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Factors affecting hyrax presence/absence and population size

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Natural Resources Management

Submission date: June 2015

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Serengeti hyraxes

Factors affecting hyrax presence/absence and population size:

A case study in Serengeti National Park, Tanzania

Natural Resources Management (Biology)

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Student: Franco Peniel Mbise

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Master's thesis in Natural Resources Management

Norwegian University of Science and Technology
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Department of Biology

Declaration

I declare to the Norwegian University of Science and Technology (NTNU), that this is my own work. Thus, findings of this work is the result of my field work which I did in Serengeti National Park (SENAPA) and none of the part has been submitted to other Universities for any academic work.

Dedication

I dedicate this work to my beloved mother (Tikisaeli Peniel) and father (Peniel Bana). Many thanks for your encouragement throughout my life journey.

Abstract

Understanding the factors influencing whether a species is present or absent in an ecosystem and how these factors affect their population size is crucial for conservation initiatives. There are two species of hyraxes in the Serengeti National Park (SENAPA): the rock hyrax (*Procavia johnstoni*) and the bush hyrax (*Heterohyrax brucei*). These two species live predominantly on kopjes (rock outcrops), forming a metapopulation community. This study is focused on the factors that affect hyrax presence/absence and population size. To assess this, I included factors such as human premises, habitat type, kopje size, and the proportions of trees, grasses, shrubs, and rocks on these types of kopjes. My field technique included point observations with three visits per kopje at different times of the day (i.e., early morning, late morning, and evening). The results show that the most important variables for hyrax presence are the habitat type and proportion of shrubs. The results also show that hyrax population size is positively affected by human premises, possibly caused by fewer predators and higher food availability in these areas. My field observations are consistent with other studies on hyrax absence in some kopjes in SENAPA. However, with the limited time period of the study, it is difficult to firmly conclude the possible reasons for hyrax absence, requiring further research for future conservation purposes.

Keywords: rock hyrax, *Procavia johnstoni*, bush hyrax, *Heterohyrax brucei*, kopjes, human premises, habitat, Serengeti, Tanzania

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Acronyms

GPS	Global Positioning System
IUCN	International Union for Conservation of Nature
SENAPA	Serengeti National Park
TANAPA	Tanzania National Parks

1. INTRODUCTION

1.1. Background

The quality of data is very important for being able to answer management questions. If a study is well designed and meets its objectives, the inferences drawn will be reliable for management purposes (Mackenzie and Royle 2005). Management programs have several questions that are important for understanding species occurrences and distributions. Some of these questions include “Does a species occur or not with reasonable certainty in an area under consideration for management? Where is the species likely to occur?” (Mackenzie and Royle 2005, Mackenzie 2006). It is relatively easy to document the presence of a species, but very difficult to state with confidence that a species is absent in a given patch or habitat, requiring greater effort of researchers (McComb et al. 2010).

Species occurrence data requires several repeated surveys to be conducted. To increase detection probabilities, it is more feasible to visit more sites than to visit the same sites more frequently (Mackenzie and Royle 2005). Occurrence data are relevant for identifying habitats, providing an overview of species distributions and shedding light on the relationship between habitat structural features and vegetation types. Occurrence data are often considered as preliminary data, providing an overview of the project area. Occurrence data has become more reliable for monitoring plant and animal populations (Mackenzie et al. 2002, Mackenzie and Royle 2005, Mackenzie 2006).

An assessment of the factors that affect the presence of a species in an area and its population size is the key to understand conservation and area monitoring efforts (Efford et al. 2005, MacKenzie 2005b, Skei et al. 2006). Data on whether a species is present or absent in an area are very useful in reserve management planning as well as in designing a suitable habitat for such species. Such data can be used to establish an overview of the environmental conditions in the selected areas regarding the types of habitats that exist for specialist species. From such data, predictions can be derived regarding the extinction probabilities of the species that are present in such habitats (Tsiftsis et al. 2012).

Models of the presence/absence data offer a better understanding on the species abundance and occurrence in a given ecosystem (Nielsen et al. 2005). When a population tends to decline, inventory for the species monitoring becomes feasible using presence/absence documentation, which will help future species monitoring (Manley et al. 2005). Also, with these types of data, reserve designing and habitat monitoring can be implemented over a long period of time (Rodrigues et al. 2000, Yee and Dirnböck 2009, Dornan 2011).

Absence is confirmed only through observations (Bayley and Peterson 2001) and, in most cases, might be biased as to whether field observations confirmed an absence or field observations failed to detect a species occurrence (Gu and Swihart 2004, Mackenzie et al. 2004, Mackenzie and Royle 2005, Mortelliti et al. 2010). Species presence data inform management practitioners about species distributions in a given habitat and the overall species occurrence in the ecosystem (Hastie and Fithian 2013). Presence/absence data on hyraxes is crucial due to their peculiar nature of residing only on kopjes (rock outcrops).

Kopjes resemble floating islands on a sea of grass, and they function as a metapopulation community. A metapopulation, as cited from Lawes et al. (2000), refers to a set of local populations found in a large area where there is a possibility of individual species to migrate to at least some of these local sub-populations. This means that in a metapopulation community, there are source-sink patterns in which the sinks would not exist without receiving migrants from the sources. In this context, large kopjes will act as sources (larger population size), whereas smaller kopjes will act as sinks (smaller population size) (Donker and Krebs 2012, Loreau et al. 2013, Eberhart-Phillips and Colwell 2014).

Kopjes increase the scenic beauty of SENAPA (TANAPA 1996) and were formed during orogenic events (Late Precambrian, about 475-650 million years ago) (Hay 1976). Kopjes provide refuge for several invertebrates, amphibians, reptiles, birds, and small mammals. Kopjes, as described by Turner and Watson (1965), tend to vary in size, and they have cracks and caves that retain humidity. Due to heat stress that hyraxes tend to experience (Hoeck 1982), humidity helps them to live in dry areas. Additionally, their body physiology enables them to live in areas with an inadequate water supply and with low food quality (Hoeck 2001). Kopjes are spatially distributed with limited resources, such as food, crevices, holes, and vegetation cover. Still, there is a gap in understanding how hyraxes colonized these kopjes.

Hyraxes benefit by having a large population size, which provides increased vigilance to predators. The population size is determined by the kopje size and number of crevices from which to hide from predators (Hoeck 1989). Hyraxes are small mammals that have numerous predators. Predation and shelter are the most common factors that control the hyrax population size (Fairall et al. 1985). The main predators include martial eagles (*Polemaetus bellicosus*), tawny eagles (*Aquila rapax*), leopards (*Panthera pardus*), jackals (*Canis spp.*), spotted hyenas (*Crocuta crocuta*), and a numbers of snake species (Fairall et al. 1985, Chiweshe 2007). Extinction risk is probably higher in some of the sinks; hence, some of these sinks might be dependent on the sources for population survival (Dias 1996, O'Keefe et al. 2009, Bansaye and Lambert 2013, Drake and Griffen 2013).

Hyrax groups predominantly consist of females. The male mortality rate is higher than that of females, especially for young males. They are frequently killed by dominant males or driven away from the group, becoming more prone to predation (Fourie and Perrin 1987). Hyrax young are more frequently predated than adults (Fairall et al. 1985). When the population size increases, safety increases proportionally due to the large number of eyes, allowing them to feed more intensively. To increase safety while foraging, one individual (sentinel) takes a position to look for predators. This sentinel position changes to give each individual an opportunity to forage (Kotler et al. 1999). Vigilance success increases with the increase in population size (Barry 1994) coupled with the confusion and dilution effects (Roberts 1996). Additionally, with sentinel presence, hyraxes may forage further away from the kopje to increase their vision compared to when they forage close to the kopjes (Kotler et al. 1999).

Rock hyraxes tend to perform better than bush hyraxes in both natural and human dominated habitats. For instance, in Matobo hills, Zimbabwe, the predation ratio between rock and bush hyraxes was 17:20 and the population decreases were 30% and 37 %, respectively. Hyrax population decreases were due to predation, extensive fires, late rains, and poaching (Chiweshe 2007). Rock and bush hyraxes can disperse up to 2 kilometres (km). This journey involves trade-offs, including predation or being unable to cope with temperature stress (Hoeck 1982, Hoeck et al. 1982). Hyraxes mainly prefer hiding in the shelters of tree cavities or rock crevices to regulate their body temperature when the ambient temperature is relatively high (Bartholomew and Rainy 1971, Hoeck 1982, Chiweshe 2007).

The main influencing factors for dispersal are population size and food availability (Fourie and Perrin 1987). Dispersal is very important for organisms for two main reasons: inbreeding avoidance and competition avoidance (Waser 1985, Bollinger et al. 1993, Pollock 1996, Lena et al. 1998, Moore et al. 2006, Nelson-Flower et al. 2012). However, dispersal may accelerate when shelter is scarce (Sherman 1981). Hyrax female dispersal rates are minimal compared to male dispersal rates, and thus, sub-adults in this social organization are usually relatives (Fourie and Perrin 1987). Findings from Armitage (1974) on the yellow-bellied marmot found a similar case for hyraxes in which males become dominant in other territories apart from where they were born.

To retain normal dispersion behaviour between the SENAPA metapopulations, sets of kopjes should include stepping stones for hyraxes to retreat in case of danger (Lewas et al. 2000). Human activities in SENAPA are increasing, and their impacts have been little documented (Timbuka and Kabigumila 2006). Previous studies on Serengeti hyraxes did not take into account how human premises together with the habitat type and kopje size influence the presence or absence as well as the population size of the two hyrax species. Understanding such factors could help conservation plans to be implemented for the conservation of hyraxes and other species. As far as human premises are concerned, it is crucial in conservation initiatives to make plans on how many human premises should be allowed in protected areas. It is a well-established fact that wildlife should pay for its own sake. This happens when tourists pay for park entrances and the accrued money is spent on conservation initiatives. Thus, having tourist facilities is inevitable, but a thorough understanding of their effects is needed.

The study aim was to determine factors affecting hyrax presence/absence and their population size in SENAPA. If vegetation cover gives hyrax sufficient cover, refuge from predators and good ambient temperature against heat stress, then we expect a positive correlation with hyrax presence. Also if human premises have higher food availability and fewer predators, we expect a positive correlation with the increase in population size. In this study, I compared areas with human premises and areas with no human premises. The results from this study coupled with previous findings were able to explain what factors affect hyrax presence/absence and population size.

1.2. General objective

The main objective of this study was to assess the factors affecting hyrax (*Procavia johnstoni* and *Heterohyrax brucei*) presence or absence and population size in different kopjes in Serengeti National Park (SENAPA), Tanzania.

1.2.1. Specific objectives

- Assess the factors that affect hyrax presence/absence on such kopjes
- Assess the factors that cause variations in population size

1.2.2. Hypotheses

Human premises were the control variable to assess why chances of hyrax presence are very high near human premises compared to areas without human premises. Furthermore, an assessment was conducted to determine the influence of human premises in relation to hyrax population size coupled with other factors, such as the habitat type (i.e., grassland and wooded grassland), kopje size, as well as proportion of trees, grasses, shrubs, and rocks on such kopjes.

The following hypotheses were tested:

- When vegetation cover increases and provides sufficient cover, refuge from predators, and good ambient temperature, there should be a positive correlation with hyrax presence.
- When human premises have higher food availability and fewer predators, there should be a positive correlation with the increase in hyrax population size.

2. METHODOLOGY

2.1. Study species

All of the species of hyraxes are found in Africa. Only rock hyraxes are found in the Middle East (Bartholomew and Rainy 1971). Hyraxes are small mammals that are important in the food chain and food web in any African ecosystem. Hyraxes belong to the order Hyracoidea and the family Procaviidae. There are three living genera (i.e., Procavia, Heterohyrax, and Dendrohyrax) with four species (i.e., Rock hyrax, Bush hyrax, Western tree hyrax – *Dendrohyrax dorsalis*, Southern tree hyrax – *Dendrohyrax arboreus*) that look similar in size and appearance (Wilson and Reeder 1993). Rock and bush hyraxes live sympatrically or allopatrically (Hoeck 1982). They feed on a variety of food of both plant and animal origin (omnivores). Rock hyraxes are both browsers and grazers, whereas bush hyraxes are strictly browsers (Hoeck 1975).

Bush and rock hyraxes are diurnal and live together on kopjes, which provide hiding places and shelter. The mean adult weight for a rock hyrax is 3.1 kilograms, which is almost double that of a bush hyrax, with an adult mean weight of 1.8 kilograms (Hoeck 1989). The size and weight tend to vary depending on food quality and average annual precipitation (Klein and Cruz-Urbe 1996). Hyraxes have a round body shape, short tail, incisor-like tusks and rounded ears. They have rubbery pads with sweat glands that enable them to climb trees and shrubs (Fischer 1992).

From the IUCN Red List of Threatened Species, rock and bush hyraxes are under the category of ‘Least Concern’ (IUCN 2014). However, in some areas, such as KwaZulu-Natal Province, South Africa, rock hyraxes are locally extinct (Wimberger et al. 2009).

2.2. Study area

SENAPA (Fig. 1) lies in the northern part of Tanzania. It neighbours Maasai Mara in the north, Ngorongoro Conservation Area in the south-east, Loliondo Game Controlled Area in the north-east, Maswa Game Reserve in the south-west, and Ikorongo and Grumeti game reserves in the west. It covers an area of 14,763 km² (TANAPA 2014). The Serengeti has different topographical features, ranging from open grassland, short grass plains, kopjes, rising and falling

hills (Roodt 2005). Kopjes are mainly found in the central part, where the field work was conducted.

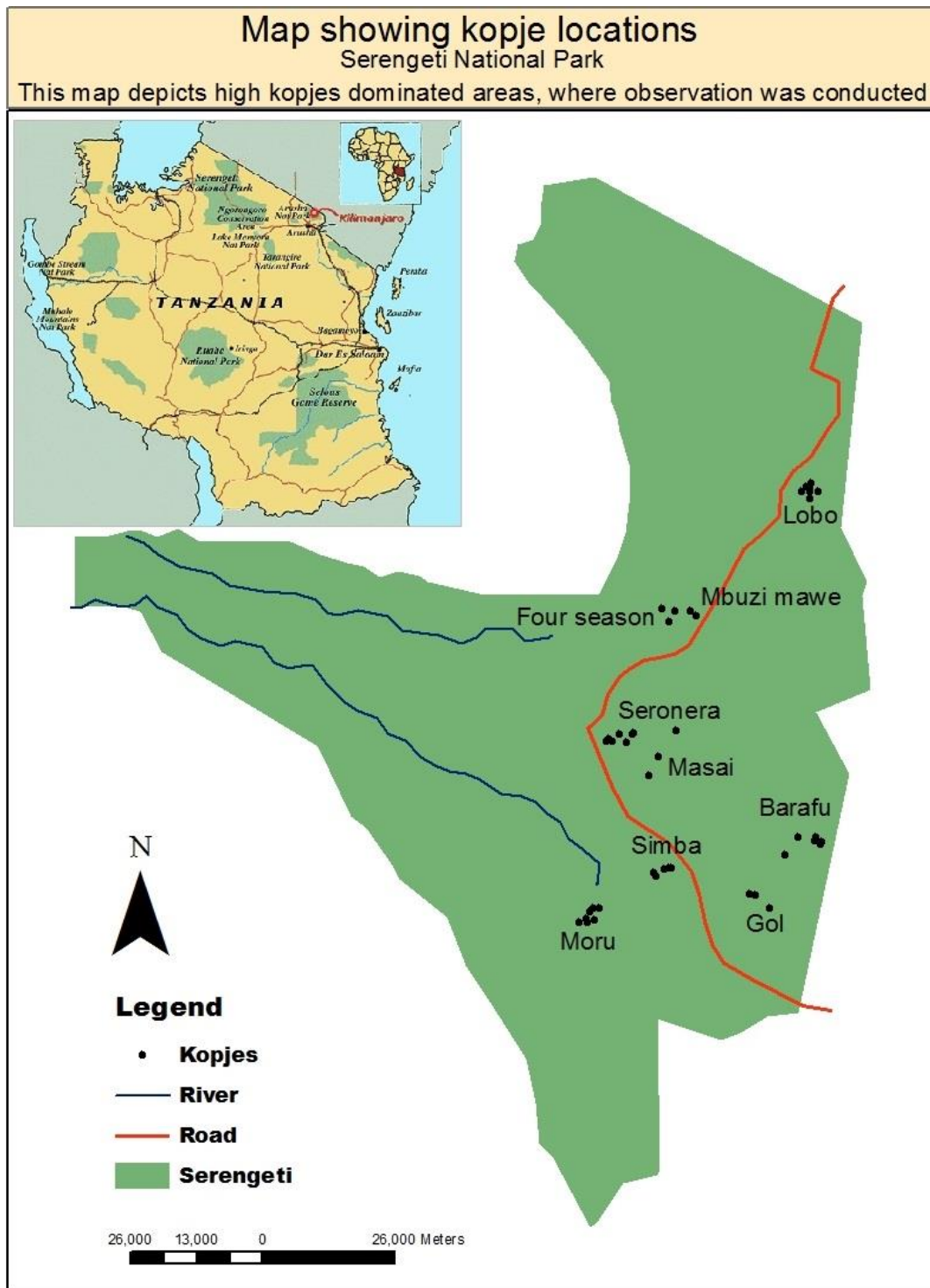


Figure 1: Map of the study area showing kopje locations (black dots).

2.3. Data collection

Seven variables were used: human premises (i.e., with and without human premises), habitat type (i.e., grassland, wooded grassland), kopje size, proportion of trees (percentage trees in the kopje), proportion of grasses (percentage grasses in the kopje), proportion of shrubs (percentage shrubs in the kopje), and proportion of rocks (percentage rocks in the kopje). My study was categorized into areas with and without human premises. Human premises include lodges, campsites, visitor centres, research centres, and staff villages. GPS, binoculars, a range finder, a notebook, a pen, a camera, and a land rover were used during the field work.

Three observers conducted the field work. The distance from the kopje edges was 10-50 metres depending on the terrain and the nature of the kopjes. When a species occurrence is high, more effort should be dedicated to surveying fewer sites rather than surveying more sites. In contrast, when species occurrence is low, most of the sites will be unoccupied, and this will lead to little information (Mackenzie et al. 2004, MacKenzie 2005b). Each kopje was visited three times for three consecutive days, as recommended by Mackenzie and Royle (2005), because the hyrax detection probability was high. This approach was applied to avoid bias in hyrax occurrence estimates.

Observations were made on different days and different times per kopje, including in the early morning (0700-0900), late morning (0930-1130), and evening (1630-1830). Our sampling technique was a mixture of stratified random sampling and purposive sampling. The study design and approach were based on Mackenzie and Royle (2005) advice on how to collect the occurrence data. We used a point observation technique, and several points around each kopje were taken. The number of points was determined by the size of the kopje. Fifteen minutes were spent at each point and observations were mainly performed with binoculars.

Presence/absence data were collected from 43 kopjes found in both types of human premises (with and without) and habitats (wooded grassland and grassland). For simplicity, 43 kopjes were grouped into 9 locations (barafu-6 kopjes, moru-7 kopjes, simba-5 kopjes, seronera-9 kopjes, gool-3 kopjes, lobo-7 kopjes, four season-3 kopjes, mbuzi mawe-2 kopjes, and masai-1 kopjes).

We used a GPS to collect coordinates at different angles of each kopje. Afterwards, the coordinates were processed using ArcGIS 10 to calculate the coverage area. By using the kopje

coverage areas, the kopjes were grouped into three different size categories (i.e., small, medium, and large). These three different size categories range between ($500 \text{ m}^2 - 9500 \text{ m}^2$), ($10000 \text{ m}^2 - 40000 \text{ m}^2$), and ($50000 \text{ m}^2 - 300000 \text{ m}^2$) for the small, medium, and large kopjes, respectively. We studied two habitats, namely, wooded grassland and plain grassland. Wooded grassland was defined as having tree coverage of more than 10%. Plain grassland was specified for plots with nearly 100% grass coverage. The proportion of trees, grasses, shrubs, and rocks was determined with naked eye observations, and inferences were made based on the variable coverage to calculate the percentage cover (i.e., %trees, %grasses, %shrubs, %rocks); the maximum percentage coverage for the four variables was 100%.

2.4. Data analyses

Data analyses were performed using the Statistical Package for Social Sciences (SPSS 21). Statistical tests were normally two-tailed, with significance levels below 0.05 ($P < 0.05$). We collected data from 43 different kopjes in the Serengeti, pooled into nine different areas. Statistical tests were performed using parametric and non-parametric tests. Parametric tests (ANOVA and Linear regression) were used when the data were normally distributed. When the data were not normally distributed, I used non-parametric tests (Chi-square tests and Binary logistic regression). Pearson correlation coefficients were used to test correlations, whereas t-tests were used to test differences between means. For differences in frequencies, I used Chi-square tests. Each kopje was visited three times at different times of the day; however, only one variable was used for each kopje, except for the number of hyraxes used the maximum counts.

Finally, binary logistic regression and linear regression analyses were performed to test the effect of different factors on hyrax presence/absence and population size, respectively. I also tested hyrax presence/absence and population size controlling for the nine areas.

3. RESULTS

3.1. Presence/absence of hyraxes

3.1.1. Human premises

There was a statistically significant relation between kopjes with or without human premises and whether hyraxes were present/absent on such kopjes ($\chi^2 = 7.14$, $df = 1$, $p = 0.008$; Fig. 2a).

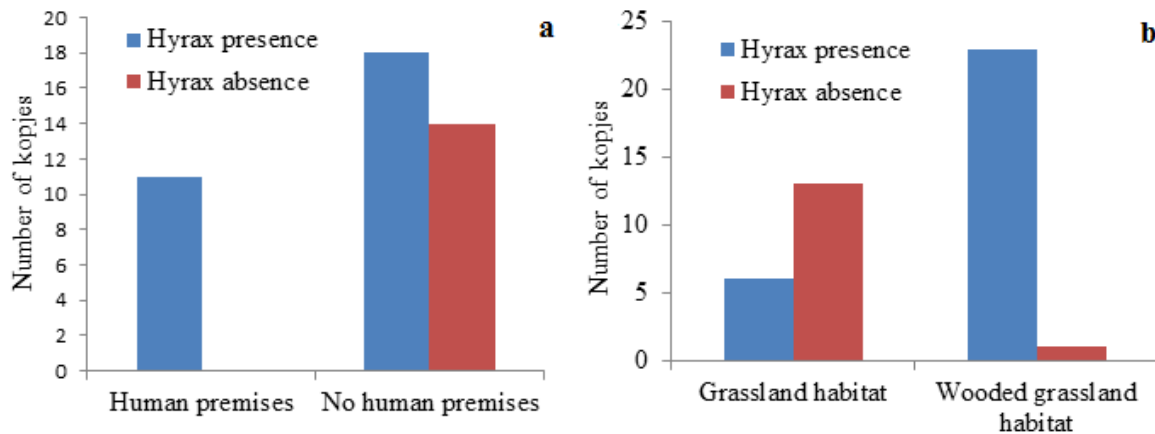


Figure 2: Presence (blue bars) or absence (red bars) of hyraxes (a) on kopjes with or without human premises, and (b) on kopjes in grassland and wooded grassland habitats.

3.1.2. Habitat type

There was a strong statistically significant relationship between the habitat type (grassland, wooded grassland) and presence/absence of hyraxes on such kopjes ($\chi^2 = 19.94$, $df = 1$, $p < 0.0001$; Fig. 2b).

3.1.3. Kopje size

There was a strong statistically significant relationship between the kopje size and the presence/absence of hyraxes on such kopjes ($\chi^2 = 15.61$, $df = 2$, $p < 0.0001$; Fig. 3).

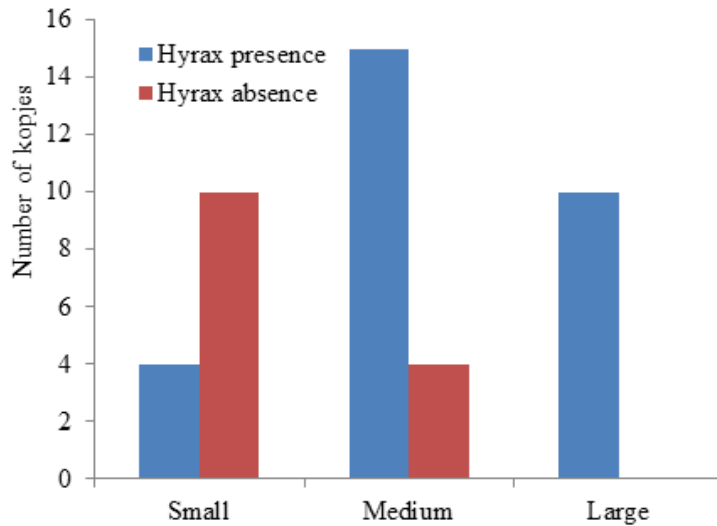


Figure 3: Presence (blue bars) or absence (red bars) of hyraxes on different kopje sizes (small, medium, and large).

3.1.4. Presence of trees, grasses, shrubs, and rocks

There was no statistically significant relationship between the percentage of tree cover and hyrax presence/absence on such kopjes ($\chi^2 = 1.80$, $df = 1$, $p = 0.180$). However, there was a statistically significant relationship between the percentage of grass cover and hyrax presence/absence on such kopjes ($\chi^2 = 8.80$, $df = 2$, $p = 0.012$; Fig. 4).

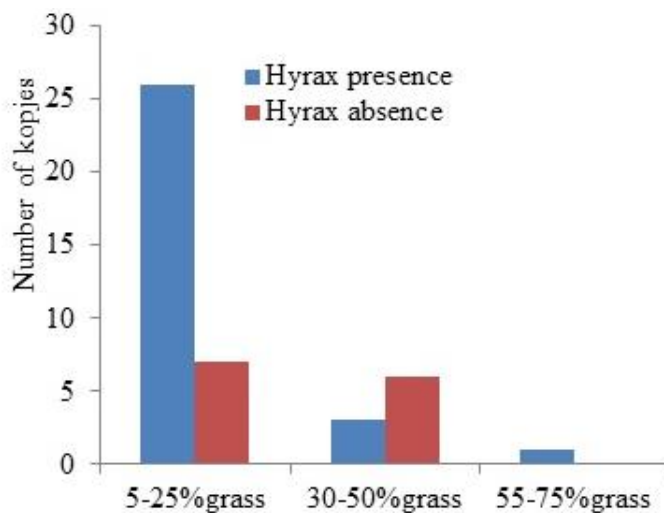


Figure 4: Presence (blue bars) or absence (red bars) of hyraxes on kopjes with different grass cover percentages.

There was a statistically significant relationship between shrub cover and hyrax presence/absence on such kopjes ($\chi^2 = 12.90$, $df = 2$, $p = 0.002$; Fig. 5a). Furthermore, there was a statistically significant relationship between the percentage of rock cover and hyrax presence/absence on such kopjes ($\chi^2 = 11.12$, $df = 2$, $p = 0.004$; Fig. 5b).

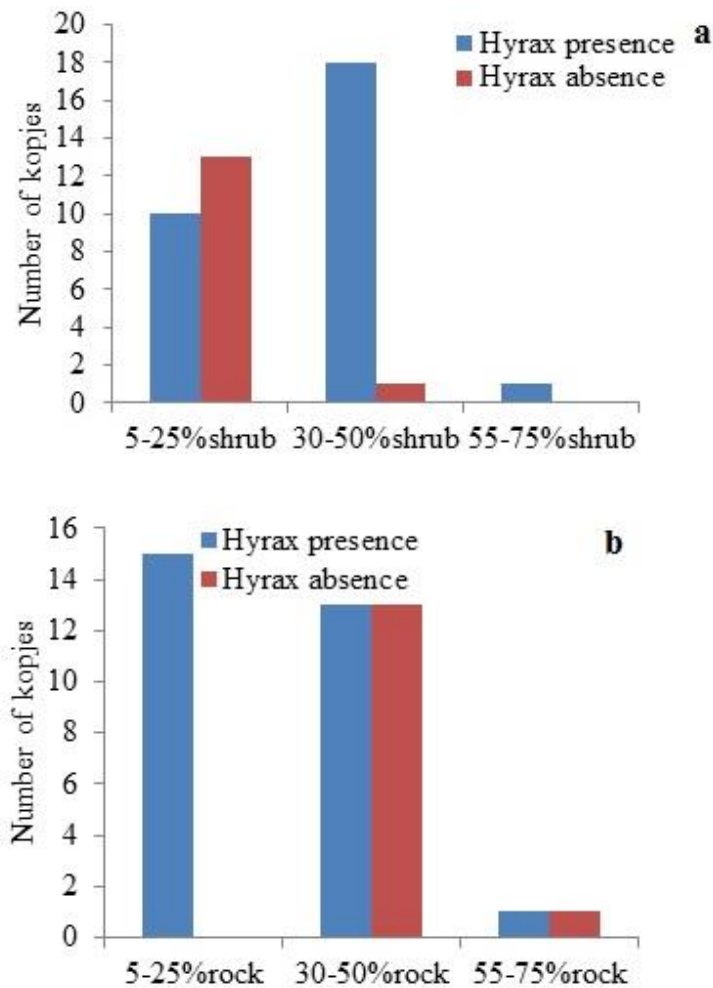


Figure 5: Presence (blue bars) or absence (red bars) of hyraxes (a) on kopjes with different shrub cover percentages, and (b) on kopjes with different rock cover percentages.

3.1.5. Binary logistic regression for hyrax presence/absence

A binary logistic regression of hyrax presence or absence as a dependent variable and human premises, habitat type, kopje size, and %shrubs as independent variables was statistically significant ($\chi^2 = 36.67$, $df = 4$, $p < 0.0001$, Nagelkerke $r^2 = 0.800$). However, only % shrubs was statistically significant in explaining the variation of presence/absence of hyrax on kopjes ($p = 0.037$; Table 1). However, the habitat type was almost significant ($p = 0.052$; Table 1).

Table 1: Results of a binary logistic regression analysis with hyrax presence/absence as a dependent variable and human premises, habitat type, kopje size, and % shrubs as independent variables.

Independent variables	β	Wald	Df	p =
Constant	-23.113	.000	1	.999
Human premises(with/without)	17.439	.000	1	.999
Habitat type	-2.890	3.776	1	.052
Kopje size	-2.356	3.205	1	.073
%shrubs	-3.411	4.356	1	.037

Note: The analysis was statistically significant when 43 areas were included. However, when controlling for areas (9 areas in SENAPA), all significance disappeared.

3.2. Hyrax population size

3.2.1. Human premises

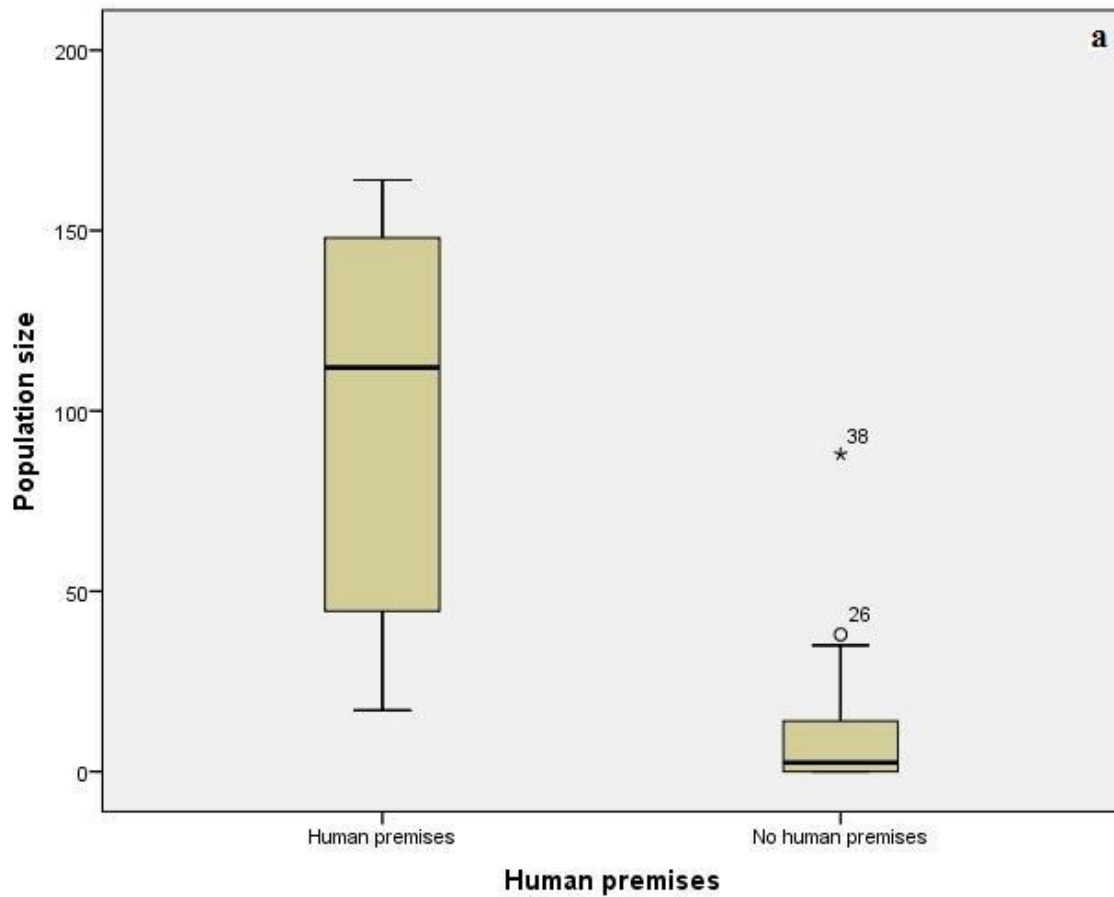
There was a strong statistically significant relationship between human premises (with or without human premises) and hyrax (both species) population size (ANOVA; $F = 66.96$, $df = 1$ and 41 , $p < 0.0001$ Fig. 6a).

3.2.2. Habitat type

There was a strong statistically significant relationship between habitat type and hyrax (both species) population size on different kopjes (ANOVA; $F = 15.44$, $df = 1$ and 41 , $p < 0.0001$; Fig. 6b).

3.2.3. Kopje size

There was a statistically significant relationship between kopje size and hyrax (both species) population size (ANOVA; $F = 3.59$, $df = 2$ and 40 , $p = 0.037$; Fig. 7).



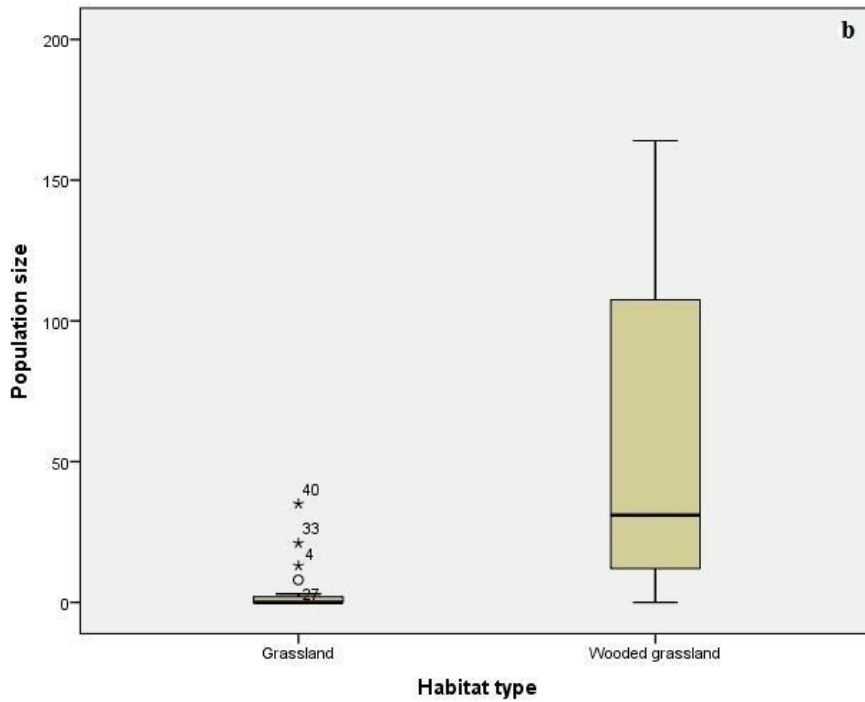


Figure 6: Population size of hyraxes (a) on kopjes with or without human premises, and (b) on kopjes in different habitats of grassland and wooded grassland.

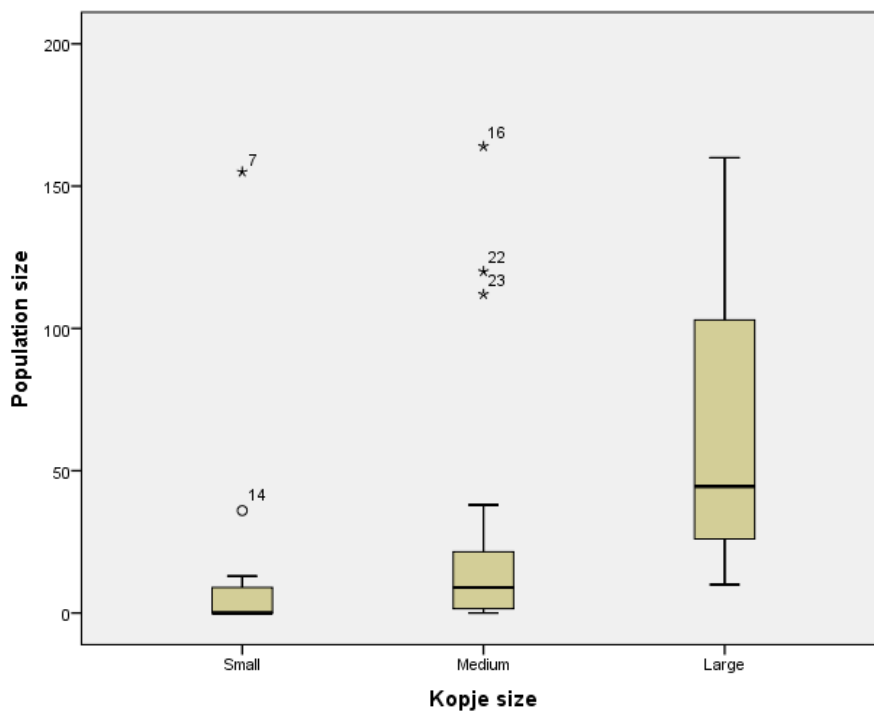


Figure 7: Population size of hyraxes found on kopjes of different sizes.

3.2.4. Presence of trees, grasses, shrubs, and rocks

There was no statistically significant relationship between tree cover and hyrax (both species) population size on different kopjes (ANOVA; $F = 0.72$, $df = 1$ and 41 , $p = 0.402$). Furthermore, no statistically significant relationship was found between grass cover and the hyrax (both species) population size on different kopjes (ANOVA; $F = 0.79$, $df = 2$ and 40 , $p = 0.457$).

Finally, there was no statistically significant relationship between shrub cover and the hyrax (both species) population size on different kopjes (ANOVA; $F = 0.96$, $df = 2$ and 40 , $p = 0.390$). However, there was a statistically significant relationship between rock cover and the hyrax (both species) population size on different kopjes (ANOVA; $F = 4.43$, $df = 2$ and 40 , $p = 0.018$, Fig. 8).

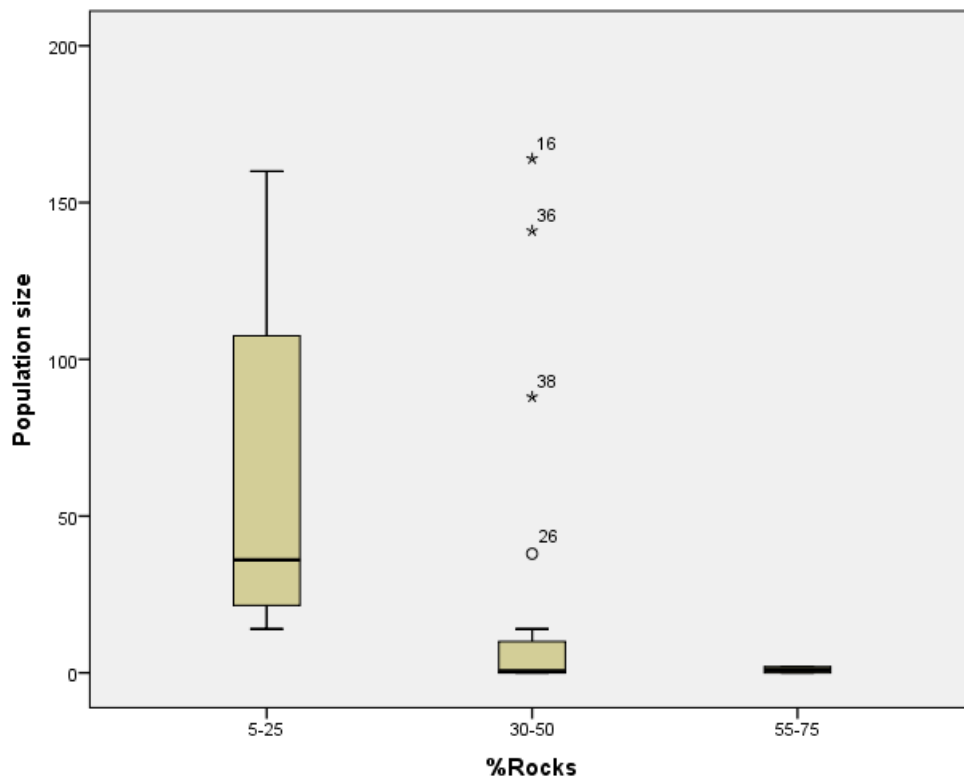


Figure 8: Population size of hyraxes on kopjes with different rock cover percentages.

3.2.5. Linear regression for the hyrax population size

A linear regression with the hyrax population size as a dependent variable and human premises, habitat type, kopje size, and %shrubs as independent variables was statistically significant (ANOVA; $F = 8.58$, $df = 4$ and 24 , $p < 0.0001$, $r^2 = 0.590$). However, human premises were the only statistically significant variable to explain the variation in the hyrax population size on different kopjes ($p < 0.0001$; Table 2).

Table 2: A linear regression analysis with the hyrax population size as a dependent variable and human premises, habitat type, kopje size, and % shrubs as independent variables controlling for kopjes where hyraxes were present (29 kopjes).

Model	Standardized Coefficients		
	Beta	T	p =
(Constant)		3.092	.005
Human premises (with/without)	-.724	-5.061	.000
Habitat type	.043	.298	.768
Kopje size	.105	.787	.439
%shrubs	-.176	-1.335	.194

4. DISCUSSION

These study findings are very important because they give insight into how human premises play a major role in favouring the increase in the Serengeti hyrax population. The phenomenon between human and hyrax coexistence is special compared to many other findings on species occurrences and distributions. Additionally, the study findings shed light on the patterns of hyrax presence/absence, as previous studies on hyraxes have not addressed this. Although the field techniques may have some potential biases, I would consider an underestimation of hyrax observations likely because of the limited time for this study.

4.1. Factors affecting hyrax presence/absence and population size

4.1.1. Human premises

All human premises found in SENAPA are built in the preferable habitats for hyraxes. Hyraxes were found in all of the locations that had human premises, whereas almost 50% of the kopjes without human premises had no hyraxes at all. The increase in the hyrax population size was positively correlated with human premises. Due to a larger population size found in these areas, one might conclude that human premises are the most influential variable explaining hyrax presence. However, a conclusion can be drawn that human premises are favourable places to maintain larger hyrax populations probably due to fewer predators and food availability. Among the factors that affect hyrax population size, the existence of human premises was the only variable that was significant to explain these variations. This may be linked to the hypothesis that hyraxes tend to associate with human premises probably for the sake of food or to hide from predators. This same phenomenon was documented in Tsitsikama National Park, South Africa, where hyraxes were often found around tourist campsites (Fairall et al. 1985).

Human premises can act as a spatial refuge for hyraxes against predation. As noted by Holt (2001), species will spend more time in a given set of habitats to readily generate coexistence. Increases in human premises in the park seem to favour hyraxes, but this will have several impacts on other species living on kopjes, such as amphibians and reptiles. Areas with human premises had fewer numbers of reptiles, especially snakes; this trend seems to be caused by

people killing the reptiles when they see them. Generally all human premises, as previously mentioned, had fewer predators. Comparatively, one of the human premises (four season lodge) had a smaller hyrax population size compared to other human premises. The lodge is new, and thus hyrax predators may not have disappeared yet. Predictions can be made that in a given time in the future, the hyrax population size will increase as in the other locations with human premises.

The coexistence of hyraxes and humans seems to correspond with a study on coyotes (*Canis latrans*) where the humanized landscape offered enough food, water, and shelter to increase the coyote population (Fox 2006). However, for the case of other wildlife species, such as microbats (e.g., little bentwing bat - *Miniopterus australis*, gould's wattled bat - *Chalinolobus gouldii*, eastern false pipistrelle - *Falsistrellus tasmaniensis*, eastern freetail bat - *Mormopterus norfolkensis*, lesser long eared bat - *Nyctophilus geoffroyi*, and greater broad-nosed bat - *Scoteanax rueppellii*), studies have found that increases in the number of human premises tended to decrease their abundance and richness (Blackthorn 2013). A strongly held belief is that due to human impacts on wildlife, they cannot use the same point location and coexist in harmony (Carter et al. 2012). Thus, understanding the coexistence of humans and wildlife species is important for future conservation endeavours (Holt 2001).

4.1.2. Habitat type

The study was performed in kopje-dominated areas with two habitat types: wooded grassland and grassland. Hyraxes were mostly present on kopjes in woody grassland habitats and mostly absent from most kopjes in grassland habitats. Additionally, the hyrax population size was larger in woody grassland habitats. This might be explained by the fact that almost all of the human premises are found in woody grassland habitats, so there will be an inter-correlation with human premises occurrence.

Areas of wooded grassland with more shrub coverage favour hyrax survival by offering enough food and hiding places from predators. A study on bats (e.g., eastern pipistrelle - *Pipistrellus subflavus*, evening bats - *Nycticeius humeralis*, large brown bat - *Eptesicus fuscus*, southeastern myotis - *Myotis austroriparius*, and hoary bat - *Lasiurus cinereus*) found a similar relationship

between vegetation cover and presence data (Ford et al. 2006, Jachowski et al. 2014). Apart from adequate food, which is found in areas of high vegetation coverage, hyraxes have numerous of predators, so areas with substantial vegetation coverage protect them from predation (i.e., from their common predators, the martial eagle and tawny eagle). Preferable areas for hyraxes are those with good vegetation cover; hence, safety is considered to be the determining factor for habitat use (Druce et al. 2006, de Lima et al. 2010).

4.1.3. Kopje size

The probability of hyrax presence increased with kopje size. A similar trend was found by Lewas et al. (2000) for the tree hyrax and the blue duiker (*Philantomba monticola*), of which both populations increased with the patch area. When the patch area increased, species occurrence tended to increase (Franc 2008). However, this positive relationship is not always true. Other findings show that immigration behaviour seems to be the determinant factor in producing a positive correlation between the patch size and population size (Bowers and Matter 1997, Bowman et al. 2002). In this context, kopjes with a high immigration rate are expected to have larger population sizes, but less can be concluded for the case of hyraxes because this was not tested in this study. Apart from a high rate of individual movement from one patch to another, the relationship is not always consistent over all patches (Bowers and Matter 1997). Findings from Hoeck (1982) also show that kopje size correlated with the presence of hyraxes.

4.1.4. Trees, grasses, shrubs, and rocks coverage

The tree cover percentage was not a statistically significant factor to explain hyrax presence/absence or the population size. This might be due to the inter-correlation with other variables (i.e., %grasses, %shrubs, %rocks). In plain grassland, most of kopjes were in poor quality (Hoeck 1982). Hyraxes were mostly found in kopjes with less grass cover. This suggests that in the plain grassland, there was no suitable habitat for hyraxes. Hence, kopjes with hyraxes had small population sizes, which might be due to the lack of shelter, high predation rate, and inadequate food.

The shrub cover percentage correlates positively with hyrax presence and the population size. Hyraxes were found in kopjes with a high percentage of shrub cover. This might be associated with shrubs acting as a shelter and source of shade and food for hyraxes compared to trees, which are taller, harder to climb and easier to be seen by predators. The hyrax population size was smaller in kopjes with the highest rock coverage. Hyraxes were mostly found in kopjes with low rock coverage. Kopjes with more than 50% rock coverage had no suitable habitat for hyraxes. As mentioned earlier, hyraxes experience heat stress (Hoeck 1982) and their body temperature changes as the ambient temperature changes (Meltzer 1971). Thus, grassland habitats cannot support larger hyrax populations. Due to the inter-correlation of these variables as mentioned above, %shrubs was the only variable that was used, coupled with other factors (i.e., human premises, habitat type, and kopjes size), to explain what might affect hyrax presence/absence and population size.

4.2. Factors that might explain the absence of hyraxes in some kopjes

Areas that lacked hyraxes occurred in grassland habitats in Barafu, Gool, and Simba. In the Barafu and Gool kopjes, no hyraxes were observed, but in the case of the Simba kopjes, a single hyrax was observed on the last day of the field work. From the field observations, these areas have many avian predators and the vegetation cover is very low. This makes hyraxes prone to predation, especially from the martial and tawny eagles.

From the reintroduction evidence in KwaZulu-Natal Province, a previous study noted that the main problem for the hyrax survival was predation (Wimberger et al. 2009), and the field observations are consistent with these results. The study findings are also consistent with five possible reasons for hyrax absence suggested by Hoeck (1982). These possible reasons for hyrax absence include the following:

- (i) Kopjes isolation makes it difficult and/or impossible for the hyraxes to recolonize these kopjes. When small populations become isolated, they are prone to extinction compared to large populations (Lewas et al.2000).
- (ii) Lack of holes/crevices for hiding from predators and cooling body temperature.

- (iii) Poor vegetation cover for food and also hiding places from predators. As previously noted, the main predators in this area are raptors. With little vegetation cover hyraxes can easily be seen by predators.
- (iv) These areas experience low rainfall which leads to the inadequate food supplies compared to wooded grassland habitats.
- (v) Inbreeding might have caused extinction of hyraxes in these kopjes because of a high degree of isolation from other hyrax populations.

5. CONCLUSIONS

As hypothesized, these results suggest a relationship between hyrax presence and the population size and vegetation cover and human premises, respectively, in SENAPA. The presence data were mainly dependent on the habitat type and proportion of shrubs, whereas the population size was influenced by the occurrence of human premises. The coexistence between hyrax and humans tended to favour hyrax presence and increase their population size. Additionally, because hyraxes occur in metapopulation communities, studies on habitat fragmentation due to the increased number of roads for tourist might also be among the factors hindering normal dispersion. Road networks impair animals normal dispersal patterns (Ament et al. 2008) and also tend to interfere with the dispersal of species living in metapopulation communities (Sullivan et al. 2012).

Due to the limited time in the field and the design of the study, no conclusive reasons can explain hyrax absence. It is well known that absence of evidence is not evidence of absence (Lawes et al. 2000) because species may not always be detected even if they are present (Mackenzie et al. 2004). Species presence/absence data are very useful to explain the functions of ecosystems (Habtamu and Bekele 2012). Additionally, these types of data are commonly used for species monitoring and habitat modelling, but they have no power to confirm the absence of species (MacKenzie 2005a). Thus, further research is needed to investigate kopjes to assess the factors behind hyrax absence in the Serengeti National Park.

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7. APPENDIX

Appendix 7: Description of each kopje with some of its variables

Coverage area(m ²)	Kopje size	Human premises	Habitat type	%Trees	%Grasses	%Shrubs	%Rocks	Presence/absence	Max counts	Kopje ID	Place name
746	Small	No human premises	Grassland	5-25%	5-25%	5-25%	30-50%	Absence	0	33	Barafu
750	Small	No human premises	Grassland	30-50%	5-25%	5-25%	30-50%	Absence	0	35	Barafu
1820	Small	No human premises	Grassland	5-25%	55-75%	5-25%	30-50%	Absence	0	30	Barafu
3185	Small	No human premises	Grassland	5-25%	5-25%	30-50%	30-50%	Presence	13	22	Moru
3248	Small	No human premises	Grassland	5-25%	5-25%	5-25%	30-50%	Absence	0	32	Barafu
3339	Small	No human premises	Grassland	5-25%	5-25%	5-25%	30-50%	Absence	0	39	Simba
4110	Small	Human premises	Wooded grassland	30-50%	5-25%	30-50%	5-25%	Presence	155	5	Seronera
4146	Small	No human premises	Grassland	5-25%	30-50%	30-50%	30-50%	Absence	0	42	Simba
4309	Small	No human premises	Grassland	5-25%	30-50%	5-25%	30-50%	Absence	0	43	Simba
4657	Small	No human premises	Grassland	5-25%	30-50%	5-25%	30-50%	Absence	0	31	Barafu
5179	Small	No human premises	Grassland	5-25%	5-25%	5-25%	30-50%	Absence	0	34	Barafu
5603	Small	No human premises	Wooded grassland	5-25%	5-25%	5-25%	30-50%	Presence	9	24	Moru
5619	Small	No human premises	Grassland	5-25%	5-25%	5-25%	30-50%	Absence	0	38	Gool
9108	Small	Human premises	Wooded grassland	5-25%	5-25%	30-50%	5-25%	Presence	36	4	Seronera
10161	Medium	No human premises	Wooded grassland	5-25%	5-25%	55-75%	5-25%	Presence	14	3	Seronera
10180	Medium	Human premises	Wooded grassland	5-25%	5-25%	5-25%	30-50%	Presence	164	13	Lobo
12187	Medium	No human premises	Grassland	5-25%	30-50%	5-25%	30-50%	Absence	0	40	Simba
12535	Medium	No human premises	Grassland	5-25%	5-25%	5-25%	30-50%	Presence	3	19	Moru
12654	Medium	No human premises	Grassland	5-25%	30-50%	5-25%	30-50%	Absence	0	37	Gool
14894	Medium	Human premises	Wooded grassland	5-25%	5-25%	30-50%	5-25%	Presence	17	7	Seronera
15976	Medium	No human premises	Wooded grassland	5-25%	5-25%	5-25%	30-50%	Presence	14	8	Seronera
16419	Medium	Human premises	Wooded grassland	5-25%	30-50%	30-50%	5-25%	Presence	120	6	Seronera
16905	Medium	Human premises	Wooded grassland	5-25%	5-25%	5-25%	5-25%	Presence	112	14	Lobo
16988	Medium	No human premises	Grassland	5-25%	30-50%	5-25%	30-50%	Absence	0	36	Gool
17652	Medium	No human premises	Wooded grassland	5-25%	5-25%	30-50%	5-25%	Presence	22	16	Lobo
20946	Medium	No human premises	Wooded grassland	5-25%	5-25%	30-50%	30-50%	Presence	38	23	Moru
21408	Medium	No human premises	Grassland	30-50%	5-25%	30-50%	30-50%	Presence	8	20	Moru
23221	Medium	No human premises	Grassland	5-25%	5-25%	5-25%	30-50%	Presence	1	41	Simba
26267	Medium	No human premises	Wooded grassland	5-25%	5-25%	5-25%	55-75%	Presence	2	17	Lobo

31550	Medium	No human premises	Wooded grassland	5-25%	30-50%	5-25%	30-50%	Presence	9	26	Four season
33629	Medium	No human premises	Wooded grassland	5-25%	5-25%	30-50%	30-50%	Presence	9	11	Lobo
36787	Medium	No human premises	Wooded grassland	5-25%	5-25%	5-25%	55-75%	Absence	0	15	Lobo
39798	Medium	No human premises	Grassland	30-50%	5-25%	30-50%	5-25%	Presence	21	21	Moru
51041	Large	No human premises	Wooded grassland	5-25%	5-25%	30-50%	30-50%	Presence	10	27	Four season
54902	Large	Human premises	Wooded grassland	5-25%	5-25%	5-25%	5-25%	Presence	160	10	Seronera
58373	Large	Human premises	Wooded grassland	5-25%	5-25%	30-50%	30-50%	Presence	141	28	Mbuzi mawe
59376	Large	Human premises	Wooded grassland	5-25%	5-25%	30-50%	5-25%	Presence	103	2	Seronera
63824	Large	No human premises	Wooded grassland	30-50%	5-25%	5-25%	30-50%	Presence	88	9	Seronera
69551	Large	Human premises	Wooded grassland	30-50%	5-25%	30-50%	5-25%	Presence	53	18	Moru
73289	Large	No human premises	Grassland	5-25%	30-50%	30-50%	5-25%	Presence	35	1	Masai
87497	Large	No human premises	Wooded grassland	5-25%	5-25%	30-50%	5-25%	Presence	26	29	Mbuzi mawe
92700	Large	Human premises	Wooded grassland	30-50%	5-25%	30-50%	5-25%	Presence	36	25	Four season
282733	Large	No human premises	Wooded grassland	30-50%	5-25%	30-50%	5-25%	Presence	14	12	Lobo