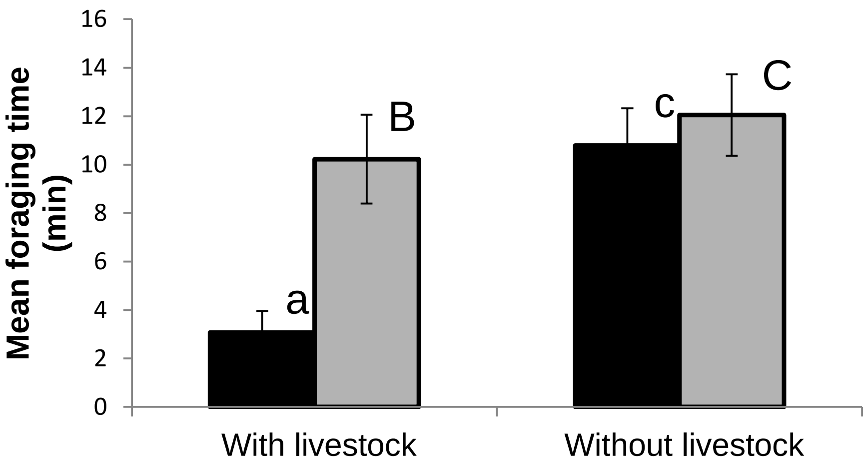

Figure 7: Mean (±SE) foraging time in zebra herds with livestock and herds without livestock, respectively, during dry (N=35 grey bars) and wet (N=53 black bars) season.

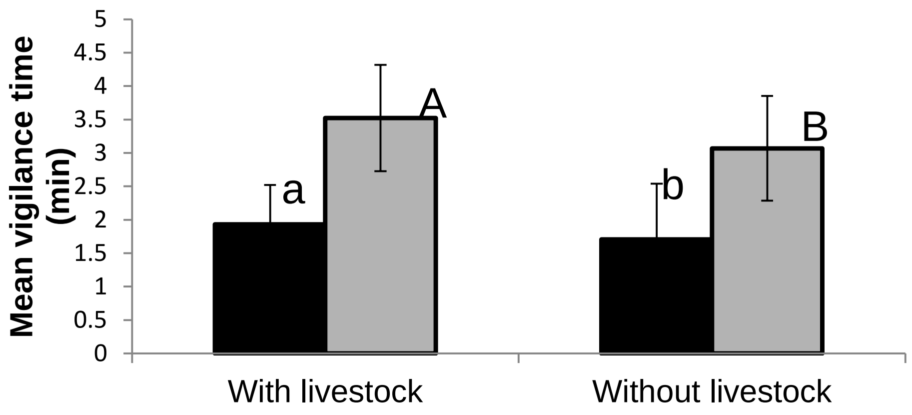

Figure 8: Mean (±SE) vigilance time in zebra herds with livestock and herds without livestock, respectively, during dry (N=35 grey bars) and wet (N=53 black bars) season.

(iii) Grant's Gazelle

Foraging time of Grant's gazelle during the wet and the dry season was significantly higher in groups without livestock than in groups with livestock species. (X^2 = 0.041, n =32, P < 0.0001 and X^2 = 5.01, n = 18, P = 0.1311, respectively; Fig. 9). In contrast, vigilance time of Grant's gazelle was not significantly different between groups with livestock and groups without livestock during wet (X^2 = 0.7761, n = 32, P = 0.0842) or the dry season (X^2 = 0.314, n = 18, P = 0.4015; Fig. 10).

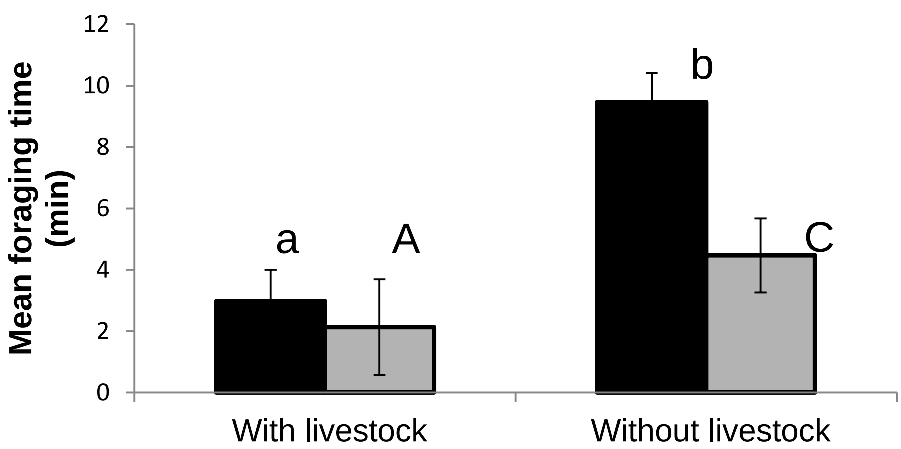

Figure 9: Mean (±SE) foraging time in Grant's gazelle herds with livestock and herds without livestock, respectively, during dry (N=18 grey bars) and wet (N=32 black bars) season.

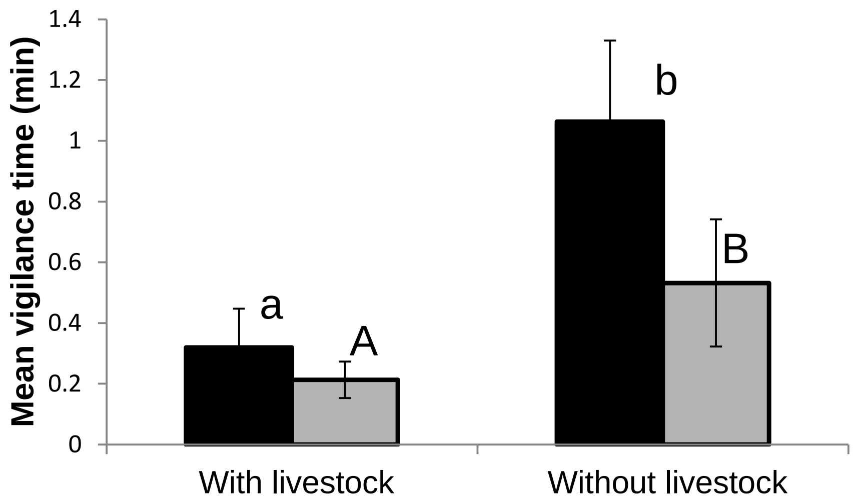

Figure 10: Mean (±SE) vigilance time in Grant's gazelle herds with livestock and herds without livestock, respectively, during dry (N=18 grey bars) and wet (N=32 black bars) season.

(iv) Thomson's Gazelle

Foraging time of Thomson's gazelle during wet and dry season was significantly higher in groups without livestock than in group including livestock species (X^2 = 16.28, n = 45, P < 0.0001 and X^2 = 7.871, n = 24, P < 0.0001, respectively; Fig. 8). Vigilance time of Thomson's gazelle was significantly higher in groups with livestock than group during wet and dry season (X^2 = 3.212, n = 45, P = 0.01) and (X^2 = 3.895, n = 24, P < 0.0001; Fig. 8) respectively.

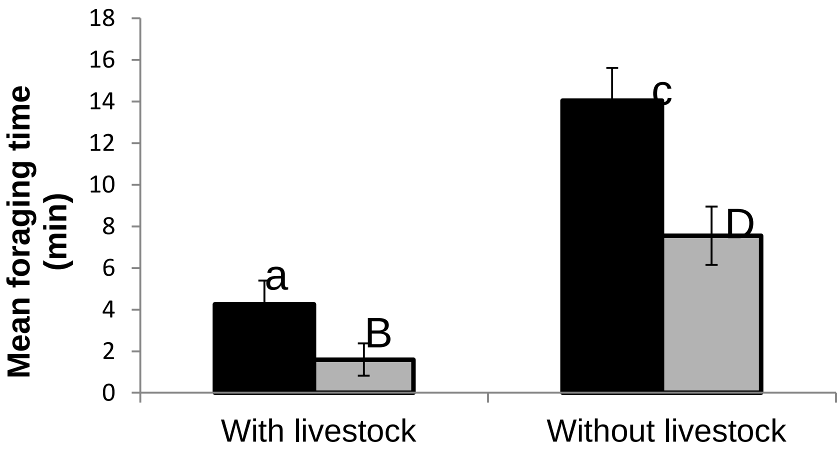

Figure 11: Mean (±SE) foraging time in Thomson's gazelle herds with livestock and herds without livestock, respectively, during dry (N=24 grey bars) and wet (N=45 black bars) season.

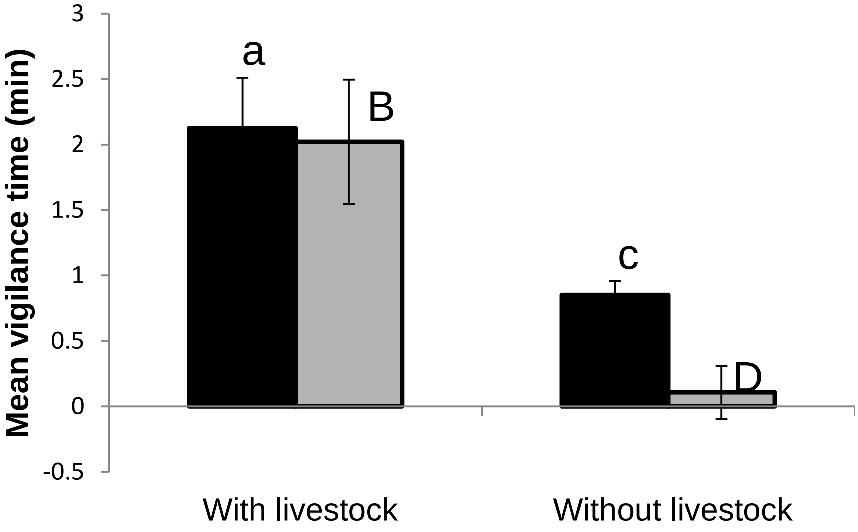

Figure 12: Mean (±SE) vigilance time in Thomson's gazelle herds with livestock and herds without livestock, respectively, during dry (N=24 grey bars) and wet (N=45 black bars) season.

The vigilance time devoted by wild herbivores in both seasons decreased in groups without livestock but increased in groups associated with livestock. This was in contrast to studies conducted by Shrader (2006, 2012), Kluever (2008) and Pe´riquet (2010) who showed that herbivores associated with other species (wildlife) gained a vigilance advantage. These studies also showed that mixed-species herds provided a relatively unexplored opportunity to tease apart the effects of dilution, whereby individual herding with other species displayed lower frequency of vigilance than when herding only. In mixed groups of livestock and wild herbivores, as well groups without livestock, the behaviour of wildlife individuals were different in Ngorongoro rangelands, where wild herbivores spent more time on foraging in groups without livestock than when associated with livestock. These results reveal that all four wild herbivore species were more vigilant in both seasons when associated with livestock, although it was not significant in all cases.

4.1.4 Herder presence, foraging and vigilance

(i) Wildebeest

For wildebeest, neither the presence of male herders (t = -0.085, P = 0.932) nor that of female herders (t = -0.108, P = 0.914) significantly influenced foraging time. The presence of livestock significantly reduced foraging time during the dry (t = -2.126, P = 0.037) but not during the wet season (t = -1.496, P = 0.139; Table 1). The presence of male herders also increased vigilance time significantly (*t* = 2.194, *P* = 0.032) while the presence of female herders did not (*t* = 0.906, *P* = 0.368; Table 2).

Table 1: Relationship between wildebeest foraging time in minutes and herder presence as well as livestock presence during the wet and the dry season according to univariate tests.

	Estimate	Std. Error	t	P
(Intercept)	20.5556	1.3189	15.585	<0.0001
Male herder	-0.1464	1.7169	-0.085	0.9323
Female herder	-0.7741	7.1891	-0.108	0.9146
With livestock wet	-11.0576	7.3893	-1.496	0.1398
With livestock dry	-12.2222	5.7490	-2.126	0.0376

Table 2: Relationship between wildebeest vigilance time in minutes and herder presence as well as livestock presence during the wet and the dry season according to univariate tests.

	Estimate	Std. Error	t	P
(Intercept)	2.222	0.703	3.161	<0.0001
Male herder	2.008	0.915	2.194	0.032
Female herder	3.472	3.832	0.906	0.368
With livestock wet	-1.050	3.938	-0.267	0.790
With livestock dry	-0.555	3.064	-0.181	0.856

(ii) Zebra

For Zebra, neither the presence of male (*t* = 1.100, *P* = 0.274) nor female herders (*t* = 0.486, *P* = 0.628) significantly influenced foraging time. However, the presence of livestock significantly reduced foraging time during the wet season (*t* = -2.761, *P* = 0.007) but not during the dry season (*t* = -0.979, *P* = 0.330; Table 3). Also, neither the presence of male (*t* = -1.335, *P* = 0.185) nor female herders (*t* = -1.483, *P* = 0.141) significantly influenced vigilance time. However, the presence of livestock in both seasons (*t* = 2.648, *P* <0.0001) and (*t* = 2.185, *P* = 0.031) significantly explained the variation in Zebra's vigilance time (Table 4).

Table 3: Relationship between Zebra foraging time in minutes and herder presence as well as livestock presence during the wet and the dry season according to univariate tests.

	Estimate	Std. Error	t	P
(Intercept)	18.962	1.095	17.307	<0.0001
Male herder	0.808	0.734	1.100	0.2743
Female herder	0.577	1.188	0.486	0.3684
With livestock wet	-8.778	3.179	-2.761	0.0070
With livestock dry	-2.116	2.161	-0.979	0.3302

Table 4: Relationship between Zebra vigilance time in minutes and herder presence as well as livestock presence during the wet and the dry season according to univariate tests.

	Estimate	Std. Error	t	P
(Intercept)	3.962	0.8221	4.820	<0.0001
Male herder	-0.735	0.5510	-1.335	0.1854
Female herder	-1.321	0.8914	-1.483	0.1418
With livestock wet	6.317	2.3857	2.648	<0.0001
With livestock dry	3.543	1.6218	2.185	0.0316

(iii) Grant's gazelle

For Grant's gazelle, the presence of male herders (t = 0.982, P = 0.331) did not significantly influence foraging time while the presence of female herder did (t = -2.022, P = 0.049). The presence of livestock did not reduce foraging time during wet and dry season (t = -1.444, P = 0.155 and t = -0.097, P = 0.923, respectively; Table 5), neither did the presence of male (t = 1.346, P = 0.18491) nor female herders (t = -1.025, P = 0.310). The presence of livestock in both seasons (t = 1.260, P = 0.213) and (t = 0.242, P = 0.809) did not also significantly influence vigilance time (Table 6).

Table 5: Relationship between Grant's gazelle foraging time in minutes and herder presence as well as livestock presence during the wet and the dry season according to univariate test

	Estimate	**Std. Error**	**t**	**P**
(Intercept)	17.7027	1.2741	13.894	<0.0001
Male herder	1.4669	1.4946	0.982	0.331
Female herder	-19.0083	9.3997	-2.022	0.049
With livestock wet	-7.4961	5.1902	-1.444	0.155
With livestock dry	-0.4196	4.3442	-0.097	0.923

Table 6: Relationship between Grant's gazelle vigilance time in minutes and herder presence as well as livestock presence during the wet and the dry season according to univariate test

	Estimate	Std. Error	t	P
(Intercept)	2.0270	0.6281	3.227	<0.0001
Male herder	0.9917	0.7368	1.346	0.18491
Female herder	-4.7521	4.6341	-1.025	0.31052
With livestock dry	-3.2254	2.5588	-1.260	0.21385
With livestock dry.	-0.5188	2.1417	-0.242	0.80969

(iv) Thomson's gazelle

For Thomson's gazelle neither the presence of herder males (t = -0.293, P = 0.770) nor herder females (t = 0.972, P = 0.335) significantly influenced foraging time. The presence of livestock also during wet and dry season (t = 1.460, P = 0.149) and (t = -0.185, P = 0.854) respectively, did not significantly influenced foraging time. (Table 7). Neither the presence of herder males (t = 0.210, P = 0.834) nor herder females (t = 0.099, P = 0.922) significantly influenced vigilance time as well as the presence of livestock in both seasons (t = -0.501, P = 0.618) and (t = -0.826, P = 0.412) did not significantly influenced vigilance time (Table 8).

Table 7: Relationship between Thomson's gazelle foraging time in minutes and herder presence as well as livestock presence during the wet and the dry season according to multivariate test

	Estimate	Std. Error	t	P
(Intercept)	19.5192	0.8498	22.970	<0.0001
Male herder	-0.2724	0.9298	-0.293	0.770
Female herder	3.9332	4.0481	0.972	0.335
With livestock wet	-4.3926	3.0084	1.460	0.149
With livestock dry	-0.7318	3.9547	-0.185	0.854

Table 8: Relationship between Thomson's gazelle vigilance time in minutes and herder presence as well as livestock presence during the wet and the dry season according to multivariate test

	Estimate	Std. Error	t	P
(Intercept)	3.7500	0.6018	6.232	<0.0001
Male herder	0.1381	0.6584	0.210	0.834
Female herder	0.2827	2.8667	0.099	0.922
With livestock wet	-1.0677	2.1304	-0.501	0.618
With livestock dry	-2.3136	2.8005	-0.826	0.412

The result revealed that the level of protection has an influence on vigilant time of wildlife species, and in particular, when the group was accompanied by male herders. Wildebeest were more vigilant when male herders were present than when females were present. This was contradicting to the study by Young (2005) that wildlife keep their distance from individuals herded by protective pastoralists.

In NCA, wildlife intermingles with herders but our results shows that wildebeest increased the time of vigilance in the presence of male herders while other species did not. However, zebra increased vigilance when associated with livestock in both seasons, but Thomson's and Grant's gazelle did not, which may be due the fact that Thomson's gazelle and Grant's gazelle were mostly associated with sheep and goats, which were mostly herded by females. Therefore, results revealed that the sex of herders as well as the type of livestock may determine the level of vigilance time however, further studies are still needed.

4. 2 Quantifying grass regrowth

4.2.1 Grass regrowth in height and cover

The grass regrowth was higher at lower grazing intensity. Grass regrowth was high in caged plots compared to uncaged plots (X^2 = 22.32, P < 0.001). The rate of regrowth over time was higher on caged compared to uncaged plots (X^2 = 43, P < 0.001 (Fig. 13). Average grass cover was high in caged plots compared to uncaged plots (X^2 = 19.24, P < 0.001). The change of cover over time was higher on caged plots compared to uncaged plots area (X^2 = 34.69, P < 0.001; Fig. 14)

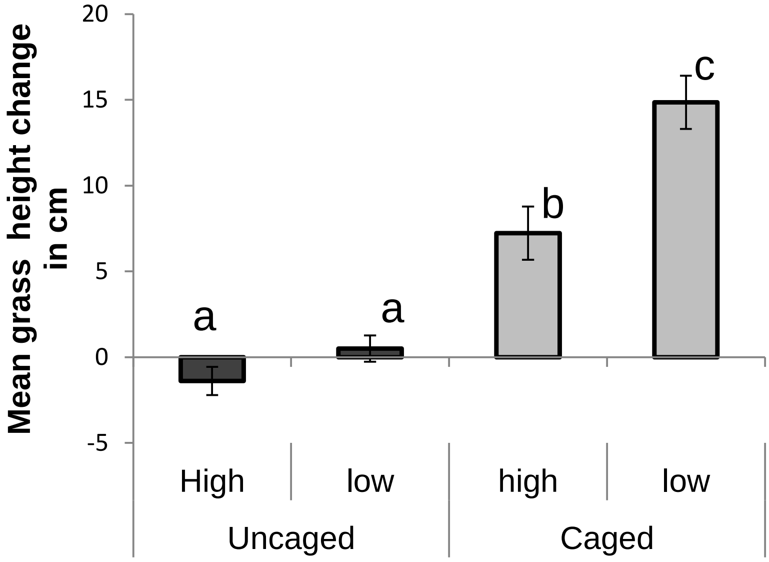

Figure 13: Mean (±SE) grass height change on uncaged and caged plots in area with low and high grazing intensity.

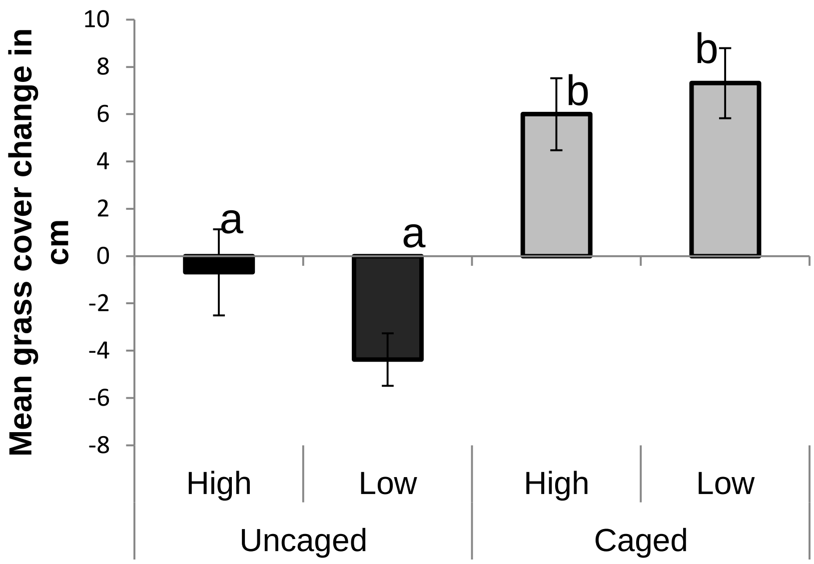

Figure 14: Mean (±SE) grass cover on uncaged and caged plots in area with low and high grazing intensity

The results revealed that grazing intensity has an influence on grass regrowth potential, especially on height and cover. This is also supported by a study conducted by Patton (2007) who showed that grazing intensity had an effect on forage production in the Missouri Coteau rangeland. Further, the study by Milchunas (1994) found that caged areas were the most productive ones, and that production decreased with grazing intensity, similar to our results. Therefore, in order to increase forage production in Ngorongoro rangelands the pastoralists should be advised on a rotational grazing scheme to produce moderate grazing pressure and to allow grass to grow in a recommendable height to be grazed. This is because wild herbivores by nature engage themselves in a rotational passage grazing system as found in the Serengeti ecosystem by McNaughton (1993).

Moreover, Holechek *et al.* (2006) showed that continuous and rotation grazing systems on rangelands increased forage production on average by 13%. Hence, a rotation system will be most advantageous to improve grass regrowth in Ngorongoro rangeland if the pastoralists will apply this system. Currently, the Maasai in Ngorongoro are depending on shifting herding strategy. However, the land is diminishing due to human population growth. This lead on the scarcity of forage for both wildlife and livestock but if Maasai will adopt the rotational grazing scheme it means will need only small piece of land for grazing and hence will have assurance of forage.

Our results also showed that the grass height and cover increased with time as in caged plots the height and cover of grass doubled after the site was caged for 30 days in contrast to plots left uncaged. This result was also supported by Skinner (1999) who found that grasses are able to recover from a single grazing incident within one month or more can put more resources into growth and can produce 30-70% more forage. However, the time of caged if will be doubled to 60-90 days the grass regrowth will increase more and hence forage assurance to Maasai for their livestock but also for wildlife.

Grazing causes losses in root mass and energy reserves of the grass and has greatly reduced forage production over the grazing season (Sollenberger, 2012). Therefore, the plots left caged over one month or above, increased grass regrowth. Thus, the area with high grazing intensity in Ngorongoro rangelands will decrease in forage production even if caged, unlike in areas with low grazing intensity which show an increase of grass regrowth. This also provides evidence in support of the grazing optimization hypothesis produced by McNaughton (1993) that grass regrowth is highest at some intermediate levels of grazing while low and intensive grazing reduce grass regrowth.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Our study illustrates how livestock behaviourally influence wild herbivores, especially with regard to foraging and vigilance behaviour. In the case of NCA, the multiple land use makes it difficult to separate Maasai pastoralists from conservation lands. We suggest that Maasai may continue to utilize other areas within NCA for their livestock use but leave out the crater for the use of wild herbivores only. This is because inside the crater, wild herbivores have more time to forage instead of being vigilant if livestock is absent. This may lead to an increase of the population of wild herbivores inside the crater (Arsenault *et al.*, 2010) and maintain the status of NCA as a wildlife species source area, while outside the crater the area might serve as a sink / trap for certain wildlife species.

In NCA, the presence of Maasai and their livestock together with livestock is of very important in order to maintain the status of being a UNESCO World Heritage site. However, the current way of using the rangeland should be put into account in order to improve the forage production and ensure forage availability for both wildlife and livestock. This study showed that the grass regrowth potential is strongly influenced by grazing intensity. Since grass productivity in rangelands should be maintained to allow both wild herbivores and livestock to access enough forage certain rangelands should be excluded from grazing for one to three months in order to allow grass regrowth.

The improvement of rangeland may be through adoption of rotational grazing schemes, which will ensure availability of forage for their livestock as the results shown during the study on grass regrowth. Foraging wildlife together with livestock is still an important combination in NCA because livestock, people and wildlife shared the land over years. Even if the results show livestock had no beneficial on wildlife's foraging time but may have beneficial in other aspects which this study did not cover like livestock and wildlife, have showed to be sustainable and to preserve biological diversity (Homewood *et al.*, 1987).

The results obtained from this study help to design an urgently needed livestock grazing management plan for NCA but also can be used with other conservation policy makers in order to ensure the rangeland has good condition to harbour both wildlife and livestock.

5.2 Recommendations

(i) The Maasai should be advised to adopt a rotational grazing system which seems to increase forage production, but they should not use fences because wild herbivores have their rotational grazing system by nature.

(ii) Livestock grazing management plan should be developed in NCA in order to ensure sustainability of rangeland for both wildlife and livestock.

(iii) Further studies are needed on salt lick sources in NCA to obtain information about other areas than the crater, where salt can be obtained for livestock in order to increase production.

(iv) The results obtained from this study help to provide the baseline data for the development of livestock grazing management plan which can be used in NCA and other protected areas. However, grazing plan must be flexible to consider various conditions across the year.

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