Modelling and predicting mammalian wildlife abundance and distribution in semi-arid Gonarezhou National Park, south eastern Zimbabwe

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Abstract

Purpose – The purpose of this study is to model and predict mammalian herbivore species abundance in Gonarezhou National Park (GNP), south eastern Zimbabwe. The study also aims to determine and evaluate the distribution-abundance patterns in GNP.

Author would like to extend our gratitude to Great Zimbabwe University for support and allowing the use of their facilities and equipment. Many thanks are extended to Zimbabwe Parks and Wildlife Authority and Frankfurt Zoological Society particularly Elsabe Van der Westhuizen for availing data on mammalian herbivore species.

Author contributions: Talent Murwendo: Conceptualisation of study and writing the original draft manuscript.

A. Murwira: conceptualisation of the study.

M. Masocha: Study design and write up.

Disclosure statement

There is no conflict of interest to report on.

Data availability statement

Data used in this study was obtained from the Frankfurt Zoological Society in Chipinda Pools, Chiredzi

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Data deposition

website: www.uz.ac.zw/science/geography/

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Design/methodology/approach – Using aerial survey data from 1980 to 2016, the authors use the rank-abundance model to determine the abundance of mammalian herbivores in GNP. Regression analysis is used to show the mammalian herbivore species distribution-abundance relationship.

Findings – The findings point to a high species richness and evenness in the study area with common species (15%), intermediate (30%) and rare (60%). There is a positive significant relationship (p = 0.00, R^2 = 0.9642) between abundance and distribution with common species occupying wider spaces and rare species occupying narrow spaces.

Research limitations/implications – Aerial surveys in GNP are not continuous and are biased towards elephants. The inclusion of other mammalian herbivore species including domestic animals in subsequent surveys made the aerial reports useful.

Originality/value – Studies in GNP have tended to concentrate on the population of mammalian herbivores and this marks a shift in emphasis in such studies. The monitoring of mammalian species improves the conservation and management of GNP. Apart from making planning and policy decisions from an informed point of view small animals also need attention as they are numerically few than the large threatened mammals.

Keywords Wildlife, Wildlife abundance, Wildlife distribution, Mammalian herbivore species, Gonarezhou National Park, Semi-arid savanna, Abundance-distribution relationship

Paper type Research paper

Introduction

Wild animals, particularly mammalian herbivore species are important for ecosystem health and status (Khaemba, 2000; Villarreal *et al.*, 2013). They help to maintain the balance of an ecosystem as they form a link in energy flows within the ecosystem (Taylor *et al.*, 2018). Mammalian herbivore species depend on vegetation and carnivorous species depend on them for survival. Some keystone mammalian herbivore species also regulate the growth of vegetation, soil structure and water availability (Verberk, 2011). Due to their co-occurrence, interaction and competition they affect vegetation distribution, phenology and morphology (Taylor *et al.*, 2018; Pettorelli *et al.*, 2009). Similarly, the abundance and distribution of herbivore species mammals vary within a landscape. Large common mammalian herbivore species have an influence on small rare mammals as they compete for resources and sometimes with detrimental negative effects when small mammals are exposed to predators (Taylor *et al.*, 2018). It is, therefore, critical to know the abundance and distributional patterns of mammalian herbivore species in south east Zimbabwe. In this study, we model and predict mammalian herbivore species to determine their relative abundance and distribution in semi-arid savanna Gonarezhou National Park (GNP), an important vehicle for economic development in south eastern Zimbabwe. Understanding mammalian herbivore species relative abundance and their distribution are important in the conservation and management of mammalian species and their habitat. In GNP little is known about the relative abundance of mammalian herbivore species and their perceived spatial distribution. While the population of each mammalian herbivore species is known, competition and interaction of such species at habitat level needs to be improved. The identification of abundant common species and rare more often, smaller and few species will, in turn, determine species richness and evenness of an ecosystem (Verberk, 2011; Gandiwa *et al.*, 2013; Winterbach *et al.*, 2015).

Globally, mammalian herbivore species are under threat due to human encroachment and environmental changes (Dunham, 2012; Khaemba, 2000; Villarreal *et al.*, 2013). In GNP, poaching of wild animals and other resources, as well as encroachment by settlements have become common ((Dunham, 2012; Gandiwa *et al.*, 2013). Trends on the rapidly changing nature of ecological landscapes at a global level have necessitated the need for monitoring of large and small mammalian herbivore species using available aerial survey data (Chamaillé-Jammes *et al.*, 2007; Pettorelli *et al.*, 2009; Redfern *et al.*, 2002; Schlossberg *et al.*, 2016; Walter and Hone, 2003). There has been an increase in data on mammalian herbivore species through aerial surveys in semi-arid parts of southern Africa and East Africa (Oindo, 2008; Omondi *et al.*, 2006; Pettorelli *et al.*, 2009; Walter and Hone, 2003). However, the literature on mammalian species relative abundance and distribution in GNP has not correspondingly increased despite availability of such aerial survey data.

The significance of understanding mammalian herbivore species relative abundance and distribution within ecosystems has been recognised for quite some time and pioneered through research (Verberk, 2011; Preston, 1948; Winterbach *et al.*, 2015; Magurran, 2004; Matthews and Whittaker, 2014; Preston, 1948). Models were formulated that highlight species abundance (Magurran, 2004) and critiqued (Matthews and Whittaker, 2014). General conclusions indicate that few species are at the high abundance and many at intermediate and low abundances, (Barker *et al.*, 2014; Godfray and Lawton, 2001; Matthews and Whittaker, 2014; Preston, 1948). Similarly, a positive relationship exists between distribution and abundance of species (Verberk, 2011), with common species being widespread and rare species being thinly spread over an area (Johnston *et al.*, 2015; Magurran, 2004; Verberk, 2011).

Lognormal curve (Preston, 1948), broken stick curve, log series, neutral theory and the geometric series models are some of the models used to depict abundance (Matthews and Whittaker, 2014). While these models have been tried and tested on plants and animals at different scales the lognormal curve theory has stood the test of time (Magurran, 2004; Matthews and Whittaker, 2014; Oliveira and Batalha, 2005). The rank-abundance plot is advantageous in that it displays contrasting patterns of abundance (Magurran, 2004). Technical challenges have been highlighted (Villarreal *et al.*, 2013; Magurran, 2004) where species are numerous. Modelling patterns of species relative abundance has become increasingly regular and popular in many parts of the world (Johnston *et al.*, 2015; Magurran, 2004; Johnston *et al.*, 2015; Oindo and Skidmore, 2002; Walter and Hone, 2003).

Data on species abundance have become easier to obtain through aerial surveys of mammalian herbivore species distribution, which are increasing in southern Africa (Dunham, 2012; Johnston *et al.*, 2015; Schlossberg *et al.*, 2016; Walter and Hone, 2003; Winterbach *et al.*, 2015). In GNP, studies using aerial survey data concentrated on elephants and other large mammalian herbivore species' population's increase (Dunham, 2012). However, reliance on aerial surveys alone for such studies has been questioned (Ndaimani *et al.*, 2017; Redfern *et al.*, 2002). Despite the questions around the use of aerial surveys census counts, they remain an emerging data source and a stepping stone towards an assessment of wildlife governance.

Using GNP census reports between 2000 and 2016, the major objective of this study is to determine mammalian herbivores species relative abundance and distribution using aerial survey data in GNP, south eastern Zimbabwe since 2000 AD. Specifically, we first model large mammalian herbivore species relative abundance using the rank-abundance model (Whitaker model) and secondly, test the distribution-abundance relationships in semi-arid savanna GNP.

Materials and methods

Study area (Figure 1)

GNP is part of the Greater Limpopo Transfrontier Conservation Area, designated to protect and conserve the ecological landscape particularly biodiversity in south eastern Zimbabwe. It is the second-largest protected area in Zimbabwe covering about 5,053 km^2 (Dunham,

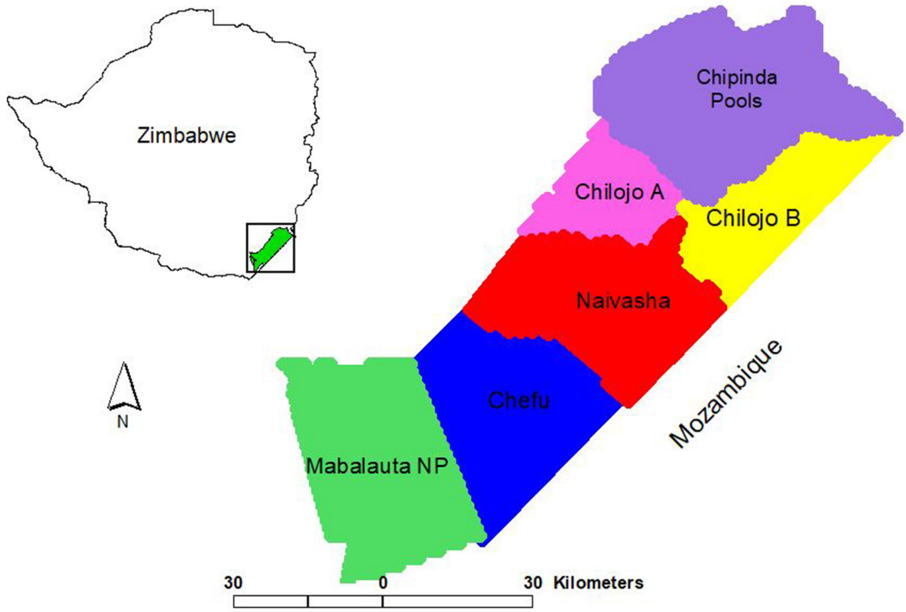


Figure 1.
Gonarezhou National Park in south eastern Zimbabwe (−21° 0.39`59.99``S; 31° 0.39`59.99``E)

Notes: Six census strata were used and their percentage area in brackets; Chipinda Pools (23.58), Chilojo A (9.29), Chilojo B (12.16), Naivasha (17.86), Chefu (20.55) and Mabalauta (16.57), which were consistently used for Mammalian herbivore counts from 2001–2016

2012; Gandiwa, 2013; Gandiwa *et al.*, 2013). GNP is a hot and dry low-lying area, therefore crop cultivation is difficult and wildlife management becomes a favourable economic activity (Dunham and Mackie, 2002).

Vegetation, which forms part of the habitat for mammalian herbivore species, comprise of **s**outhern African Bushveld, **s**outhern miombo woodlands, Zambian and Mopane woodlands biomes and is an important source of food and shelter for herbivores (Cunliffe *et al.*, 2017; Gandiwa, 2013). Deciduous forested broadleaved woodlands with a mixture of shrublands and grassland are common. C*olophospermum Mopane*, dominated by dry deciduous savanna woodlands comprising physiognomic types of 59% woodland savanna, 40% scrubland and 1% savanna grassland (Cunliffe *et al.*, 2017; Gandiwa, 2011; Gandiwa *et al.*, 2013; Martin *et al.*, 2016) make up the classifications. Shrublands thrive on deep sandy alluvium soils and are surrounded by acacia trees, while forested deciduous woodlands of *Julbernadia globiflora*, *Brachystegia glaucescens and Guiborrtia conjugata* are found in sandstone and basaltic Central GNP. **A** mixture of Mopane woodlands, scrubland and grasslands are found in southern GNP (Dunham and Gandiwa, 2009; Dunham, 2013; Martin *et al.*, 2016; Clegg and O'Connor, 2012).

A number of herbivore mammalian species, namely, elephants (*Loxodonta Africana*), buffalo (*Syncerus caffer*), zebra (*Equus quagga burchelii*), giraffe (*Giraffa Camelopardalis*), kudu (*Tragelampus strepsiceros*), impala (*Aepyceros melampus*), eland (*Taurotragus oryx*), nyala, (*Tragelampus augastic*), wildebeest (*Connochaetes taurinus*), waterbuck (*Kobus ellipsiprymnus*), warthog (*Phacochoerus africanus*), common duiker (*Sylvicapra grimmia*), steenbok (*Raphicerus campestris*), ostrich (*Struthio camelus*), grysbok (*Raphicerus melanotis*), sable (*Martes zibellina*) and of late cattle (*Bos Taurus*), sheep (*Ovis aries*), goats (*Capra aegagrus hircus*) both treated as shoats in this research and donkeys (*Equus africanus asinus*) have been observed (Dunham, 2012).

Aerial census data

Aerial survey census counts for GNP have been carried out since 1980 to date (Dunham, 2012; Dunham and Mackie, 2002; Ndaimani *et al.*, 2017). The census surveys in GNP were and are still biased towards elephants as defined by the search effort and sampling intensity (Dunham *et al.*, 2007; Dunham, 2013). Aerial surveys in GNP were conducted in 1980, 1981, 1982, 1983, 1984, 1986, 1987 and 1989 (Dunham, 2013). In the 1990s, some large mammalian herbivore species were added to the census counts particularly in 1991, 1995, 1996 and 1999. Since 2000s, comprehensive aerial surveys were conducted in 2001, 2007, 2009, 2013, 2014 and 2016 (Dunham and Van der Westhuzein, 2016).

Aerial census count surveys in GNP used GPS receiver fitted small aircraft flying at an average of 170 km/h and a height of 296 m above the ground (Dunham, 2012). CITES MIKE programme standards were used (Dunham, 2013) so that the data are comparable with earlier surveys especially for the 2001 survey. Systematic parallel transects with a width of 300 m were demarcated in each stratum (Dunham and Gandiwa, 2009; Dunham, 2013). The sampling intensity of 12% was used. Other mammalian herbivore species including domestic livestock such as *Equus africanus asinus*, *Bos Taurus*, *Ovis aries* and *Capra aegagrus hircus* (collectively referred to as shoats) were also included as they contributed to the degradation of the national park.

The 2001, 2007, 2009, 2013, 2014 and 2016 surveys were the only ones conducted for GNP between 2000 and 2016. These were, however, comprehensive, comparable and included a variety of mammalian herbivore species (Dunham, 2013; Dunham *et al.*, 2007; Dunham, 2012; Dunham and Gandiwa, 2009). The results of the census counts were obtained from *Frankfurt Zoological Society* stationed at Chipinda Pools, Chiredzi. A year in which some of the species were not included it was assumed that such animals were not observed. Sampling intensity was no less than 20% in all the census counts.

The hippopotamus (*Hippopotamus amphibious*), the crocodile *(Crocodylus porosus), Loxodonta Africana* carcasses, the ground hornbill *(Bucorvus leadbeateri)* and poachers' tents were left out for a number of reasons related to data compatibility. Each of the selected mammalian herbivore species was recorded and their totals tallied with the total for the whole of GNP. Ultimately, each strata for GNP became an important entry point for data analysis rather than the census count years.

Data analysis

The frequency of occurrence in the strata was used to classify mammalian herbivores species, with percentages greater than 60% classified as common, 30–60% as intermediate and less than 30% as rare. The mammalian herbivore species were ranked in decreasing order of abundance, the most abundant specie was ranked as 1 and the second most as 2 up until the least abundant species. These were placed on the x-axis as rank. The relative abundance of species was placed on the y-axis as a percentage. Even though the number of mammalian herbivore species was small, the data was log-transformed to reduce the clustering of data at lower levels in the testing of the distribution-abundance relationship curve. Measures of an abundance-distribution relationship were calculated as the mean density of each species across all the strata where each species occupied over a six-year period. The computation of local density for each species was performed by taking density in each occupied stratum and then averaging them across the years. Similarly, the measures of distribution were simplified to confinement to the number of strata occupied and the presence of mammalian herbivore species. Distribution-abundance relationship was obtained by plotting abundance on the *y*-axis and distribution on the *x*-axis. A goodness of fit line through regression analysis was used to test the significance of the relationship.

Results

Patterns in species abundance in Gonarezhou National Park

The results on abundance show two important trends in GNP. Firstly, the spatial distribution of mammalian herbivore species indicates the total number of species, the percentage of species and species richness in GNP in each stratum (Table 1). Mammalian herbivore species' commonness and rarity classes are indicated as 15% of the species are common, 25% are intermediate while about 60% are rare (Table 2). Some species were observed irregularly in census strata as Chilojo A and B, the roan antelope (*Hippotragus equinus*) was observed only once in 2007 while the *Raphicerus melanotis* was observed once in 2009, at the same time domesticated animals (*Bos Taurus*, *Ovis aries*, *Capra aegagrus hircus* and *Equus africanus asinus*) are regular sights on strata sharing the boundaries with settlements and are becoming moderately common in the Mabalauta stratum. *Bos Taurus* has increased in abundance and distribution since 2000 AD except for strata further away from settlements such as Chilojo B, Naivasha and Chefu. *Ovis aries* and *Capra aegagrus hircus* are also prevalent but on the rare side while *Equus africanus asinus* are also rarer. The *Taurotragus oryx* and the *Aepyceros melampus* are featuring quite often on common species. In Chipinda pools, the *Aepyceros melampus* is the dominant species than the *Loxodonta Africana*.

Secondly, the result shows the rank-abundance distribution for mammalian herbivore species in each stratum and GNP. In all cases, there is a dominance of two or three species with clustering at the lower ranks. The hierarchical distribution is shown in Figure 2 below.

Distribution-Abundance relationships

Regression analysis showed a significant positive relationship (p = 0.000; R^2 = 0.9641) between the distribution and abundance. An increase in an area results in a corresponding increase in density. Figure 3 shows that the abundant herbivore species with high densities occupying larger areas in GNP and rare species with low densities are clustered in smaller specific areas. Common mammalian herbivore species occur at more sampling localities and rare mammalian herbivore species are narrowly distributed. The common species are found in all the census strata at dominant levels and have a high density at around between 0.85/km^2 to 4.0/km^2. Rare herbivore species have lower densities and are clustered on smaller proportions of land (Table 3).

Table 1.
A summary of the total estimate, percent of estimated species and species richness of census strata and GNP

Stratum	Total no. of species	Percent of total species	Individual species present
Chipinda	10,340	38.62	16
Chilojo A	2,657	9.92	16
Chilojo B	5,361	20.02	17
Naivasha	1,928	7.20	15
Chefu	2,825	10.55	14
Mabalauta NP	3,666	13.69	19
Total	26,777	100	19

Table 2. The common, intermediate and rare species in the six strata and GNP in general between 2000 and 2016

Stratum	Common	(%)	Moderately common	(%)	Rare	(%)
Chipinda Pools	Aepyceros melampus; Loxodonta Africana; Syncerus caffer	19	Equus quagga burchelii; Bos Taurus; Tragelampus strepsiceros; Connochaetes taurinus	25	Giraffa Camelopardalis; Tragelampus augastic; Struthio camelus; Equus africanus asinus; Raphicerus campestris; Taurotragus oryx; Shoats; Kobus ellipsiprymnus; Taurotragus oryx	56
Chilojo A	Loxodonta Africana; Syncerus caffer; Taurotragus oryx	19	Bos Taurus; Kobus ellipsiprymnus; Connochaetes taurinus; Tragelampus strepsiceros	25	Tragelampus augastic; Shoats; Martes zibellina; Aepyceros melampus; Giraffa Camelopardalis; sylvicapra grimmia; Raphicerus campestris; Raphicerus melanotis	56
Chilojo B	Loxodonta Africana; Syncerus caffer; Taurotragus oryx	19	Aepyceros melampus; Giraffa Camelopardalis; Tragelampus strepsiceros	19	Tragelampus augastic; Phacochoerus africanus; Equus quagga burchelii; Kobus ellipsiprymnus; Connochaetes taurinus; Martes zibellina; sylvicapra grimmia; Struthio camelus; Raphicerus campestris; Raphicerus melanotis	69
Naivasha	Loxodonta Africana	16	Aepyceros melampus; Equus quagga burchelii; Syncerus caffer; Giraffa Camelopardalis; Taurotragus oryx	13	sylvicapra grimmia; Raphicerus campestris; Tragelampus strepsiceros; Tragelampus augastic; Connochaetes taurinus; Phacochoerus africanus; Kobus ellipsiprymnus; Martes zibellina; Raphicerus melanotis	63
Chefu	Loxodonta Africana	15	Aepyceros melampus; Syncerus caffer; Taurotragus oryx	23	Raphicerus campestris; Phacochoerus africanus; Equus quagga burchelii; Kobus ellipsiprymnus; Giraffa Camelopardalis; Cattle; Tragelampus strepsiceros; Struthio camelus; Tragelampus augastic	62
Mabalauta	Loxodonta Africana; Taurotragus oryx; Syncerus caffer; Aepyceros melampus	18	Giraffa Camelopardalis; Bos Taurus; Tragelampus strepsiceros; Shoats; Equus quagga burchelii	29	Connochaetes taurinus; Tragelampus augastic; Phacochoerus africanus; sylvicapra grimmia; Kobus ellipsiprymnus; Raphicerus campestris; Raphicerus melanotis; Martes zibellina	53
GNP	Loxodonta Africanas; Aepyceros melampus; Syncerus caffer	15	Tragelampus strepsiceros; Shoats; Giraffa Camelopardalis; Equus quagga burchelii	30	Struthio camelus; Tragelampus augastic; Kobus ellipsiprymnus; Taurotragus oryx; Martes zibellina; Bos Taurus; sylvicapra grimmia Raphicerus campestris; Connochaetes taurinus; Phacochoerus africanus; Equus africanus asinus; Raphicerus melanotis	65

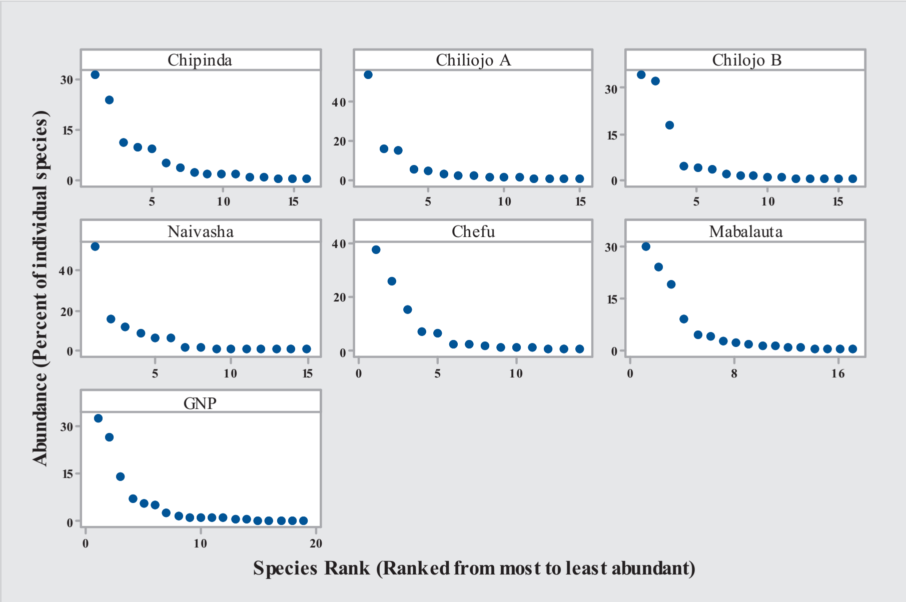


Figure 2.
Rank abundance distribution for Chipinda Pools, Chilojo A, Chilojo B, Naivasha, Chefu Mabalauta and GNP

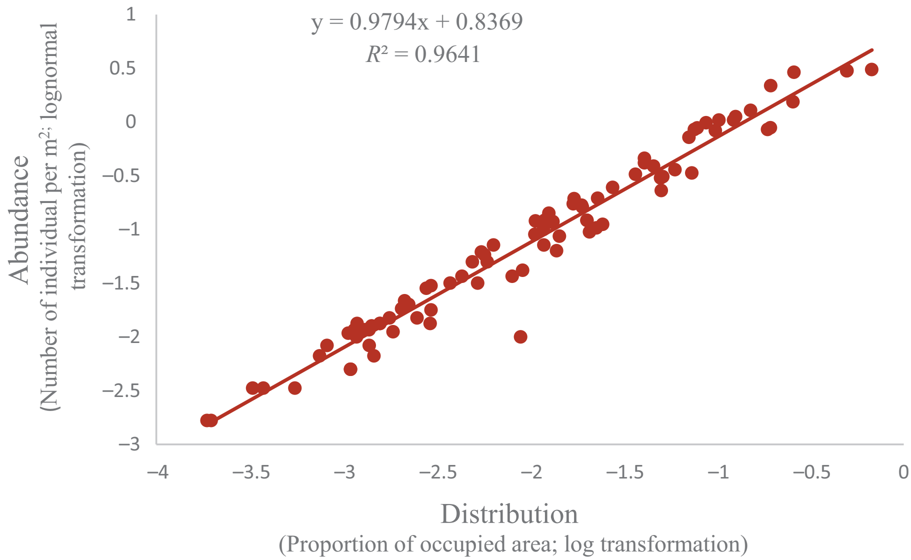
Notes: The overall rank abundance distribution for GNP is calculated from a total abundance of individual species for each stratum. The high species evenness is shown by the clustering of species at lower levels. Except for Mabalauta and GNP, the other strata show a species richness not extending 16 species as compared to the 19 species under consideration

Discussion

Patterns of species abundance

The results of the study show patterns of mammalian herbivore species abundance and their distributional patterns in GNP. The results indicate the common, intermediate and rare herbivore species and their proportions in GNP. We note the dominance of at least three common species in each strata and a sizeable number of the intermediate and rare species. The hierarchical distribution shows the dominating species in GNP is made up *Loxodonta Africana; Aepyceros melampus; Syncerus caffer*. However, *Aepyceros melampus* has been increasing in population and will be challenging the top position occupied by *Loxodonta Africana* (Dunham *et al.*, 2007). The rare species are numerous and are clustered at lower levels as shown in Table 2. The rare species co-exist with the dominating species in each stratum and hence compete for resources with dominating species. This makes rare species vulnerable as they have to compete with the dominating species for resources and this may expose them to predation and extinction (Verberk, 2011).

The clustering of mammalian herbivore species at lower levels indicates species evenness for the GNP strata in general. As shown by Figure 2, the species richness for Mabalauta, Chilijo A and Chilojo B are high, perhaps, because of favourable habitat conditions of these areas (Gandiwa *et al.*, 2013) while Chipinda Pools, Naivasha and Chefu are low due to the rugged nature of the terrain (Dunham, 2012) as rare species are pushed into low-lying areas a situation that would result in such habitats being degraded (Taylor *et al.*, 2018). Rare species would require monitoring, management and conservation



Note: A significant (p = 0.00) positive linear relationship between abundance (density) = 0.8369 + 0.9794 * distribution (proportion of occupied area)

Figure 3. Distribution-abundance relationship of GNP

Table 3. Regression parameters for distribution-abundance relationships in GNP

Variable	Coefficient	SE coefficient	t-value	p-value	R^2	Adjusted R^2
Constant	0.84	0.04	19.10	0.00	0.96	0.96
Area	0.98	0.02	48.37	0.00		

Notes: Abundance-density = 0.84 + 0.98% of the occupied area. An increase in area by a single unit will result in an increase of 0.98 in density.

measures aligned towards their proliferation (Taylor *et al.*, 2018). Verberk (2012) contends that clustering is related to what he termed specialists species, which would occupy homogenous areas as opposed to what he termed generalists herbivores, particularly the common species, which are selective in their foraging habits would occupy heterogeneous areas.

Studies on species abundance, as well as richness and evenness patterns carried out by a number of authors whose results are similar to trends found in GNP (Barker *et al.*, 2014; Fauchald *et al.*, 2017; Johnston *et al.*, 2015; Pettorelli *et al.*, 2005; Villarreal *et al.*, 2013b; Winterbach *et al.*, 2015). The studies covered various aspects such as plants and insects. In these studies, practical use of such studies especially in tourism has been singled out (Winterbach *et al.*, 2015) an activity that can benefit GNP.

Another important observation from the study is that in GNP there are mammalian herbivore species, which have been sited in some strata that never existed before like the *Tragelampus augastic* whose population has been increasing in recent years (Gandiwa, 2011; Gandiwa *et al.*, 2013; Dunham *et al.*, 2007). An increasing number of domesticated animals in GNP aerial surveys that cannot be ignored anymore. This is because of increased settlements around GNP and this has caused human-wildlife conflicts especially given the increasing number of mammalian herbivores in GNP (Gandiwa *et al.*, 2013; Dunham, 2013; Dunham *et al.*, 2007; Dunham, 2012). Given the above issues, it has to be reiterated that monitoring and conservation measures such as restoration (Verberk, 2011), translocation and introduction of new species will be carried out with a clear understanding of abundance and distribution patterns.

Distribution-abundance relationships

Regression analysis shows a positive linear relationship between mammalian herbivore distribution and their abundance in GNP. Quantifying distribution-abundance relationships is becoming common in community ecology (Verberk, 2011; Khaemba, 2000; Villarreal *et al.*, 2013) and this points towards habitat modification. In GNP observations are that common herbivore species have a widespread distribution and the rare species have a narrow distribution as is often the agreed observations (Kerr and Ostrovsky, 2003; Pettorelli *et al.*, 2009; Walter and Hone, 2003). This has often resulted in the grouping of herbivore species into those that can survive on a wide heterogeneous geographical distribution and those that survive on specific local homogenous environmental conditions particularly patches (Barker *et al.*, 2014; Khaemba and Stein, 2000; Matthews and Whittaker, 2014). However, these results may be influenced by a low number of species considered or the dry period when the aerial surveys were carried out when species tend to congregate along with scarce resources.

Mammalian herbivore species such as the *Loxodonta Africana*, *Aepyceros melampus* and *Syncerus caffer* in GNP maintain their numbers by positive feedback mechanisms as they produce more offsprings because of their numbers, which allow the species to increase and may maintain this position for some time. This results in more colonisation and expansion of their habitat (Verberk, 2011). Stochastic factors such as birth, death, immigration, extinction and speciation (Dunham, 2012; Godfray and Lawton, 2001; Khaemba and Stein, 2000; Schlossberg *et al.*, 2016) are other factors, which result in an increase in population. The introduced *Taurotragus oryx* in GNP (Dunham, 2013) whose numbers are becoming noticeable is because of the above. However, biophysical conditions such as droughts will restrict the survival and reproduction of species where diet, reproduction, dispersal and habitat specialisation are considered. Competition and predation have a role to play in increasing populations of rare species, which are localised (Verberk, 2011; Gandiwa *et al.*, 2013; Oindo and Skidmore, 2002; Pettorelli *et al.*, 2009) mostly in a reduction of their numbers. Neutral and niche dynamics are important elements in considering the restoration of communities in protected areas like GNP. However, migration patterns have not been considered extensively at different times of the year to make comparisons effective.

The increasing number of domesticated animals in strata such as Chipinda pools, Chilojo A and Mabalauta is explained by the fact that the period under study is associated with a revolutionary land reform approach in Zimbabwe and peripheral grazing of parts of GNP particularly those close communal lands are affected by encroachment. The abundance of cattle has been noted in Chipinda Pools and Mabalauta NP and has led to competition for GNP resources (Beck and Suring, 2015; Gandiwa, 2013; Gandiwa *et al.*, 2013). Incidences of poaching of resources particularly wildlife had also increased but now look curtailed were also related to encroachment.

The rank-abundance distribution and distribution-abundance relationships are important ways of highlighting herbivore species patterns in a protected area. The models are important in highlighting the conservation and management needs of GNP. Herbivore species, which are endangered and threatened can be identified and possible remedies quickly implemented. An increasing trend for herbivore species population requires an understanding of their habitat and their carrying capacities.

Conclusion

The rank-abundance model and regression could be used to depict the abundance and distribution of mammalian herbivore species successfully in GNP. Mammalian herbivore species spatial abundance is more in Mabalauta, Chipinda and Chiliojo B. Similarly a hierarchical distribution of mammalians is observed with a dominance of four wildlife species. The dominant species are common and the rest of the species are clustered in the intermediate and rare species. Distribution-abundance relationships show that common species occupy heterogenous habitats while rare species are found in homogenous habitats. Aerial census surveys can be depended upon to show mammalian herbivore species, particularly if they are systematic and comprehensive. Studies of a similar nature need to be extended to carnivorous wildlife and insects, as well as vegetation. There is a need to distinguish vegetation species in terms of occurrence in GNP to improve wildlife protection measures.

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