Impact of the Exotic Weed, *Lantana Camara* L. on Abundance of Native Plants in Nairobi National Park, Kenya: Implications for the Conservation of Wildlife

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Abstract: ***Lantana camara L. (Verbenaceae) is an exotic plant considered a serious problem in protected ecosystems globally. Despite this, information about its impact on native plant species in Nairobi National Park is limited yet its invasion is an important conservation and management challenge. We tested the impact by randomly sampling plant species in invaded and un-invaded sites of the park using Modified Whittaker plot design. Two sample t-test results on Shannon diversity values of plant species sampled from invaded (H' = 3.592) and un-invaded (H' = 4.003) riverine indicated significant variations (t_{121} = 2.01; p = 0.047) but no significant differences were recorded on data of plant species sampled from invaded and un-invaded shrub-grassland and forest (p < 0.05). However, the results showed that the un-invaded riverine and shrub-grassland were more diverse and abundant in species richness. The sites were also more homogenous in spatial distribution of native species compared to the invaded ones. The results of this study suggest that Lantana camara has remarkable negative impact on native plant species and may gradually reduce the endemic species which are the main source of forage and browse for the herbivores in the conservancy.***

Keywords: Impact, Forage, Invasive plants, Conservation, Understory

1. Introduction

Alien plants predominantly known to invade island habitats [4] have of recent expanded their invasions to terrestrial ecosystems where they cause irreversible damage on biodiversity [14]. There is evidence to show that the invasive plants which are generally considered to be a major threat to wild ecosystems globally are of great continental concern especially in arid and semi arid parts of Africa, Asia, Australia and North America [5], [6]. Recent investigations have reported that exotic plant invasions alter soil nutrient pools by changing their direction of flow [37], [38] reduce biodiversity, decrease production, degrade bios-systems, displace indigenous plants and alter community functions [34], [29], [7]. As a result, they exploit the soil nutrients well compared to their native counterparts [23]. Consequently, they alter the rates of important nutrient cycling processes which include litter decomposition, mineralization and nitrification [19] on the invaded sites and subsequently reduce the quality of the habitats by inhibiting the acquisition of the nutrients by native plants. The global scale of the negative effects of the alien plants on terrestrial ecosystems is alarming to the extent that they are considered to be a serious threat to loss of biodiversity only second to habitat destruction [2], [4] and number one in islands [20]. Among the most pervasive and malignant exotic plant with significant impact on global ecosystems is *Lantana camara* **L.** The invasive weed has been ranked top 100 most impacting among the invasive species on earth [26], [10] which has impaired agriculture and devastated many ecosystems in over 47 countries around the global [15]. Since the introduction of *L camara* in Kenya in 1930 [35], the insidious invasive shrub has spread and become a naturalized weed in many ecosystems including the Kenyan nature reserves [36]. Despite well knowledge of allelophatic effects of *Lantana camara* L. on native species in protected areas globally [11] studies to quantify its impact in Nairobi National Park are limited. This study attempted to evaluate the impact on native plant species abundance in the park.

2. Materials And Methods

2.1 Study Area

The study area (Fig 1) was the Nairobi National Park.

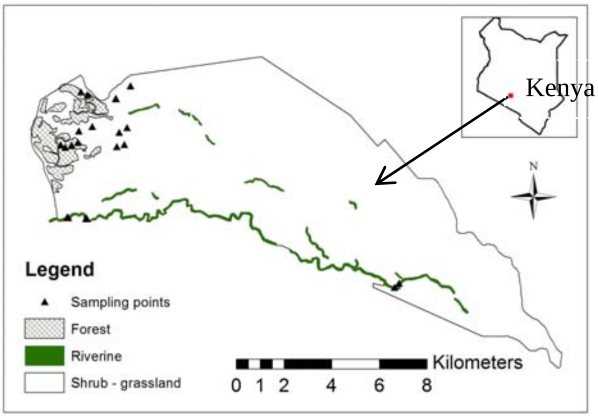

Figure 1: Map of Nairobi National Park showing locations of the sampling points.

The park was gazetted in 1947 [9] and is located 10km south of the city of Nairobi. It covers 117km^2 and lies between latitudes 2°18' to 2°20'S and longitudes 36°23' to 36°28'E. The park has an electric perimeter fence leaving a length of about 20km to the South which opens to the Athi-Kapiti plains for animals' dispersal. However, increased human activities along this corridor, has of recent been a source of human-wildlife conflicts [18].The rainfall pattern is bimodal. The long rains (150mm mean per annum) occur in March to May and the short rains (90mm mean per annum) come in the months of November to December [24]. The annual mean temperatures range from a minimum of 13.6°C to a maximum of 25.3°C.

The terrain of the park is gentle undulation from elevation of 1500m in the South East to 1800m to the north. It comprises three main habitat types: the forest which occupies the western parts, open grassland scattered with several shrubs found within the central and southern parts while the riverine occurs to the south and central parts of the park [9]. Most of the park is covered by neutral to alkaline clay soils commonly described as 'black cotton soils'. The soils crack on drying and become sticky when wet. They are characterized by poor drainage. The common invasive plants in the park include *Lantana camara* L., *Parthenium hysterophorous* (L.), *Opuntia valgaris* (L). Mill, *Opuntia ficus indica* (L.), Mill, *Datura stramonium* (L.), *Ceasalpinia decapetala* (Roth Alston), *Argemone mexicana* (L.), *Opuntia exaltata* (A. Berge), *Tagetes minuta* (L.) *and Ricinus communis* (L.). The forest is predominated by *Croton megalocarpus* (Hutch.), *Brachylaena hutchinsii* (Hutch.), Olea *africana* (L.) [9] and *Themedia triandra* (Forsk). The riverine is marked by *Acacia xanthophloea* (Benth.) and *Acacia kirkii* (Oliv.) with *Themedia triandra* (Forsk) as the dominant grass while the shrub-grassland is dominated by *Acacia drepanolim* (Sjostedt ex Harms), *Themedia triandra* (Forsk), *Pennisetum mezianum* (Leeke), *Digitaria macroblephara* (Hack*) and Panicum maximum* (Jacq.). The common animal species in the plains include wildebeest, *Connochaetes tyaurinus* Burchell; Zebra, *Equus burchelli* Gray; Eland, *Taurotragus oryx* Pallas and Kongoni, *Alcelaphus buselaphus* Pallas [13]. The other animal species found in the park are Thomson's gazelle, *Gazella thomsonii* Gunther; Impala**,** *Aepyceros melampus* Lichtenstein; Giraffe, *Giraffa camelopardalis* Linn; Granit's gazelle, *Gazella granti* Brooke; Buffalo, *Syncerus caffer* Sparrman; Lion, *Panthera leo* Linn.; Leopard, *Panthera pardus* L. and Black rhinoceros, *Diceros bicornis michaeli* Groves 1967.

2.2 Data collection

Data was collected using Modified Whittaker plot design [32] (Fig 2) in the months of October, November and December, 2011.

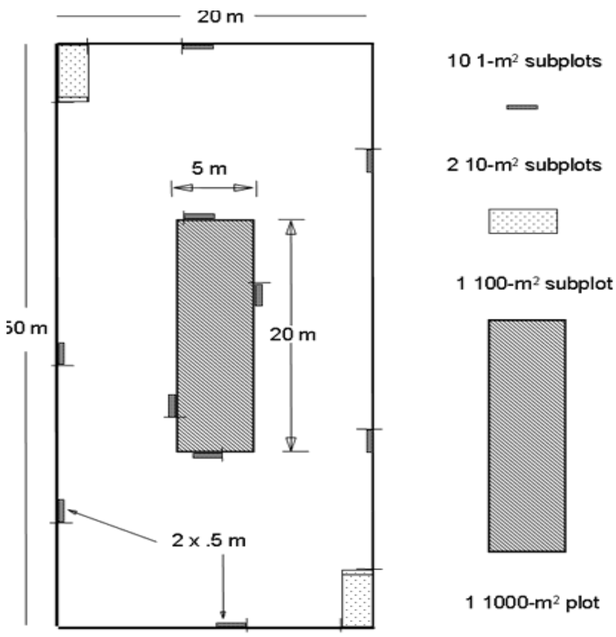

Figure 2: Modified Whittaker Plot design [32].

The plot is modified to use rectangular subplots dispersed within the main plot. They capture more environmental variation than the original plot with ten 1m^2 subplots placed linearly at the centre of 10m×10m plot within 1000m^2 main plot [28]

Sampling was done in both invaded and un-invaded sites of each habitat type within the park (Fig 1).Three, four and two plots were randomly laid in the invaded sites of the forest, shrub-grassland and riverine respectively and all the plant species falling within the 1m^2 sub-plots of each Modified Whittaker plot were collected, identified, counted and recorded in a prepared data sheet. The procedure was also repeated in the un-invaded sites. Identification and nomenclature of plant species was done according to Agnew [1] and Bentje [3].

2.3 Data analysis

Simpson's (ג) [30] and Shannon-Weaver indices [25] were performed in order to estimate and compare species dominance, richness and diversity between invaded and un-invaded sites. Simpson's index is more weighted towards abundant species but less sensitive to species richness while Shannon's index evaluates species richness and evenness.

Therefore both indices were used. Shannon index (H') was calculated using the following formula:
H' = ∑ (Pí × Loge (pí)

Where:
H' = Diversity index
Pí = proportion of each plant species in the sample
Loge (pí) = natural logarithm of the proportion of each species in the sample
The Simpson index **(ﻻ)** was calculated using the formula:

ﻻ = ∑ (Ní (Ní -1)/N (N-1)
Where: ﻻ = Simpson index
Ní = Total number of individuals of all species found in the sample. N = Total number of individuals of each species in the sample

Since the Simpson's index **(ﻻ)** increases with increase in diversity, 1/ ﻻ was used to quantify dominance and evenness [20]. However, the two indices are known to give inadequate information to order sites in diversity and categorically state them in order of diversity ranks, [16], thus species abundance distributions curves (SADCs) of species log abundance against species rank were also plotted using Zipf-Mandelbrat model [22]. The hypothesis that abundance of plant species was not different between the invaded and un-invaded sites of was statistically tested by carrying out two sample *t*-test. All the analyses were done using Gen Stat software.

3. Results and Discussion

3.1 General introduction

Although protected areas are widely accepted globally as rich in biodiversity due to their natural landscapes and high soil fertility, alien plants species continue to threaten these areas especially in developing countries in Africa including Kenya.
These plants have recurrently become harmful in altering the habitat structure by decreasing biodiversity, reducing productivity, degrading wildlife habitats and displacing native species [6]. Therefore, estimating the impact by comparing invaded and un-invaded sites with respect to abundance of plant species may provide sufficient data to compare the effects of plant invasion in ecosystems [12]. The current study evaluated the impact of *Lantana camara* on the abundance of plant species in three habitats namely forest, riverine and shrub-grassland in Nairobi National Park and the possible implications of the results for the conservation of wildlife in this protected ecosystem**.**

3.2 Abundance of plant species

The plot of the species cumulative count of all the plant species collected from the eighteen modified Whittaker plots revealed that the species richness approached an asymptote around the 10^{th} plot (Fig 3). This indicated that only ten plots randomly laid within the study habitats were sufficient in our sampling efforts. Also analysis of results from two sample *t*-test (Table 2) suggested that invasion of *L. camara* in the riverine habitat had a substantial negative impact on species abundance in the invaded sites. Two sample *t*-test on Shannon diversity values of plant species sampled from the invaded riverine (H' = 3.592) and un-invaded site (H'=4.003) (Table 1) were significantly different ($p = 0.047$) (Table 2).

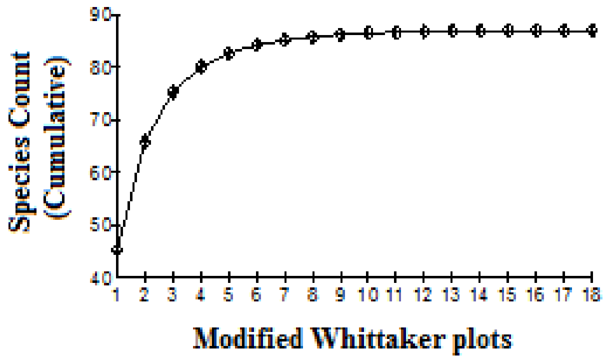

Figure 3: Species accumulation curve based on species count within the 18 sampled Modified Whittaker plots

Table 2: Two sample *t-test* results of plant species sampled from invaded and un-invaded riverine, forest and shrub-grassland

Site	*Species richness*	*Mean Abundance ± SE*	*df*	*t*	*P value*
Invaded riverine	50	1.484± 0.063	121	-2.01	0.047
Un-invaded Riverine	73	1.638± 0.047			
Invaded shrub-grassland	56	1.558± 0.053	129	-0.56	0.575
Un-invaded shrub-grassland	75	1.599± 0.050			
Invaded forest	71	1.623± 0.044	146	0.05	0.957
Un-invaded forest	77	1.629± 0.051			

However, Shannon values of 3.762 and 3.993 of plant species sampled from invaded and un-invaded shrub-grassland respectively (Table 1) were not significantly different ($p = 0.575$) (Table 2). Similarly, abundance of the plant species sampled from the forest site harbouring *L. camara* and the site without the invasive plant did not vary significantly ($p = 0.597$) (Table 2).These results suggest that the riverine could be more affected by the invasion than the forest and shrub-grassland habitats. *Lantana camara* is a better competitor of water resources and reduces dispersion of light to the ground level where grasses and herbs grow [11]. Thus its proximity to the riverine habitat hence water resources could have been conducive for its spread in this area. This facor coupled with increased disturbance in this watering point accelerated its regeneration and growth hence inhibiting the native plant species due to its heavily branched thickets [27].

Table 1: Results of Diversity Indices

Parameter	Riverine		Shrub-grassland		Forest	
	Invaded	Un-invaded	Invaded	Un-invaded	Invaded	Un-invaded
Total individuals (N)	2310	4596	2747	4711	4035	5045
Shannon's index (H')	3.592	4.003	3.762	3.993	4.007	3.976
Simpsons Index (1/ג)	30.88	46.29	36.91	45.75	45.66	42.06

Plant species data obtained from the invaded riverine recorded a lower value of Simpson's index (1/ג) (30.88) than the value obtained on data from the un-invaded site (46.24) (Table 1).Similarly, data of plant species collected from the invaded shrub-grassland recorded a lower index of 36.91 compared to Simpson's index of 45.75 of the data from the un-invaded sites. Likewise, results of the species accumulation distribution curves (SADCs) indicated steeper and fast declining curves of ranked abundance in invaded riverine (Fig 4) and shrub-grassland (Fig 6) whereas the un-invaded riverine (Fig 5) and shrub-grassland (Fig 7) had relatively long and less steep curves. However, the invaded and un-invaded forest sites showed minimal differences in diversity indices (Table 1) and these values were not significantly different (*P* = 0.957) (Table 2). The SADCs results indicated that the curve was less steep in the invaded forest (Fig 8) than the un- invaded one (Fig 9).

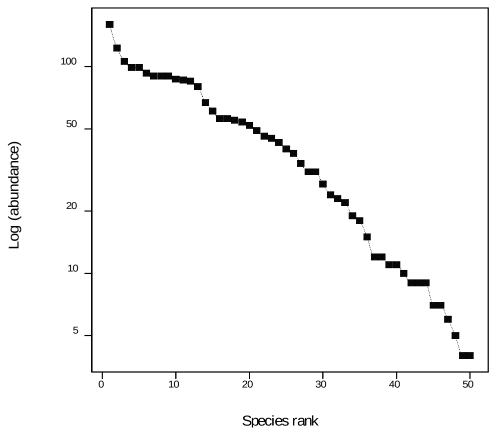

Figure 4: Species abundance distribution curve for un-invaded riverine

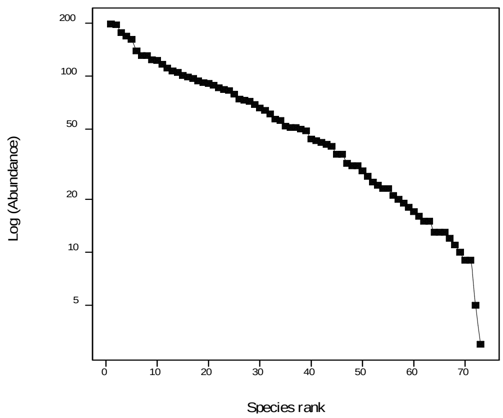

Figure 5: Species abundance distribution curve for un-invaded riverine.

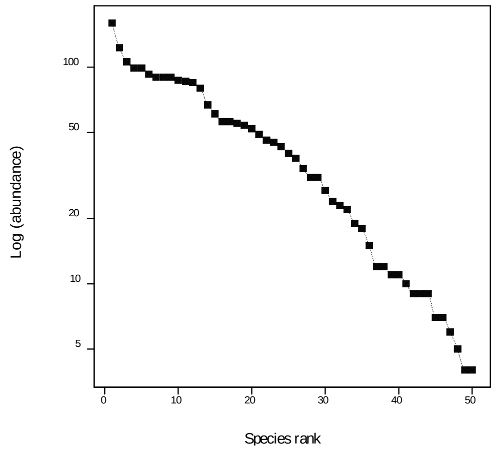

Figure 6: Species abundance distribution curve for invaded shrub-grassland

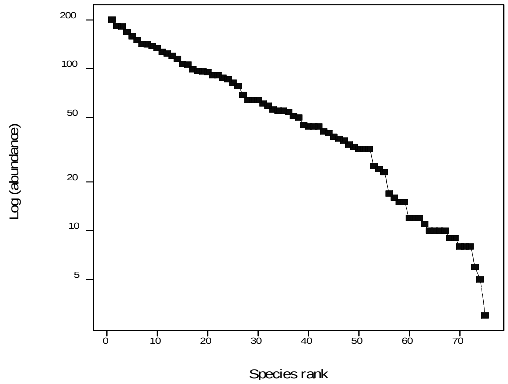

Figure 7: Species abundance distribution curve for un-invaded shrub-grassland

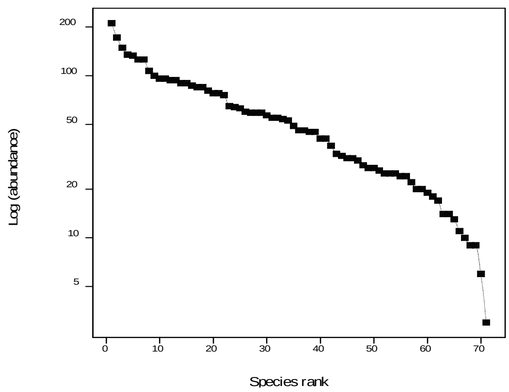

Figure 8: Species abundance distribution curve for invaded forest

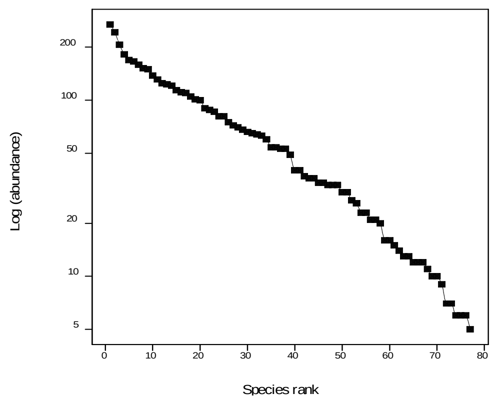

Figure 9: Species abundance distribution curve for un-invaded forest

Overall, the results (Table 1) showed that the un-invaded riverine and shrub-grassland were more diverse and abundant in species richness than the invaded sites. Similarly, the spatial distribution of the plant species in the un-invaded riverine and shrub-grassland were also more homogenous compared to the invaded sites as indicated by the species accumulation distribution curves (viz. Figs 4-9) where a less steep curve indicates homogeneity in species distribution. In the forest, homogeneity was more depicted in invaded site than un-invaded one (Figs 8, 9). However, this site generally showed slightly greater diversification of species richness compared to riverine and shrub-grassland (Table 1).

The results of this study suggest that the impact of an invasive species does not only depend on the ability of the invasive species to invade but also on the type of the site invaded. Smith et al. [31] suggested that species evenness in a site facilitates invasion resistance, production and native species extermination. In the present study, species evenness and diversity in the forest habitat were more less the same in the invaded sites and un-invaded ones suggesting that the forest habitat was more resistant to invasion than the riverine and shrub-grassland. The different species in a diverse site are likely to utilize resources more efficiently thus creating a strong competitive environment for the invasive species to flourish [33].

3.3 Implications for the conservation of wildlife

The results of this study suggest that invasive species can reduce species abundance and diversity. The reductions in species diversity and abundance have profound impact on forage diversity. Tracy and Sanderson [33] further reported that forage diversity and weed invasion are negatively correlated. This can be a potential hazard in an ecosystem like Nairobi National Park which is expected to provide long term production of pasture for its enormous animal species. *Lantana camara* is known to exude allelochemicals from its roots which severely damage recruitment of nearly all plant species in its understory [18]. This accompanied with its high litter accumulation, high ability in nutrient acquisition, and smothering effect as a result of its dense thickets may cause local plant species declines [27]. Consequently, it causes decline in wildlife forage, quality and abundance. The invasion of *L. camara* in Nairobi National Park is therefore a serious conservation challenge which needs to be addressed urgently because the invasion has negative impact on species diversity, abundance and slowly will degrades the quality of the habitat.

4. Conclusion

The results obtained in this study demonstrate that invasion of *L. camara* can initiate significant changes in the invaded ecosystem. The changes which manifest in the form of uneven distribution of native species and reduction in abundance as noted in this study have important conservation bearings. The fast acquisition of monolithic stands after invasion coupled with exudation of chemical substances from its roots have been of important value in its invasion success but harmful to the native plant species within its vicinity. Apart from blocking free movement of wildlife animals in search of palatable and preferred forage, *Lantana camara* thickets smothers understory endemic species thus causing biodiversity loss. The results from this study should therefore be interpreted in form of global biodiversity conservation and form the basis in the conservation of pasturelands especially in protected areas.

5. Acknowledgement

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