

How do Rhino affect Grassland heterogeneity and what is the impact on Mammal diversity in Hluhluwe-iMfolozi Park?



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Abstract

Habitat heterogeneity is a key feature of African savannas, facilitating the greatest diversity of ungulate species anywhere on Earth. White rhino have a significant role in habitat heterogeneity by creating and maintaining short grass habitats known as grazing lawns. These areas of nutrient-rich stoloniferous grass are important for a number of ungulate species. In this research, a fieldwork-based study has been conducted to find out the effect grazing lawn habitat has on the abundance of ungulate species in an African savanna, Hluhluwe-iMfolozi Park. This study aims to build upon current theories that state the importance of habitat heterogeneity for ungulate species. By recording the abundance and distribution of herbivore species via dung counts and grazing lawn extent via grass species identification, this study looks at relationships between herbivores and lawn habitat found along 21 line transects. The results indicate that White rhinos are more abundant in areas of high grazing lawn extent. Smaller ungulates also show a positive correlation to the extent of lawn habitat highlighting the importance of rhino for ungulates reliant upon grazing lawn habitat. The extent of grazing lawn is declining over a 15-year period which could have far-reaching implications for ungulate species. It is suggested that further research is conducted into the loss of grazing lawn habitat and what can be done to mitigate this.

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1. Introduction

Due to the large Human influence on the environment, it is now widely accepted that we are entering a new era, known as the Anthropocene (Steffen et al., 2011). Rapid biodiversity loss is occurring globally at unprecedented rates (Dirzo et al., 2014). Furthermore, the current rate of extinction is greater than that of the last mass extinction event during the Cretaceous period, 65 million years ago (Raven, Chase, & Pires, 2011). Whilst figures regarding the rate of extinction compared with background rates are hugely varied, using conservative estimates it is largely agreed that we are now in the midst of the 6th mass extinction event, which will result in vast biodiversity loss (Ceballos et al., 2015; Pimm et al., 2014). Even when using conservative it is estimated that between 11,000 – 58,000 animal species are lost annually (Dirzo et al., 2014; Scheffers et al., 2012). As a result, it has been stated that humanity has already surpassed the planetary boundary for the rate of biodiversity loss (Rockström et al., 2009). Hence, because of the magnitude of extinction and the decline of species, conservation of keystone species such as the White rhino (*Ceratotherium simum*) is of vital importance. A keystone species is one that has a disproportionately large effect on an ecosystem compared to its abundance including facilitating the abundance of other species who would otherwise become over or underpopulated (Paine, 1969; Power et al., 1996). The resulting trophic downgrading that occurs following the decline of keystone species has far-reaching impact for ecosystem functioning and human well-being (Dirzo et al., 2014). In conservation, focussing on conserving keystone species provides a way in which to focus efforts to have maximum gain.

1.1. Key Concepts

1.1.1. Trophic downgrading, alternative stable states & connectivity

There are a number of important key concepts that have been developed in past literature, which are fundamental to understanding savanna ecosystems. Ultimately the understanding of such key concepts is vital to successful conservation. Firstly, three important elements provide the basis for an understanding of trophic downgrading patterns (Estes et al., 2011). It has long been theorised in ecology that apex consumers have a significant role in shaping ecosystems and hence changes in abundance of these consumers can lead to major shifts in ecosystems (Fretwell, 1987; Hairston, Smith, & Slobodkin, 1960). The definition of trophic downgrading was later re-defined as trophic cascading, which means that impacts on consumers cascade downward through food chains (Paine, 1969). The next important element was the development of the theory regarding alternative stable states. Ecosystem dynamics were found to be nonlinear and perturbations with sufficient magnitude could result in a catastrophic shift of ecosystems (Scheffer et al., 2001). Shifts in the 'phase' of an ecosystem can occur and are known as tipping points. This important theory describes how tipping points can result in large often rapid changes in the function of an ecosystem towards another state. In savanna ecosystems, where resource pressure and disturbance is great, losing species key to the functioning of an ecosystem could lead to an alternative stable state of greater woody cover or greater grassland cover (Langevelde et al., 2016). In Hluhluwe-iMfolozi Park (HiP) is evidence of a shift from C₄ grassland to C₃ abundant thicket and forest with implications for grassland specialists and overall biodiversity (Gillson, 2015). Finally, connectivity regards ecosystems as interaction webs in which interactions between species as important for many species. The interactions can be in the form of biological

processes such as predation and competition or natural physical processes including nutrient & water availability and temperature changes. These interactions between living beings and the physical environment links species at spatial scales ranging from millimetres to thousands of kilometres (Estes et al., 2011). By understanding that all processes are linked, and interactions govern the survival of species over large temporal and time scales one can better understand how the conservation of a particular species may have far-reaching implications for several species.

1.1.2. Keystone species

Following on from the concept of trophic cascading, the concept of keystone species uses this underlying foundation to examine whether it is better to conserve keystone species whose importance to the ecosystem is greater than most other species. Due to the rapid biodiversity loss occurring currently it is important to be able to identify and conserve these species whose loss would have a cascading effect on an ecosystem (Dunne & Williams, 2009). Current research on white rhino shows that they facilitate smaller herbivores (Verweij et al., 2006) and evidence for their 'mega-herbivore' status has increased since the term was first introduced by Owen-Smith (Waldram, Bond, & Stock, 2008).

Because of successful conservation programmes, the White rhino has made a comeback to become the most numerous species of rhino in the world. The role rhino play in shaping the savannah ecosystem has been of increasing interest in recent years. Initially, the importance of herbivores in shaping ecosystems was underestimated and unclear (Martin & Klein, 1984). Owen-Smith (1987) coined the term 'Mega-Herbivore' for herbivores >1000 kg in weight and assessed their impact upon savanna ecosystems (Owen-Smith, 1987). In fact, within this classification, these megaherbivores, including Rhinoceros, Elephants, Hippopotamus and Giraffe, were labelled as keystone herbivores. In recent literature Rhinos have been identified as hugely significant drivers of habitat heterogeneity especially in the formation of grazing lawns – intensely grazed areas of stoloniferous grass species (Cromsigt & Olff, 2008; Cromsigt & te Beest, 2014; Hempson et al., 2015). The role rhino play in shaping savannah grasslands has become better understood and now there is a need to understand to what extent rhino facilitate the abundance of other species in savannah ecosystems. Research on savanna ecosystems is finding more interconnected relations that involve rhino because of their ability to change the vegetation structure in savanna grasslands. For example, the effect of grassland type on avifauna revealed that the distribution of birds was linked to vegetation structure (Krook et al., 2007).

In HiP in South Africa conservation efforts have seen a significant rise in the population of White rhino from 30 around 1920 to more than 1600 in 2008 (Cromsigt, Archibald, & Owen-Smith, 2016). Following their rapid decline due to hunting in the 19th and early 20th century, the rhino were given full protection after the 1920s and their numbers increased significantly, so much so that the white rhino was exported from HiP to other parks including reintroduction in Kruger National Park from the 1960s. However, since 2008 there has been a significant increase in rhino poaching, at first mostly targeting Kruger National Park, but more recently also in the KwaZulu-Natal province, including HiP. Poaching has decreased in Kruger National Park and now poachers are turning more attention to HiP where the population of White rhino is relatively large. The increasing threat rhino face because of poaching may have an effect on the ecosystem as a whole.

1.2. Ungulates & Habitat heterogeneity

African savanna biomes have the greatest diversity of ungulate species on Earth (du Toit & Cumming, 1999). The large diversity of ungulate species is directly linked to spatial heterogeneity of savannas, including the availability of nutrients and hence plant types partly due to seasonality, moisture, and fire (du Toit & Cumming, 1999). An important factor of ungulate diversity is the varied habitat selection by different sized ungulates. Smaller ungulates require more nutritious, shorter grass, than larger ungulates who have a greater tolerance for taller less nutritious grass (Arsenault & Owen-Smith, 2011). The low tolerance levels of smaller ungulate species means that they are reliant upon specific habitat types to feed upon. Impala (*Aepyceros melampus*) and Warthog (*Phacochoerus africanus*), often referred to as lawn specialists, are reliant upon habitat characterised by short stoloniferous grass areas or grazing lawns (Hempson et al., 2015). These habitats are created and maintained largely because of grazing by White rhino. In the past, poor understanding of the importance of short stoloniferous grasslands led to poor management practices including culling of grazers. Now, however, it is understood that grazing lawns are of vital importance for faunal and floral diversity (Cromsigt & Olf, 2008; Cromsigt, Prins, & Olf, 2009; Krook, Bond, & Hockey, 2007). Rhino are largely responsible for maintaining these grazing lawns and grassland areas that are not influenced by White rhino are associated with tall tussock bunch grasses.

By understanding the importance of rhino on grassland heterogeneity and mammals, conservation efforts can be focused upon key species whose impact on the ecosystems is more significant than most. This research aims to fill the gap in knowledge regarding the effect of White rhino on other components of biodiversity, particularly ungulate species in grazer dominated landscapes. By linking grazer distribution and abundance to grazing lawn extent, one can begin to further understand the importance of White rhino for other ungulate species. This understanding can help in formulating effective management practices that improve diversity and functioning of the savanna system which has been poorly understood in the past. It is hypothesised that rhino abundance and distribution will be positively correlated to the extent of grazing lawn. Further, the smaller ungulates that require highly nutritious biomass will be more abundant in areas of high lawn presence.

1.3. Research Question

This research will study the importance of white rhino for facilitating numerous herbivore species.

Hence, the following research question is suggested:

RQ: *To what extent do rhino affect grassland heterogeneity and what are the impacts on ungulate diversity in Hluhluwe-iMfolozi park?*

Sub-questions:

1. *What is the spatial extent of grazing lawns in HiP and how does this change over time?*
2. *To what extent do rhino affect grassland heterogeneity?*
3. *To what extent is ungulate abundance affected by GL extent?*
4. *How does the presence of rhino vary along the transects?*
5. *How does the presence of ungulate species vary across the transects?*

2. Methods

2.1. Study area

HiP was established in 1895 making it one of the oldest reserves of its kind in the world, ahead of Kruger (1926) and behind Yellowstone (1872). Located in the Kwa-Zulu Natal province of South Africa the park covers 960km² of non-uniform topography ranging from mountainous areas 700m asl to savanna grassland, at lowest 40m asl. HiP had a sub-tropical climate with mean minimum and maximum temperatures of 13°C and 35°C respectively. Average annual precipitation ranges from 650mm in the lower southern areas to 985mm in the higher altitude north of the park (Cromsigt et al., 2009).

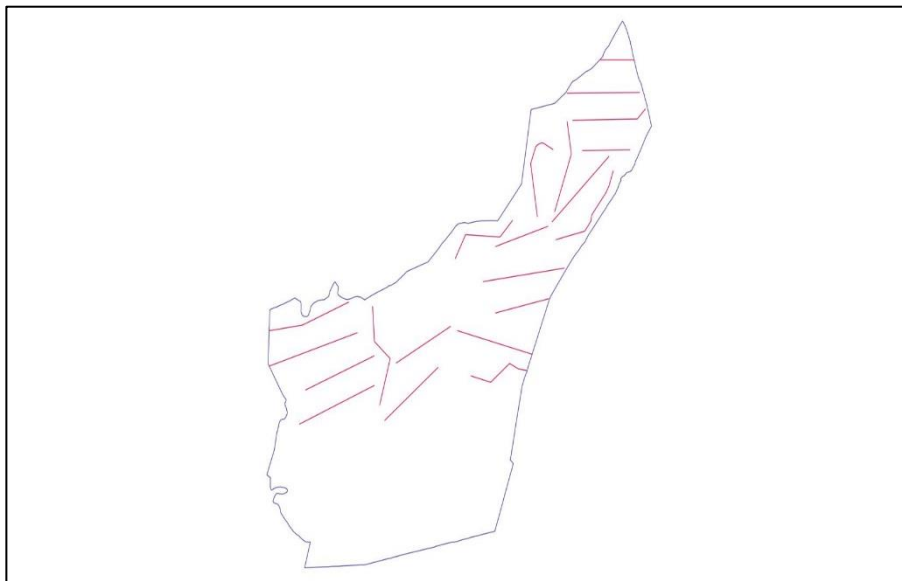


Figure 1. Shows the location of the transects walked within Hip.

2.2. Geology and vegetation

The predominant soil type in Hip is shales and sandstones with intermittent fractures of doleritic intrusions (Archibald, Bond, Stock, & Fairbanks, 2005). The soil type is related to the underlying geology of the park (Graham, 1992). The vegetation in HiP in the south largely consists of savanna woodlands, dominated by Acacia. In the more northern regions conditions are more mesic and as a result, the park is covered mostly by broadleaved species. Most of the grassland is associated with tall-bunch grass, whilst grazing-lawns areas make up a smaller proportion of the park's vegetation. Much of the grazing lawn species consist of grasses such as *Urochloa mosambicensis*, *Digitaria longiflora*, *Panicum coloratum*, and *Sporobolus nitens* (Whateley & Porter, 1983).

2.3. Line transects

Data collection took place along 21 line transects throughout HiP covering a large variety of habitats and conditions (Fig. 1). The transects range from 4-11 km in length totalling 190 km taken from Cromsigt et al., (2009). Along the transects, data was recorded for the presence of grazing lawns and the presence/abundance of herbivore species via dung counts. Grazing lawn presence was recorded

every 5 m in a 5x10 m area (5 m along the transect and 5 m either side of the transect). A grazing lawn is present if >75% of the plot is dominated by lawn species (Table 2). Dung counts take place on the transect and 1 m either side of the transect. the number of pellet groups is recorded for the herbivore's species along each 5 m plot giving an abundance of a species per 5 m. Rhino often use middens to mark their territory with dung spread other the landscape at low density, in this case, middens visible from the transects were recorded. All data collection has been done with the assistance of a guard and a field assistant, both of which, have great species identification skills required for accurate data collection.

Table 1. Herbivore species and associated codes

Elephant (<i>Loxodonta africana</i>)	El	Wildebeest (<i>Connochaetes taurinus</i>)	Wi
White rhino (<i>Ceratotherium simum</i>)	Rw	Nyala (<i>Tragelaphus angasii</i>)	Ny
Black rhino (<i>Diceros bicornis</i>)	Rb	Impala (<i>Aepyceros melampus</i>)	Im
Giraffe (<i>Giraffa</i>)	Gi	Warthog (<i>Phacochoerus africanus</i>)	Wh
Buffalo (<i>Syncerus caffer</i>)	Bu	Zebra (<i>Equus quagga</i>)	Ze

Table 2. Grazing lawn grass species and associated codes

Dactyloctenium australe	Da	Sporobolus nitens	Sn
Panicum coloratum	Pc	Cynodon dactylon	Cd
Urochloa mosambicensis	Um		
Digitaria longiflora	DI		

2.4. Grazing Lawn extent

ARCGIS has been used to produce lawn species presence/absence maps, which can be used to visualise the extent of grazing lawns spatially. Each 5m plot along a transect will have either a presence or absence of species. The percentage of grazing lawn is calculated as the length of lawn on a transect divided by the length of the transect multiplied by 100 to give a percentage value. The grazing lawn extent over time is compared using presence/absence maps as well as carrying out a one-way ANOVA tests including post-hoc (Tukey) tests to show the variance in the mean number of lawns per transect for each data collection year.

2.5. Herbivores

To see the relationship between herbivores and grazing lawns, regressions, ANOVA's and general Linear models were used. First, the dung count of each species was transformed to dung per m² and grazing lawn was calculated as percentage of grazing lawn along each transect. This then gives the abundance of herbivores per m² which can be compared to the percentage of grazing lawn on the transect. Then, to understand the initial relationship between the abundance of herbivores and the extent of grazing lawn a simple scatter plot is used to see the correlation between the herbivore species and the lawn extent. A general linear model was used to analyse the response of herbivores abundance to the number of grazing lawns. To run this model relative abundances were calculated by dividing the number of dung piles on grazing lawns by the number of 5m plots on the transects. Finally, a one-way ANOVA was used to analyse the variance in means of the number of grazing lawns for each data collection year.

2.6. Habitat Selection

To understand whether herbivore species were selecting for lawn or not, Jacobs Selection index was used.

The selection for lawn by herbivores is calculated as:

$$D = (r-p) / (r+p-2rp)$$

Where D is selection, r is the proportion of habitat used, and p is the proportion of habitat available. So, r= the dung on a lawn divided by the dung on a transect. p= the length of lawn on a transect divided by the length of the transect. Then the average selection for each species (>5 dung piles on the transect) is calculated to compare selection for each species.

3. Results

3.1. Grazing Lawn extent

The Percentage of grazing lawns varies across the transects, with the highest percentage of grazing lawn found on transect 10 with over 8% of the transect being dominated by grazing lawn. The average extent of lawn cover is 2.57% (Fig. 2).

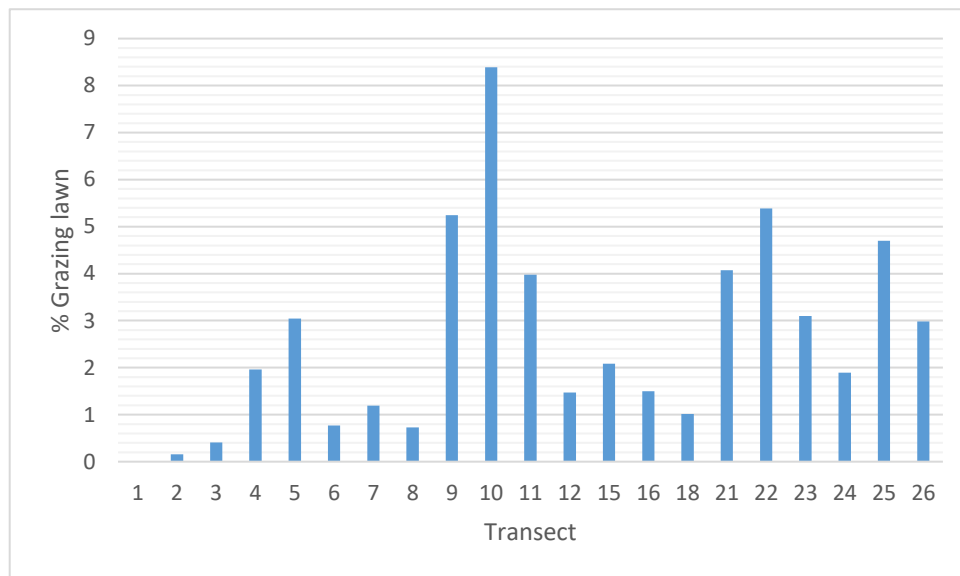


Figure 2. Percentage of grazing lawn cover across each transect.

The total number of grazing lawns has decreased dramatically since 2004. Less than half the 2004 total was found in 2014 and 2016. The number of lawns in 2010 (pre-drought) are lower than those during

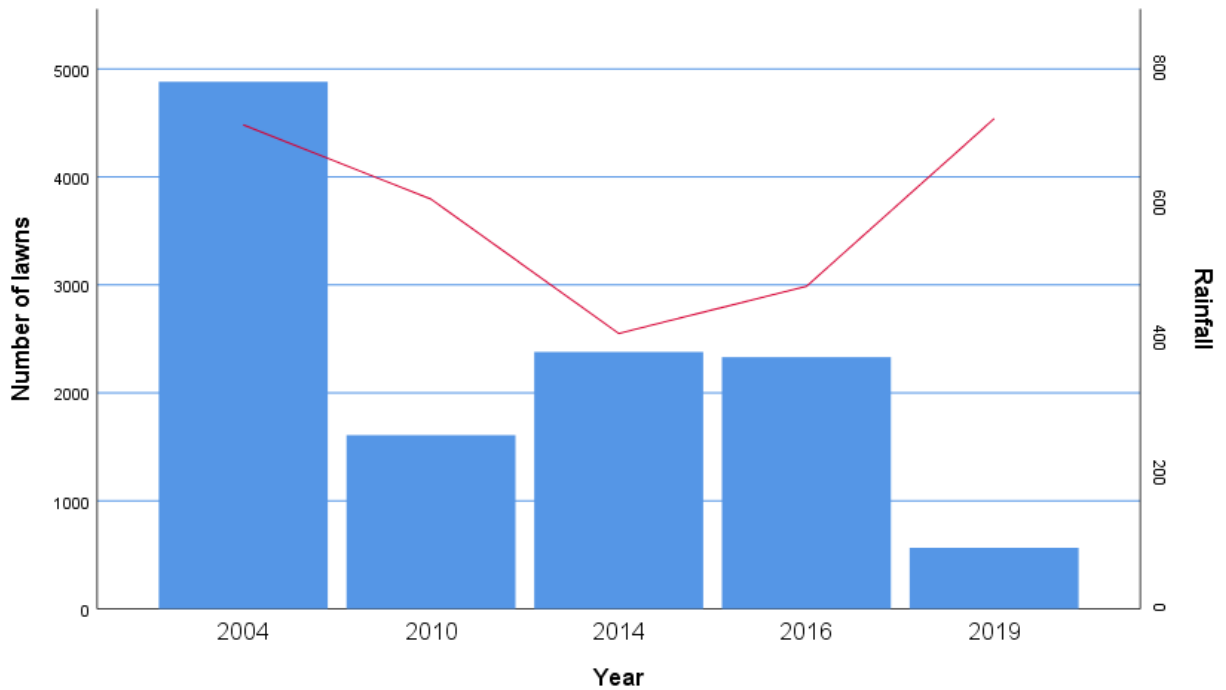


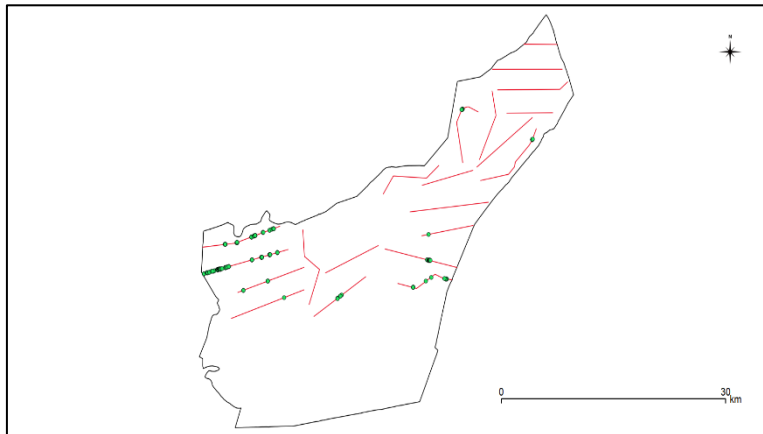
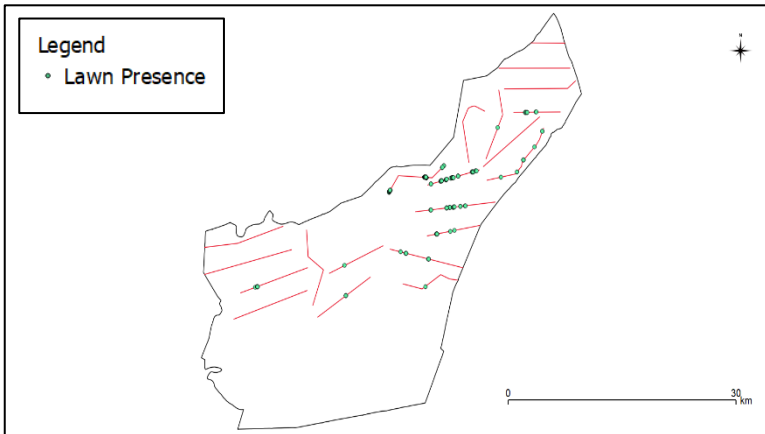
Figure 3. Total number of grazing lawns for each data collection year with average rainfall. Rainfall is taken as the average across weather stations for the data collection year. *The rainfall data for 2019 is taken from the previous year.

the drought whilst the number of lawns in 2019 (post-drought) are the smallest of all data collection years (Fig. 3).

The presence of grazing lawn is evenly distributed in the park except for the 3 most northern transects which have very little or no grazing lawn presence (Fig. 4). The distribution of the 6 lawn species is varied across the park with certain patterns emerging. *D. longiflora* is found in the central and northern regions of the park whilst *D. Australe* is shown to dominate the more northern part of the park and is sparse in the southern part. In contrast, *U. mosambicensis* and *S. nitens* are found almost exclusively found in the south of the park. *P. Coloratum* is found sparsely across the park mostly in the central and southern regions and *C. dactylon* is found only once.

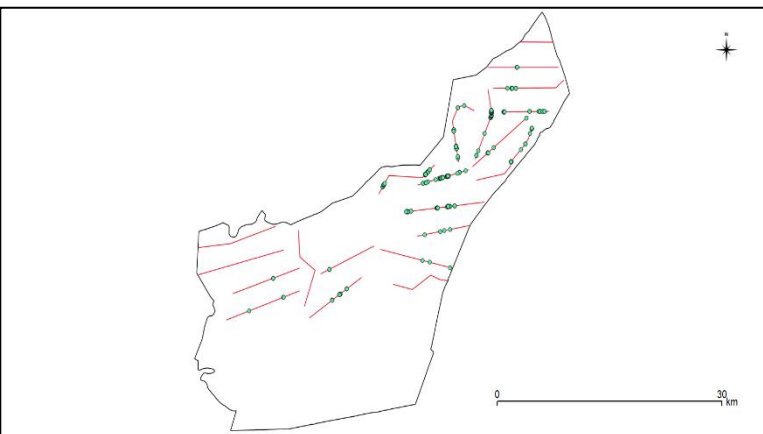
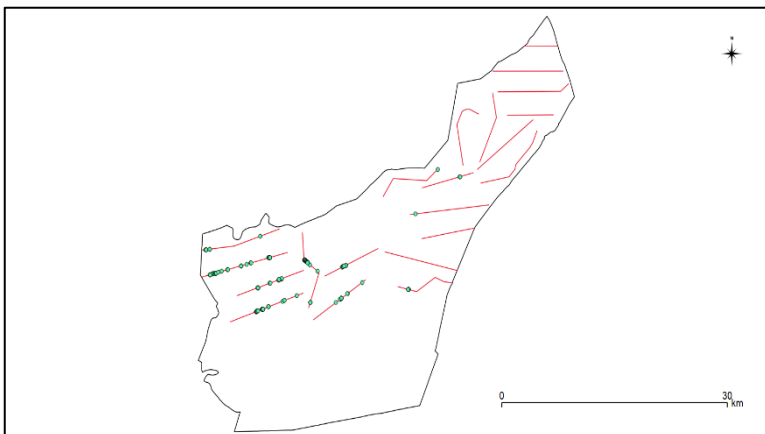
Digitaria longiflora

Urochloa mosambicensis



Sporobolus nitens

Dactyloctenium australe



Panicum coloratum

Cynodon dactylon

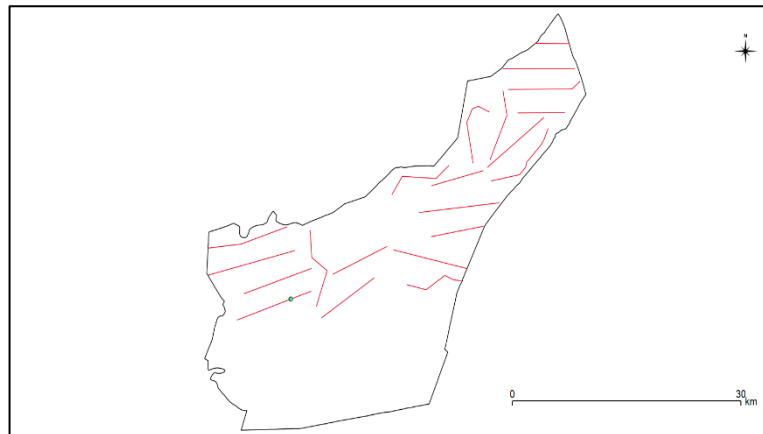
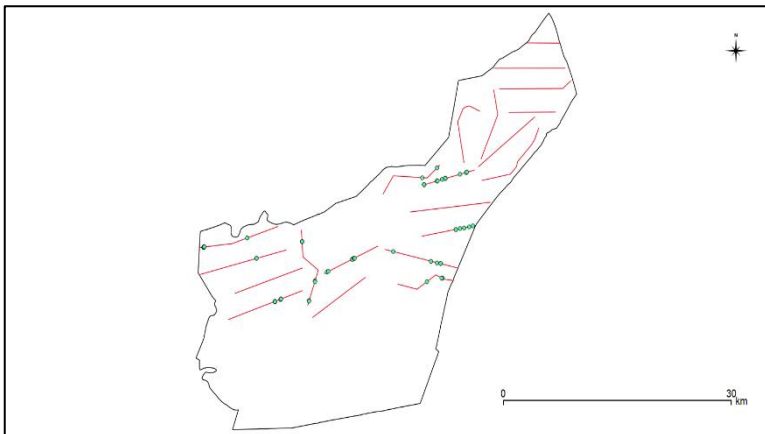


Figure 4. Presence of 6 lawn species (*Digitaria longiflora*, *Urochloa mosambicensis*, *Sporobolus nitens*, *Dactyloctenium australe*, *Panicum coloratum* and *Cynodon dactylon*) along the transects.

3.2. Herbivore distribution and abundance

The distribution and abundance of the short-grass specialists differs between species. Warthog are spread fairly evenly across the park without any presence in the 3 most northern transect and a slightly higher presence in the more central part of the park. White rhino are more abundant in the northern region of the park but are spread across most regions. Impala are the least distributed of the short grass species occurring mostly in the southern parts of the park (Fig. 5).

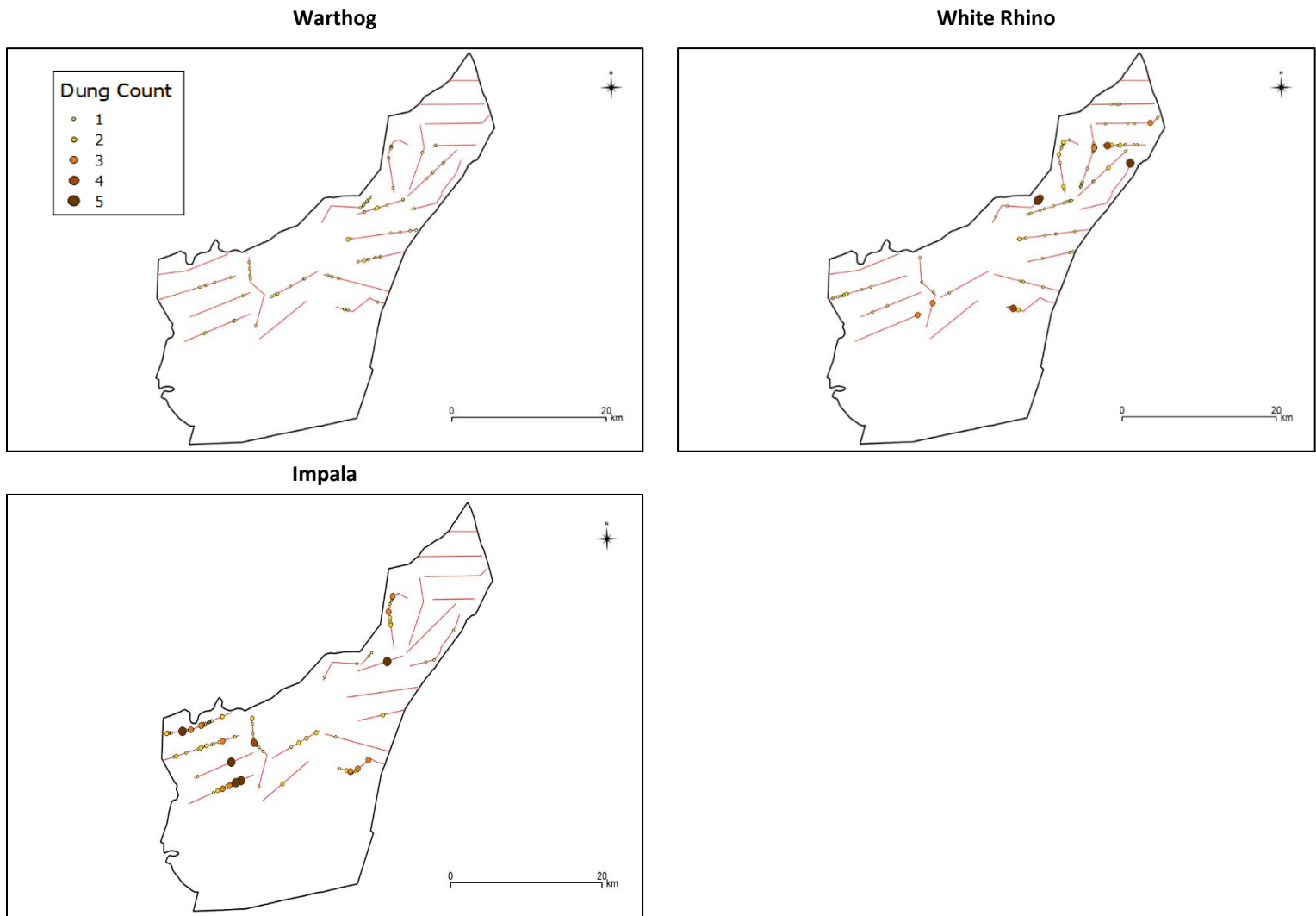
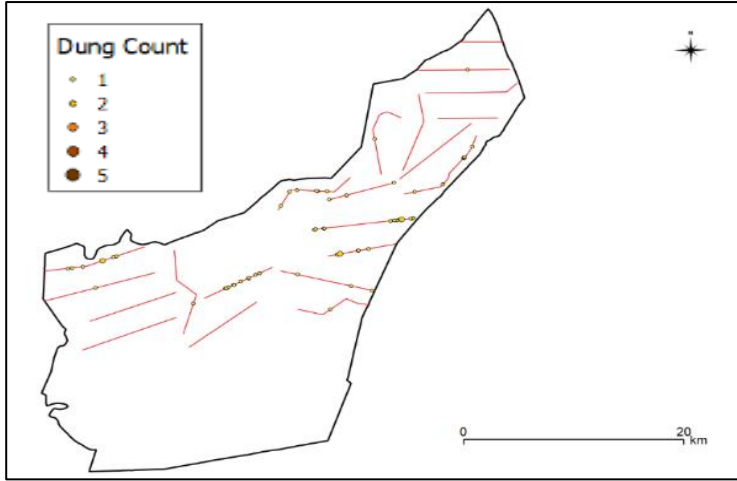


Figure 5. Shows dung counts for short-grass specialists; White rhino, Warthog and Impala along transects of Hluhluwe-iMfolozi park.

Buffalo have the second highest number of dung pellets groups in the park behind Elephants. The distribution of Buffalo is across the park. Zebra are located mainly in the central areas of the park with a higher presence in the south than in the north (Fig. 6).

Zebra



Buffalo

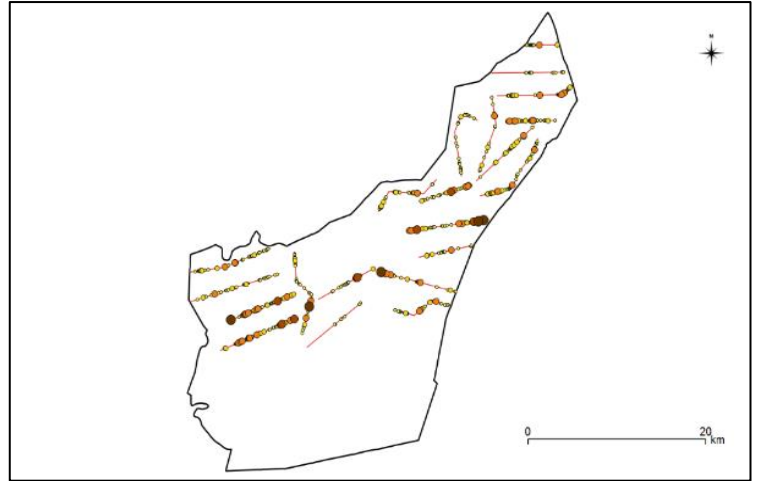


Figure 6. Shows the dung counts for the large grazers Zebra and Buffalo.

Elephant have the highest number of pellet groups of all species recorded. They are widely distributed across the park with presence recorded on all transects. Nyala are most abundant in the northern parts of the park. Giraffe are most abundant in the southern parts of the park (Fig. 7).



Figure 7. Dung counts for browsing species; Elephant, Nyala and Giraffe.

3.3. Herbivores and grazing lawn extent

White rhino shows a positive relationship to the percentage of grazing lawn (R^2 0.17). Warthog shows a slightly smaller correlation to lawn cover (R^2 0.12) whilst Impala shows only a very slight positive correlation with lawn percentage (R^2 0.017). Nyala is the only species to show a negative correlation to the percentage of grazing lawn (R^2 0.11) (Fig. 8).

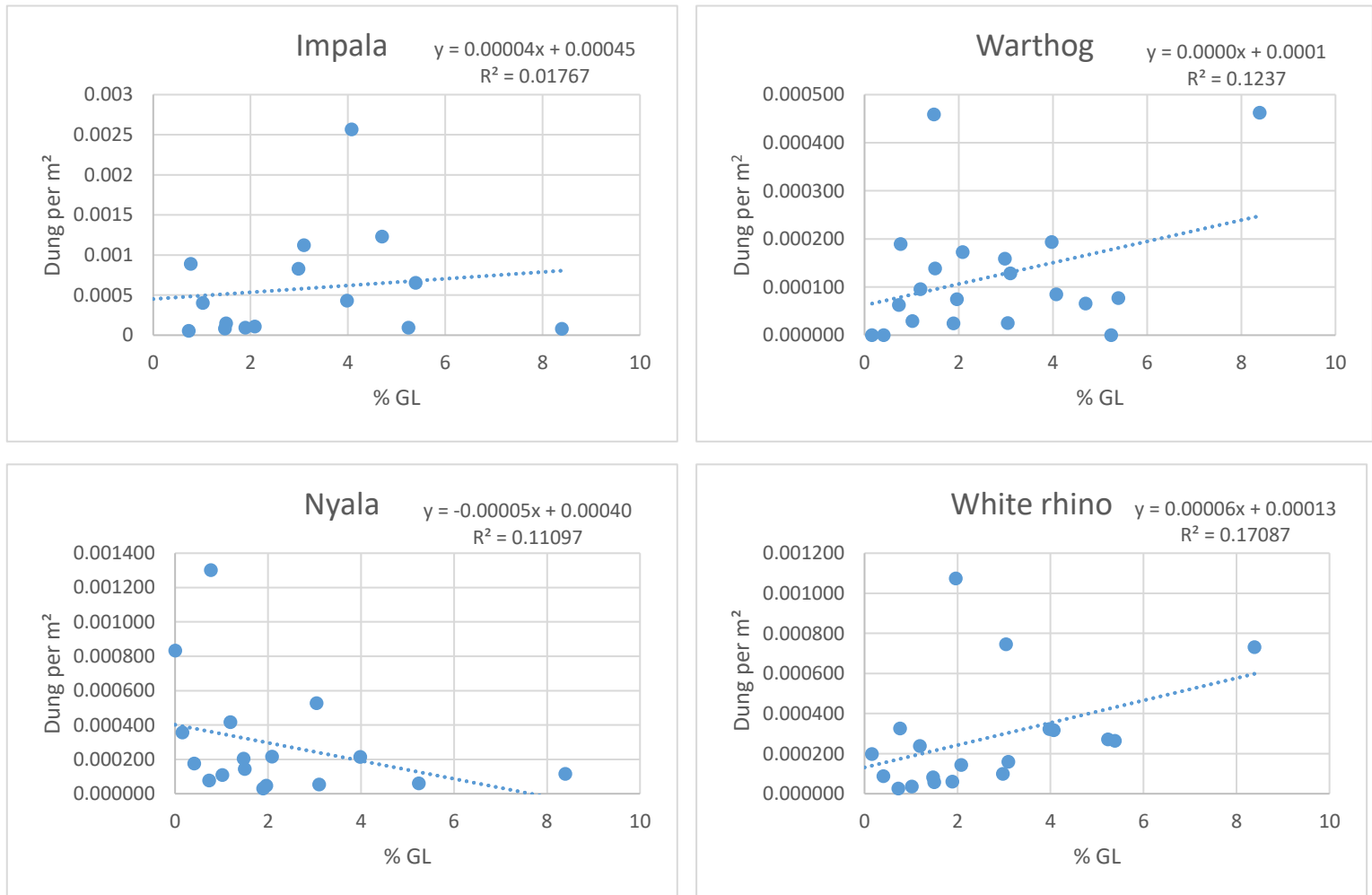


Figure 8. Dung per m² vs Grazing lawn percentage for Impala, Warthog, Nyala and White rhino.

The highest percentage of grazing lawn found occurs on transect 10 which coincides with the second highest White rhino dung per square metre. The peaks of the two seem to match as grazing lawn

percentage increases white rhino dung does so as well with exceptions along transects 16, 25 and 26 (Fig. 9).

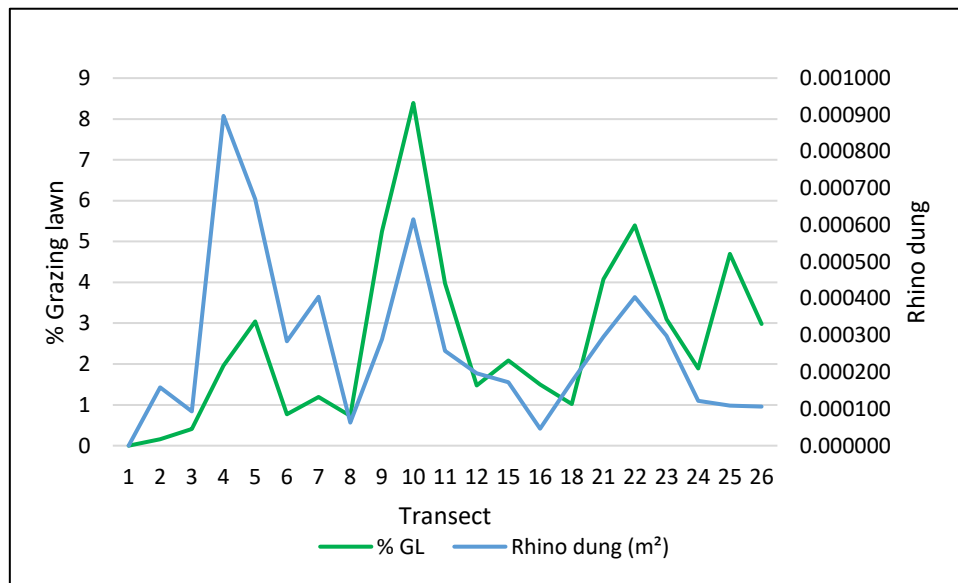


Figure 9. Grazing lawn percentage with Rhino dung (m²) along all transects.

The strongest effect of grazing lawn on herbivore presence is for White rhino, Warthog, Impala, and Nyala. White rhino shows the only statistically significant effect ($P < 0.05$) whereas, Buffalo and Zebra show little response to lawn cover ($P 0.477$, $P 0.544$ respectively) (Table 3). The effects of lawn on Warthog are not statically significant ($P 0.062$) but still strong whilst Nyala and Impala show a relatively strong effect to the cover of grazing lawns in comparison to the remaining species ($P 0.111$, $P 0.178$ respectively).

Table 3. General Linear model Results testing the effect of grazing lawn extent on Herbivore species abundance. Statistically significant results are shown in bold.

Dependent variable	df	F	P
Midden	1	.812	.379
White rhino	1	5.173	.035
Giraffe	1	1.684	.210
Buffalo	1	.526	.477
Zebra	1	.382	.544
Nyala	1	2.8	.111
Impala	1	1.960	.178
Warthog	1	3.943	.062
Elephant	1	2.176	.157
Error	19		

3.4. Selection

To test for habitat selection, in this case, grazing lawns, Jacobs selection index was used. The results find that Impala are the only species to select for lawn habitat, Impala has an average selection of (0.07), all other species show a negative selection of; -0.16 (Buffalo) to -0.806 (Nyala).

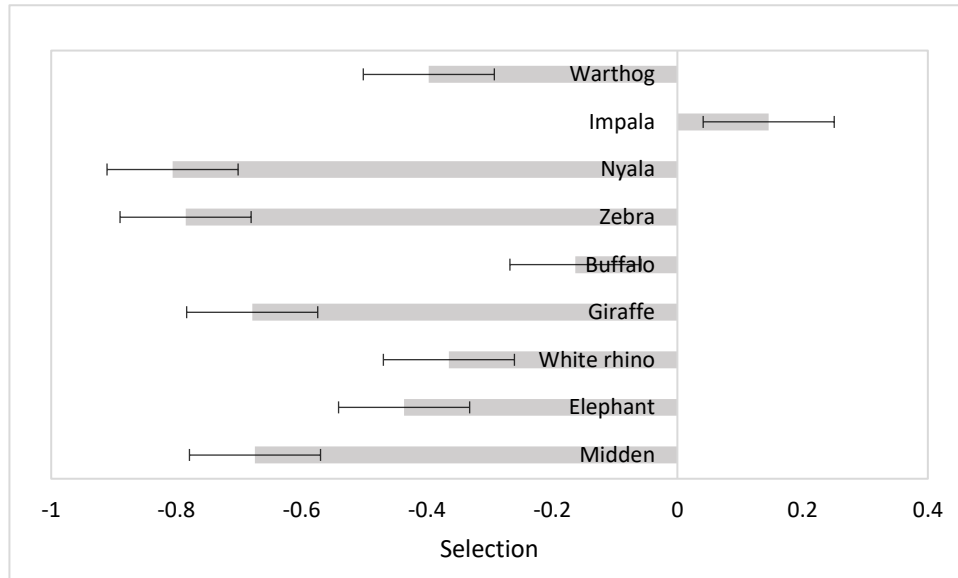


Figure 10. Jacobs selection index. Average selection for each species (>5 dung piles on the transect).

3.5. Lawn extent over time

The mean number of lawns per transect per data collection year shows significant differences. There is a >50% decline in the numbers of lawns since 2004 with 2019 having the fewest amount of lawns. In fact, 2004 is significantly different to 2010 & 2019 ($P < 0.001$, $P < 0.0001$) and to 2014 & 2016 ($P 0.019$, $P 0.016$) (Fig. 11).

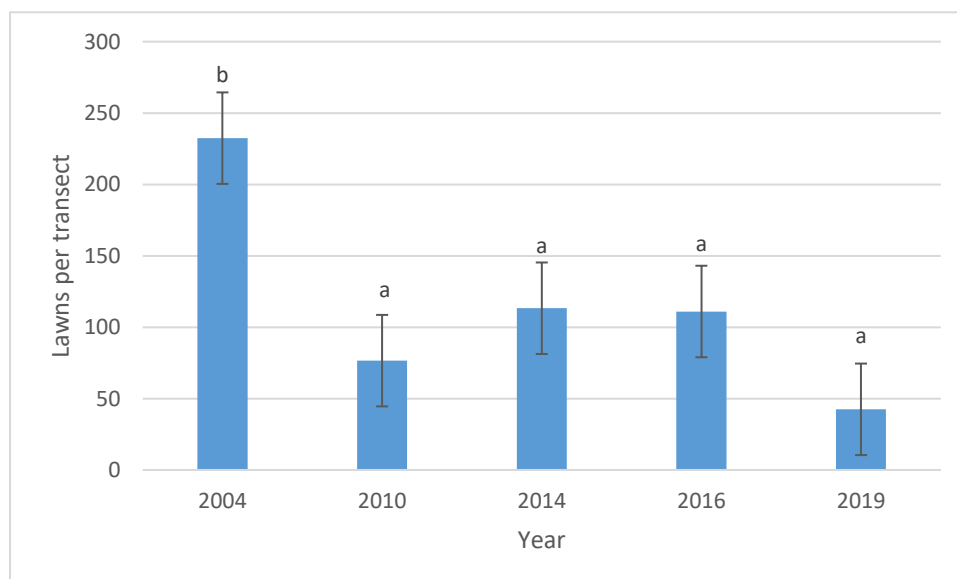


Figure 11. The mean number of lawns per transect across data collection years is shown including Standard error.

The spatial distribution of lawns does not appear to change throughout data collection years except for the presence of lawn on transect 1&2, the most northern transects, where there is recorded presence for the first time in 2016 and again for transect 2 in 2019. The change in the density of lawn along transect is the biggest difference across data collection years (Fig. 12).

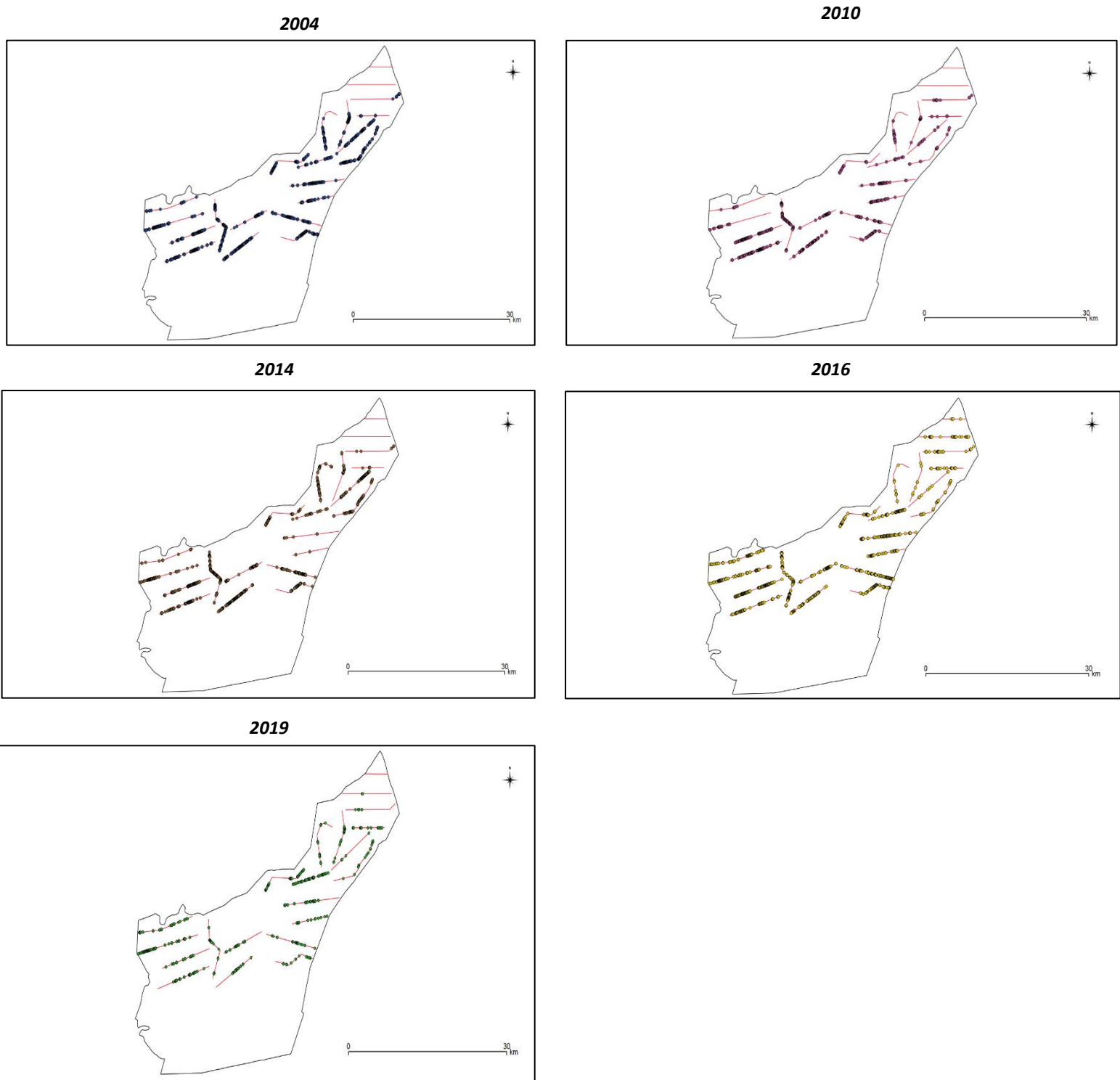


Figure 12. Presence/absence of grazing lawn across all data collection years.

4. Discussion

The results of this study found that the distribution of White rhino was positively correlated to the extent of grazing lawns, agreeing with initial hypotheses that White rhino are more abundant in areas of higher grazing lawn extent (Fig. 9; Table 3). Because White rhino are short-grass specialists the positive relationship with grazing lawns supports the idea that rhino are important for facilitating habitat heterogeneity, especially in forming and maintain grazing lawn habitat. The relationship found was analysed between single dung piles for White rhino and grazing lawn extent. However, as rhino often use territorial dung heaps (middens), to see the true extent of the relationship requires that middens are included. When comparing grazing lawn extent to the number of middens per m² there is no relationship (see Appendix A; Fig. 13). However, middens are not easily spotted and are not often found along the transects themselves. Hence it is difficult to use middens as an approximation of rhino abundance in this study. It is, therefore, required that a quantification for the number of rhinos using middens is established in order to improve the data assessing rhino abundance.

The effect of grazing lawn extent on the remaining ungulate species is found to be consistent with current theories that explain the importance of short stoloniferous habitat for several ungulate species. All herbivore species, except for Nyala, show positive correlations with the extent of grazing lawn cover. The herbivore species with the strongest relationship to grazing lawn cover are; Warthog, and Impala (Table 3). Interestingly, Warthog and Impala show different eating habitats in Hip compared with other parks. Impala, normally mixed feeders, have a diet consisting of more grass than in other areas (70% grass in their diet) whilst Warthog also predominantly graze in Hip (80% grass-dominated diet) (Botha & Stock, 2005). Given that smaller ungulates such as Impala and Warthog are more reliant upon smaller more nutritious grass habitats the strong effect of lawn extent on the abundance of these species is to be expected. Therefore, the effect seen of grazing lawn extent on the distribution and abundance of the smaller ungulate species is in line with our hypothesis and goes some way to explaining the importance of White rhino for creating and maintain lawn habitat which is vital for smaller sized ungulates.

Larger ungulates such as Buffalo and Zebra, who are not reliant upon lawn habitat, do not show a strong relationship with lawn. The feeding strategy of larger ungulates involves high biomass with lower nutritional value compared with the high nutrition low biomass diet of smaller ungulates. The distribution and abundance of buffalo and Zebra reflect these feeding strategies as both species are not found to be more abundant when the extent lawn habitat is higher. Furthermore, the abundance of the browsers (Nyala, Elephant & Giraffe) is not affected by grazing lawn extent. In fact, we see that Nyala has a negative relationship with lawn cover whilst elephant and giraffe show insignificant relationships with lawn extent (Fig. 7).

The results from the selection index seem to contradict the correlation and Linear effect models results. However, there is an important difference between the scale of each analysis which is one of the reasons for contrasting results. Firstly, by analysing the amount of dung on a transect scale against the proportion of lawn found on a transect you can see the effect of grazing lawn extent on herbivore abundance at a landscape level scale. This is important, especially when considering white rhino, again because of their use of middens. The use of middens as a proxy for determining habitat use is flawed because these middens are often not on the transect, are difficult to spot, and represent more than one rhino. Thus, assessing the selection of habitat through this method for White rhino is not representative of the real picture. Furthermore, the presence of dung on habitat which is not characterised as lawn does not necessarily mean that a species is not selecting for lawn. In order to collect more reliable data for this index, one must use a method that collects data on the species

habitat use for a longer period of time. This study only collected data for transects once over a 3-month period which may not be enough to get a full picture of species habitat use.

The extent of grazing lawn has declined since the first data collection in 2004. There are statistically significant differences in the lawn cover for all data collection years (Fig. 11). This decline in lawn extent could be a by-product of local changes in mechanisms involving, herbivory, fire, precipitation and soil nutrients (Sankaran, Ratnam, & Hanan, 2008). Slight changes or disturbances of the aforementioned mechanisms and their interrelations can result in a number of key changes occurring. One such change is the amount of woody cover found in savannas. Woody encroachment in savanna ecosystems has become widely reported in recent years, including in HiP (Buitenwerf, Bond, Stevens, & Trollope, 2012; Roques, O'Connor, & Watkinson, 2001; Balfour & Midgley, 2008). Local drivers of this change are complex but park managers are working hard to understand and manage these drivers. However, it is suggested that climate change is an important global driver influencing this vegetation change. In fact, the observed increase in CO₂ has been linked to increases in woody shrubs and tree densities in African savannas (Buitenwerf et al., 2012; Wigley, Bond, & Hoffman, 2010). Although, to what extent each factor influences this vegetation change is still hotly debated. Nevertheless, the observed increase in woody vegetation is well-reported and its implications for grassland cover are clear. Hence, there is a requirement for further research into the extent of this encroachment in HiP if its impact on grazing lawn cover is to be truly known. It has been suggested that an increase in drought frequency coupled with low grazing pressure can result in a reduction of shrub encroachment (Case & Staver, 2017). Although the mechanisms and exact reasons for woody encroachment are still being debated the decline of lawn cover found in this study is clear. This decline of lawn has potential implications for lawn specialists, White rhino, Impala, Warthog, and Wildebeest who are more abundant in areas with higher lawn presence (Wildebeest are excluded from this study due to a lack of data). Therefore, it is clear that more research is required to further understand the factors that influence encroachment and the best practices for restoring grassland habitat that is so important for ungulate species.

There are of course other factors that are potentially impacting the extent of grazing lawns and the abundance/distribution of herbivores. Firstly, the season in which data collection took place was different to previous data collection years. Hence, there could be a difference in the number of lawns found and dung counts made because of this. Certainly, the wetter summer season means that grass length is much longer than the drier winter months. This impacts the visibility of dung in tall grass areas, therefore, impacting the number of dung counted along the transects. Also, there are differences in feeding habitats of ungulates across different times of year (Codron et al., 2007). These could be linked to the availability of nutrients from specific food sources that are available at different times of year or the raising of young impacting the choice of habitat type, especially for smaller more vulnerable ungulates. The response of Herbivores to Predators is also something that influences the distribution of ungulates, which is particularly true for smaller ungulates that are at higher risk of predation (Hempson et al., 2015).

5. Conclusion

In conclusion, the results of this study indicate that White rhino are linked to grazing lawn extent, which in turn affects the abundance of ungulate species. The impact that White rhino have upon grassland heterogeneity comes from their ability to maintain large areas of short stoloniferous grass. This research has found that Lawn grass is important, especially for small ungulates with a low biomass, high nutrient feeding strategy. Past research regarding the influence White rhino has on maintaining grazing lawns is further backed up here by showing the spatial link between the two. When comparing previous data on grazing lawn extent, it was found that grazing lawn extent is declining. The affects this could have on the herbivores and other biodiversity in HiP requires further research. There are indeed many other factors influencing the distribution and abundance of ungulates, which have not been tested here. However, this study shows a clear link between ungulates and the presence of lawn habitat. The findings of this study increase our knowledge regarding the influence of White rhino on grassland heterogeneity in savanna ecosystems as well as their impact on the distribution of ungulate species.

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Appendix A – Regression Analysis

Contains regressions figures and GIS maps that have not been included in text but were part of the analysis.

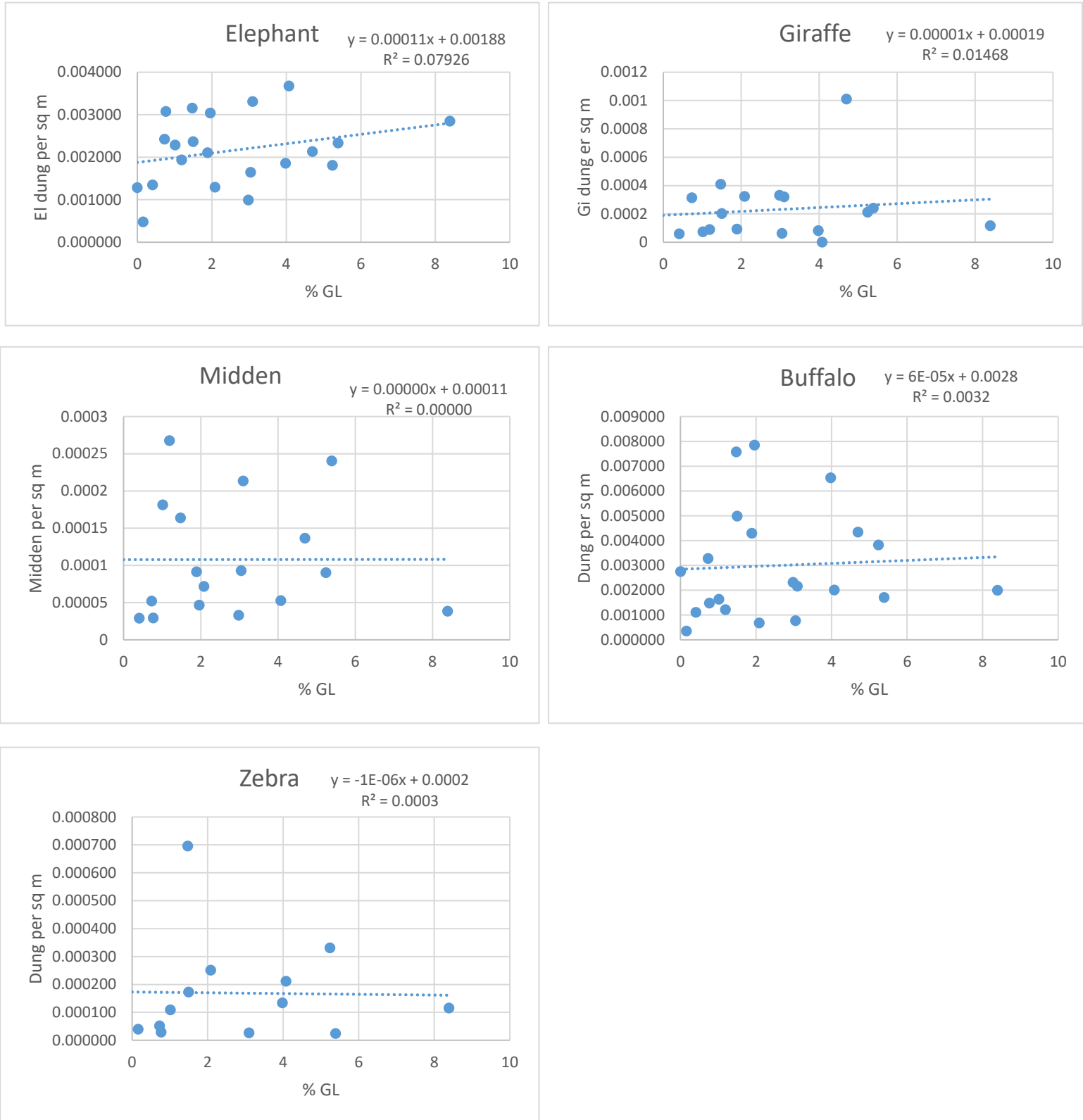


Figure 13. Regression analysis of remaining ungulate species not included in text.

Appendix B – GIS Maps

Figure x. Distribution of Middens

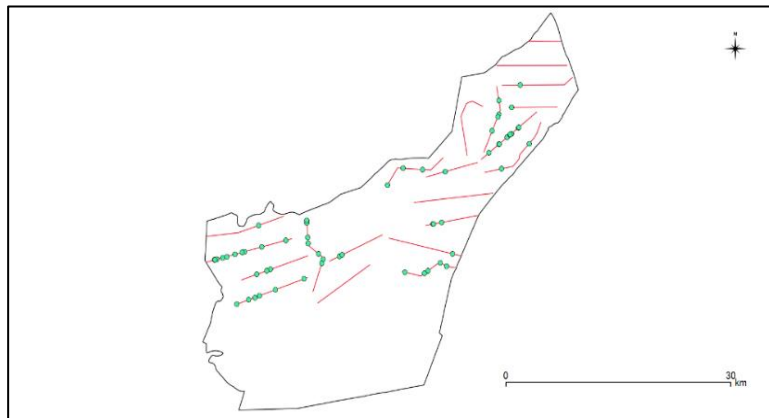


Figure x. Black rhino

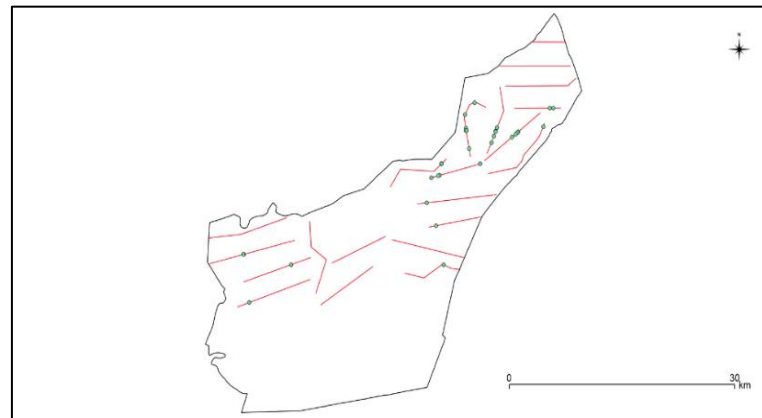


Figure x. Wildebeest



Figure 14. Distribution of dung for Herbivores not included in text.