Factors influencing impala distribution patterns in Nairobi National Park, Kenya

Obade Vincent de Paul[1*] and Eva De Clercq[2]
[1] Geographical Information Science Center of Excellence, South Dakota State University, 1021 Medary Ave, Wecota Hall, Box 506B, Brookings SD 57007, U.S.A.
[2] Laboratory of Forestry and Spatial Information Techniques, Ghent University, Coupure 653, 9000 Gent Belgium

*Corresponding author email: vincent.obade@sdstate.edu

ABSTRACT

Monitoring the distribution of wild animals using appropriate methods and survey techniques is essential not only for sustainable management but also to avoid wastage of resources. This study applied remote sensing to investigate the factors influencing the distribution of herbivores in Nairobi National Park, Kenya. Impala was selected as indicator specie for the herbivores within the park, because the population of impala had drastically reduced over time. The influence of food availability, water and disturbance on herbivore presence was investigated. A positive significant statistical relationship between impala population density and feed availability was observed. However, the correlation between impala population density and water distance was negative, indicating less impalas as the distance from water sources increase. An interesting finding was the expectation of greater impala population presence next to roads. The study demonstrated a rapid method for gaining information useful for conservation and land use planning practices, such as in the determination of the carrying capacity or even for redistributing animals within the park.

Key words Habitat, impala, Kenya, management, patterns, remote sensing

INTRODUCTION

Sustainable habitat management requires a thorough understanding of the factors that influence species distribution patterns. In Kenya, the factors responsible for spatial variability of wildlife populations are still not fully understood, despite numerous attempts to identify them. Reliance on data that is predominantly from sparse 'in situ' point samples has been one key constraint. Wildlife managers would prefer to have continuous information over time on the number of animals in a park (abundance), the spatial distribution of these animals and the availability of pasture (Ottichilo et al. 2001). In recent times, the increasing isolation of protected areas has created a serious threat to the long-term viability of many wildlife populations and migrations within Africa (DeFries et al. 2005, King'oriah 1995). While the impact of isolation on wildlife populations in reserves have been a subject for debate, the rapid decline in wildlife populations together with the habitat transformation within the park boundaries have created the demand for different management approaches. Identification of potential wildlife habitat sites is a prerequisite for successful protection. Remote sensing technology could fill the need for accurate, up-to-date information that is essential for wildlife management. However, the capabilities of this technology are yet to be fully exploited (Serneels et al. 2001).

The basic resource that fuels life on earth is solar energy, which is captured by plants and converted to carbon compounds, otherwise referred to as primary productivity (Botkin and Keller 2007). Since herbivores feed on the carbon compounds in plants, higher animal populations would be expected where vegetation is abundant. The numbers of consumer individuals are basically determined by the productivity of the vegetation, which in turn is influenced by climatic variability (Lovett et al. 2005). Therefore, in order to better understand the factors determining distribution of animal species, it is important to investigate the relationship between vegetation and animals (Huston, 1994, Fensholt et al. 2006, Chapman et al. 2006). Other factors that could influence species abundance include predators, the presence of water, and the effect of disturbance (Dale & Beyeler, 2001). The objective of this study was to establish the relationship between impala (*Aepyceros melampus* Lichtenstein) population density and specific environmental parameters with a view to providing information that can improve the capacity for policy formulation.

IMPALA HABITAT AND FEEDING HABITS

The impala is a medium sized animal with a body size of 1.2 to 1.6 meters. Males weigh between 60 and 65 kilograms, while females weigh between 40 and 45 kilograms. The ears are pointed and of medium length and horns found in males, though cases of long horned females have been reported. The female herd is the breeding group usually made up of 20 to 40 animals. The group scatters whenever they are disturbed. In running away they leap in the air changing direction frequently in their flight. A herd of males is usually between 6 and 100 animals. The male impala shows curiosity when in danger. When disturbed they usually lift their heads and scan the horizon for a few seconds before they take flight (DRSRS, 1994). Impalas are found on ecotones, such as where savannah meets woodland. They generally avoid floodplains and are absent from mountainous areas. Impalas are both grazers and browsers, feeding on grasses and the leaves, flowers and seed pods of shrubs.

MATERIALS AND METHODS

Nairobi National Park which was gazette in December 1946, occupies an area of 117 km^2 and is located in Kenya between latitudes 1° 20’ to 2° 25’S and longitudes 36°20’ to 36° 28’ E. The park experiences alternating wet and dry seasons, with the long rains falling mainly around March to May, while the short rains occur between October and December. The migrations of wild herbivores within the park are believed to be regulated by rainfall patterns (Gichohi 1996). The vegetation in the park is mostly grassland, although there are deciduous forest in the west and some riverine woodland (Bryan and Cokayne 2005, Gichohi 1996).

To collect animal census data in Kenya, the Directorate of Resource Surveys and Remote Sensing (DRSRS) uses low flying aircraft (heights of 120m), together with calibrated grids and counters (Ottichilo et al. 2001). The aerial surveys are conducted along transects oriented in the east-west direction and spaced at 5km intervals. Animals are counted and tape recorded or photographed from the aircraft (Oindo et al. 2003). Although this method is appropriate for larger animals, e.g. zebra, wildebeast, etc, it is not suitable for small animals, such as the impala. For example, in the Nairobi National Park the grass can be as high as a metre towards the end of the rainy season, thus making it difficult to see the impala at this time. An alternative to aerial census is ground census whereby teams of rangers are sent to the field to count the animals observed in specific blocks. The rangers record the animals observed within each block without capturing the animals. The fifteen different block sizes in Nairobi National Park varied between 1000 to 3000 hectares. All wild animal census data that is both the aerial and ground census are archived at the Kenya Wildlife Service (KWS). This study relied only on the actual ground census data acquired from KWS records.

For more than a decade, the populations of most wild-animals in Nairobi National Park have been on the decrease. From a study conducted by Obade (2003) the migratory species showed a remarkable decline in population. The decline ranged from 9% for Thompson gazelle to 76% in wildebeests. The grant gazelle reduced by 46%, while the impala had a decline in population of 59%, eland was reduced by 54%, while buffalos reduced by 40%. It was only the Kongonis and Zebras that interestingly registered a population increase of 42% and 6% respectively.

The impala was chosen as an *indicator species*, since (1) there is similarity in feeding habits among herbivores (Hacker & Ternouth, 1987), and (2) the relatively high impala population decline which was noted in the park between the years 1990 and 2002 (Obade 2003). In this study only the following parameters were selected: (1) food availability estimated by the Normalized Difference Vegetation Index (NDVI); (2) presence of water and (3) disturbance represented by density of roads, despite the existence and complexity of several biotic and abiotic drivers that affect wildlife habitat (Reed et al. 2008).

A model of the *impala population density,* which was assumed to be referenced from the center of the respective counting blocks and distance to water sources, was created. Given that the animal census were conducted within each blocks and the fact that there were only fifteen blocks, which represents a small sample size, a simple correlation analysis without emphasis on the statistical significance of the variables, was considered sufficient to give an idea about the factors influencing animal distribution. The impala animal census data used was for the month of February, 2002. The satellite data used was Landsat 7-ETM+ imagery for February, 2002.

The road data were digitized using carta Linx® digitizing software from an analog topographic map covering Nairobi National Park and the digitized road exported from carta Linx to *IDRISI*®. The digitized ‘road’ data was geometrically corrected by resampling, in order to make the co-ordinates for the road network to conform to those of the satellite imagery. The *road density* was computed using Equation 1:

$$\text{Road density} = TL / AR \qquad (1)$$

Whereby “TL” is the total length of road in metres and “AR” is the area of corresponding block in square metres. All the roads in the park, that is whether tarmacked or not were included in the analysis.

In the subsequent analysis, the average water distances from the center of each of the individual blocks, which was assumed to be the reference point for each block, was extracted using *IDRISI*®

software. The population density of impala was then plotted against the average water distance for each block using *SPSS 11.0* software. Alternately, the NDVI which provides an effective measure of photosynthetically active biomass of plant canopies (Tucker & Sellers, 1986), was computed using Equation 2. NDVI combines the reflectance in the red and near infra-red parts (NIR) of the electromagnetic spectrum into one index; whereby high positive values correspond to dense vegetative cover, whereas negative values are associated with bare soil, very dry non photosynthetic vegetation or snow. During the dry season, the grasses have an NDVI similar to that of bare soil (Mayaux et al. 2004). The NDVI was computed from the Landsat 7-ETM+ satellite imagery for February, 2002 which had no clouds.

$$NDVI= (NIR-Red) / (NIR+Red) \qquad (2)$$

RESULTS AND DISCUSSION

The positive significant statistical relationship ($p=0.05$) and trend of the curve between impala population density and NDVI (Figure 1 and Table 1) supports the findings of both Rosenzweig and Abramsky (1993) and Bourgarel et al. (2002), indicating that fewer animals occur where there is less vegetation and vice versa. Under conditions of low primary productivity in natural ecosystems, the landscape would mostly be non-vegetated but as productivity rises, a more diverse community of plants that can support a larger number of herbivore species is expected. The derived equation for the fitted lines for impala density per hectare (y) versus NDVI (X) were: $y = 7.076*X^2 +2.396*X+0.201$ and had a graphical $R^2 = 0.519$, while the equation for impala density per hectare (y) versus water distance (X) was y = 0.3054-0.0507*natural logarithm (X), with a graphical $R^2 = 0.427$. The equations confirm that in the circumstances observed in this situation, NDVI (remote sensing data) can be used for the prediction of animal abundances. However, the non significant negative correlation between impala population density and water distance (Table 1 and Figure 1), indicates that fewer impalas would be expected as the distance from water sources increase. Furthermore, less vegetative cover would be expected as the distances from the water-sources increase, as evidenced by the negative correlation between NDVI and water sources (Table 1). Thus, further from water sources, impala populations would be less due to water scarcity and also due to the reduced feed resources.

Table 1: Statistical relationship between impala density, vegetation, distance to water source and road density within Nairobi National park, Kenya.

Figure 1: Impala density per hectare versus NDVI (left) and water distance (right). NDVI = Normalized Difference Vegetation Index.

An interesting finding was the positive correlation between impala population and road density (Table 1), which is contrary to the findings of Little *et al.* (2002 that wild animals are disturbed by human activities, such as roads. The positive correlation between impalas and road density could be attributed to either the utilization of roads as the platform for the animal counting procedure or the proximity of the park to the city, which could have made the animals more accustomed to vehicular presence.

A potential source of error includes the use of averaged NDVI values for each block. For example the determination of the correlation between NDVI and the total number of animals within that block, using averaged NDVI values. Given the large size of the individual blocks, it is possible that there is some level of spatial heterogeneity in the NDVI values within blocks and at certain times, the animals can graze in areas that do not reflect vegetation represented by the "average" NDVI values used in the model. Furthermore, Impala tend to avoid tall grasses or forested areas due to the potential threat presented by predators such as lions. Another limitation in this study was that the variability of animal distribution patterns with scale which can provide useful information for predicting specific spatial patterns of herbivores was not considered (Oindo et al. 2003).

CONCLUSION

The study was able to demonstrate a rapid method for identifying some of the important factors influencing the distribution of herbivores within Nairobi National Park. However, the weak empirical relations observed could imply that remote sensing alone may not adequately provide precise predictions of herbivores distribution patterns. The possible reason for the weak correlation could be because of the inter relationship among the factors influencing herbivores and the fact that only few variables were considered despite the complexity of the environment. We recommend that future research should incorporate techniques that can locate the impala more precisely, for example by radio tracking, so as to verify the correlations on point data (or a small window around the points) rather than using only aggregated data.

Acknowledgements: Authors are grateful to Dr. Richard Bagine and Mr. Shadrack Ngene of the Kenya Wildlife Service for granting permission to conduct field visits and providing ancillary data. Ghent University, Belgium provided funding for the study. We are also grateful to the reviewers for providing useful comments that drastically improved the article.

REFERENCES

Botkin D. and E. Keller (2007). Environmental Science: Earth as a Living Planet, 6th Edition ISBN: 978-0-470-04990-7.

Bourgarel M, H. Fritz, J. Gaillard, M. De Garine-Wichatitsky and F. Maudet (2002). Effects of annual rainfall and habitat types on the body mass of impala (*Aepyceros melampus*) in the Zambezi Valley, Zimbabwe. *African Journal of Ecology* 40 (2): 186-193.

Bryan S. and A. Cokayne (2005). Vigilance and group size in impala (Aepyceros melampus Lichtenstein): a study in Nairobi National Park, Kenya. *African Journal of Ecology* 43, 91–96.

Chapman C.A., M.J. Lawes and A.C. Harriet (2006). What hope for African primate diversity? *African Journal of Ecology* 44 (2): 116–133.

Dale V.H. and S.C. Beyeler (2001). Challenges in the development and use of ecological indicators. *Ecological Indicators journal* 1, 3-10.

Department of Resource Surveys and Remote Sensing (DRSRS) (1994). Some Biological Attributes and Populations of Impala, Grant Gazelle, Thomson's Gazelle, Waterbuck and Hunters Hartebeest in Kenya. *Ministry of planning and national development, Kenya technical report*.

DeFries Ruth, Andrew Hansen, Adrian Newton and Matthew Hansen (2005). Increasing Isolation of Protected areas in tropical forest over the past twenty years. *Ecological Applications* Vol. 15, No. 1 : pp. 19-26

Fensholt R., I. Sandholt, M. Rasmussen, S. Stisen and A. Diouf (2006). Evaluation of satellite based primary production modeling in the semi-arid Sahel. *Remote Sensing of Environment* 105: 173-188.

Gichohi, H. (1996) Ecology of a truncated ecosystem. The Athi-Kapiti plains, Kenya. PhD thesis, University of Leicester, UK.

Hacker J.B. and J.H. Ternouth (1987). *The nutrition of herbivorous,* Academic press, Sydney.

Huston M.A. (1994). Biologic Diversity. The coexistence of species on changing landscapes, Cambridge University Press, Cambridge.

Little S.I., R.G. Harcourt and P.A. Clevenger (2002). Do Wildlife passages act as prey traps? *Biological Conservation* 107: 135-145.

Lovett J.C., G.F. Midgley and P. Barnard (2005). Climate change and ecology in Africa. *African Journal of Ecology* 43 (3): 167–169.

Mayaux P., E. Bartholome, S. Fritz and B. Alan (2004). A new land cover map of Africa for the year 2000. *Journal of Biogeography* 31: 861-877.

King'oriah, G. (1995) An economic appraisal of wildlife and biodiversity conservation as a land use in Kenya's Game Dispersal Areas. *Report on land use planning and coordination study*. Kenya Wildlife Service, Nairobi, Kenya.

Obade, V. (2003). Spatial Information Techniques for Wildlife Habitat Management: Case of Nairobi National Park, Kenya. Masters thesis, Ghent University, Belgium.

Oindo B., A. Skidmore, P. Salvo (2003). Mapping habitat and biological diversity in the Maasai Mara ecosystem. *International Journal of Remote Sensing* 24 (5): 1053-1069.

Ottichilo K., J. Leeuw and H. Prins (2001). Population trends of resident wildebeests (*connochaetes taurinus hecki* (Neumann)) and factors influencing them in the Maasai mara ecosystem, Kenya. *Biological conservation* 97: 271-282.

Reed D.N., T. M. Anderson, J. Dempewolf, K. Metzger and S. Serneels (2008). The spatial distribution of vegetation types in the Serengeti ecosystem: the influence of rainfall and topographic relief on vegetation patch characteristics. *Journal of Biogeography* 36 (4): 770-782

Rosenweig L. and Z. Abramsky (1993). How are diversity and productivity related? In, *Species Diversity in Ecological communities. Historical and Geographical perspectives*, R.E. Ricklefs and D. Schluter (eds.), University of Chicago Press, Chicago, USA. pp. 52-65.

Serneels S., M. Said, E. Lambin (2001). Land-cover changes around a major East African wildlife reserve: the Mara Ecosystem, Kenya. *International Journal of Remote Sensing* 22 (17) 3397-3420.

Tucker C.J. and P.J. Sellers (1986). Satellite remote sensing of primary production. *International Journal of Remote Sensing* 7: 1395-1416.

Table 1: Statistical relationship between impala density, vegetation, distance to water source and road density within Nairobi National park, Kenya.

	Pearson Correlation**	Significance
Impala density vs. water distance in metres	-0.443	0.099
Impala density vs. NDVI	0.644	0.01
Water distance vs. NDVI	-0.329	0.232
Impala density per hectare vs. road density	0.323	0.240

**Correlation is significant at the 0.01 level (2-tailed) and N = 15. NDVI = Normalized Difference Vegetation Index.

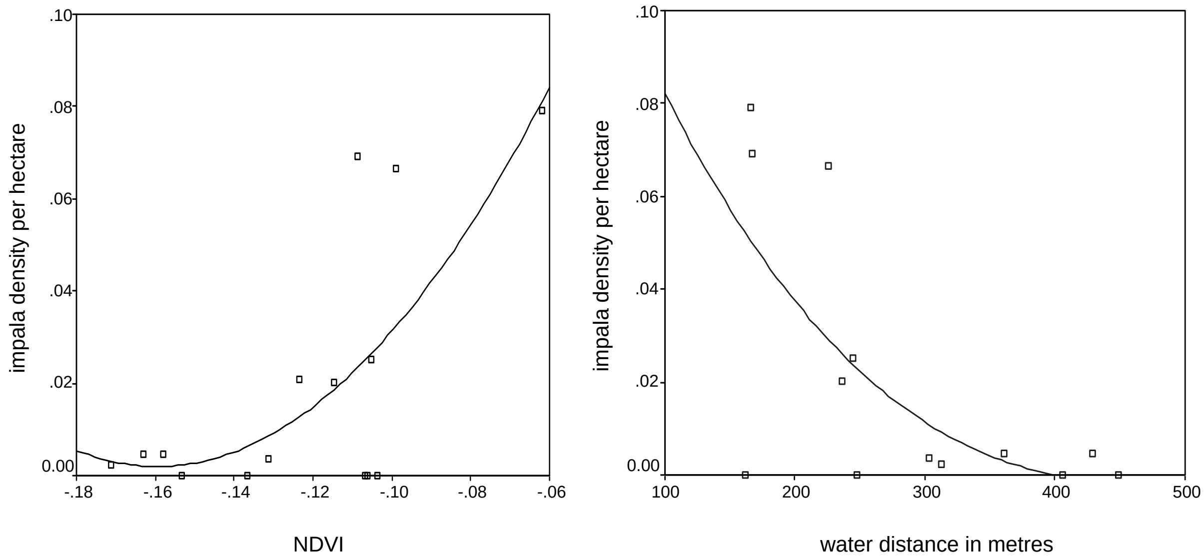

Figure 1: Impala density per hectare versus NDVI (left) and water distance (right). NDVI = Normalized Difference Vegetation Index. Fitted lines correspond to regression equations for NDVI ($y = 7.076*X^2 + 2.396*X + 0.201$; $R^2 = 0.519$) and for water distance ($y = 0.3054 - 0.0507*\text{natural logarithm}(X)$; $R^2 = 0.427$).