Effects of *Lantana camara* (L) invasion on the native vegetation of Gonarezhou National Park, Zimbabwe.

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Abstract

The study assessed the impact of *Lantana camara* (L) invasion on native vegetation of the northern part of Gonarezhou National Park (GNP), Zimbabwe. Stratified random sampling using three categories; uninvaded, moderately invaded and heavily invaded, was employed. The distribution of *L. camara* in the northern part of Gonarezhou National Park was mapped using GIS. Parameters measured for native vegetation included basal area, woody plant density, canopy and herbaceous cover. Species diversity (H^1) and species richness (S) were determined in each category. *Lantana camara* was found to be most prevalent among the riparian vegetation and in the low-lying areas of the northern part of GNP. A total of 41 native woody species and 2 native herbaceous species were identified in the study area. Basal area, canopy cover, herbaceous cover, woody plant density, H^1 and S of native vegetation significantly varied ($P<0.05$) across the categories of *L. camara* intensity. These variables were highest in the uninvaded category and lowest in the heavily invaded category. The uninvaded category was the most diverse (H'=1.875) while the heavily invaded category was the least diverse (H'=1.334). The significant differences in vegetation variables suggest that *L. camara* is altering native vegetation structure and composition in GNP to the detriment of wildlife management. Effective control of *L. camara* in Gonarezhou National Park is therefore urgently required to enhance wildlife and biodiversity conservation in the area.

Keywords: Alien plants, Biodiversity,Invasive plants, *Lantana camara,* Vegetation composition

Introduction

Invasive alien plant species have become a major threat to global plant biodiversity (Meffe *et al.*, 1997; Holmes *et al.*, 2000), second only to habitat destruction (Holmes *et al.*, 2000; Willis *et al.*, 2000). The non-native plant invasions produce a marked change in composition and structure of communities as well as ecosystem processes (Crowling *et al.*, 1997).

One of the most invasive alien plant species is *Lantana camara* (L) which is widely distributed worldwide.

The distribution of *L. camara* species indicates a severe threat to ecosystems in biodiversity hotspots. The moist evergreen rain forests of the Eastern Highlands of Zimbabwe are being threatened by alien invasive plant species such as *L. camara*, black wattle (*Acacia mearnsii* De Wild), Mauritius thorn (*Caesalpinia decapetala* (Roth) Alston) and *Eucalyptus* species (Timberlake and Musokonyi, 1994; Mudereri *et al.*, 2009), to the detriment of plant and animal biodiversity.

Lantana camara is poisonous to ungulates and its invasion can adversely affect wildlife in GNP.

The spreading and subsequent formation of monospecific *L. camara* stands may adversely affect the beautiful scenery of national parks and other natural habitats. The encroachment of *L. camara* in the northern part of Gonarezhou National Park therefore necessitated the assessment of its impact on native plant species in order to help formulation of appropriate management strategies to tackle any problems owing to the presence of the invasive alien species.

Materials and Methods

Study Area

The study was carried out in the northern part of Gonarezhou National Park (GNP). The Park is situated in the south-eastern lowveld of Zimbabwe and it is part of the Great Limpopo Transfrontier National Park (Figure 1).

The Park lies between latitudes 21°00' and 22° 15'S and longitudes 30° 15' and 32° 30'E. It is 5 053 km^2 in extent. Gonarezhou is characterised by low relief, with altitude ranging from 162 m to 578 m above sea level. The park is semi-arid with mean annual precipitation of 466.56 mm (Walker, 1979).

Methodology

A field reconnaissance survey was done in the northern part of Gonarezhou National Park to establish areas with *L. camara* occurrences. Stratified random sampling was used in this study with three categories, namely; heavily invaded (*L. camara* cover 50%), moderately invaded (*L. camara* cover<50%) and uninvaded (no *L. camara*) areas.

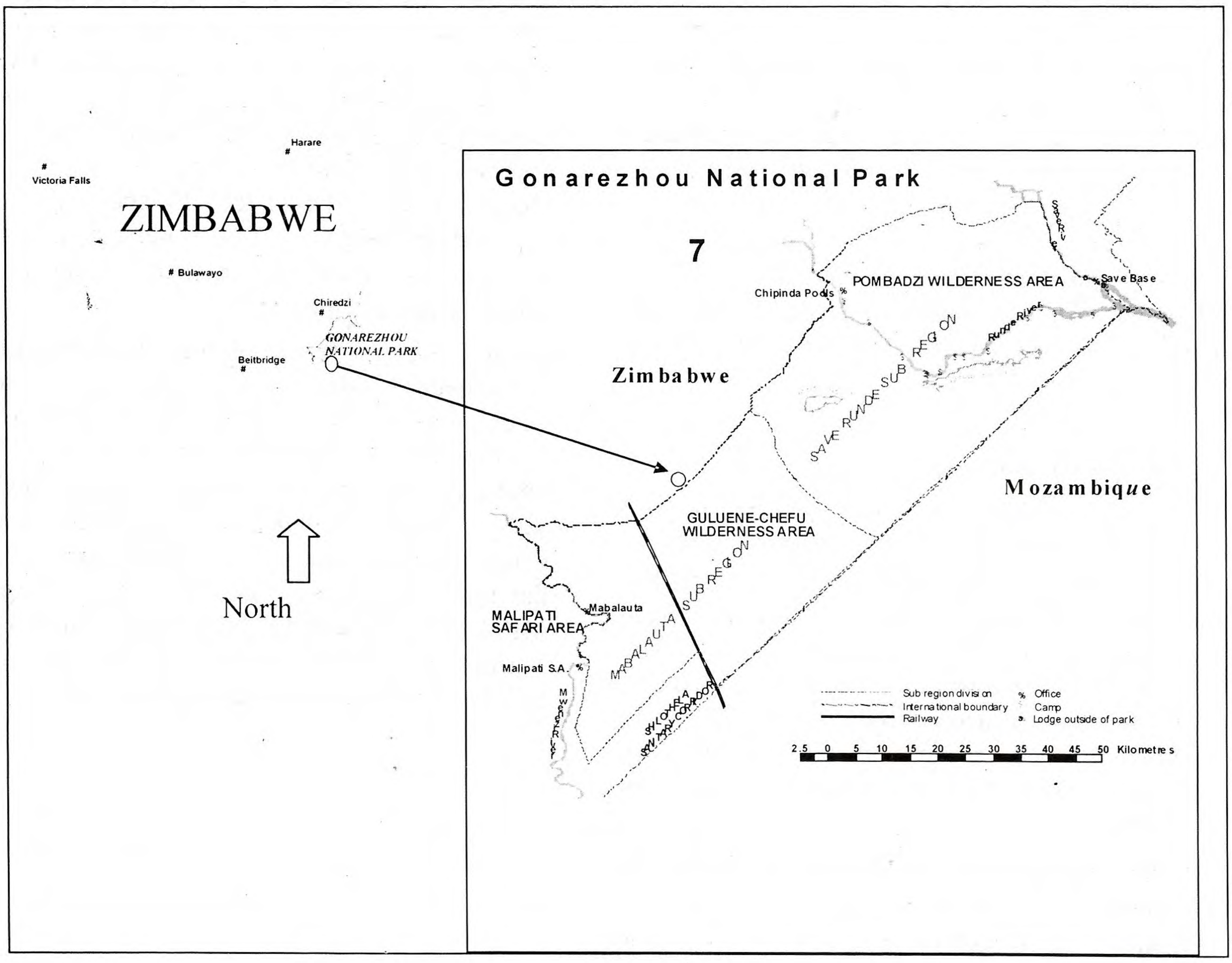

Figure 1: Map and location of Gonarezhou National Park

A total of 20 sampling plots was randomly selected using computer generated random numbers based on GNP topographical map grid square intercept system. Each plot, measuring 10 m x 10 m, was located at least 30 m from rivers and roads to avoid possible river and road effects. Six plots were sampled from the heavily invaded category and seven in each of the moderately invaded and the uninvaded categories. Within each plot, a subplot of 4 m x 4 m was randomly demarcated for shrub component assessment. For herbaceous species, five 1 m x 1 m quadrats were randomly thrown and assessed within each 10 m x 10 m plot.

Vegetation Assessment

Both woody and herbaceous vegetation components were assessed at the end of the rainy season (April-May 2007) when species composition was best represented. The woody vegetation comprised trees and shrubs. Trees were defined as rooted, woody, self-supporting plants ≥ 3 m in height with one or a few definite trunks ≥ 6 cm in basal stem diameter while shrubs were defined as rooted, woody, self-supporting plants <3 m in height and < 6 cm in stem basal diameter (Brown *et al*., 2005). All woody plants rooted within the plot were recorded and measured. Woody plants occurring along plot margins were included if at least half of the rooted system was inside the plot.

Woody species attributes

Woody vegetation heights were measured using a ranging rod. Height is the vertical distance from the ground to the highest living part of a plant. For multi-stemmed plants, only the height of the tallest stem was recorded. Two greatest crown diameters (D1and D2) of each woody plant, perpendicular to each other were measured to the nearest 0.1 m and averaged to get the mean diameter (D). The mean diameter was used to estimate canopy cover using the formula:

Canopy cover= $(D/2)^2$ (Meffe *et al.,* 1997) where D is the mean crown diameter.

Circumference of each plant stem was measured at breast height to the nearest centimetre

Basal area was calculated using the formula:

Basal area = $(C^2/4\pi)$ (Meffe *et al.,* 1997) where C stem circumference.

For multi-stemmed species, stems were treat individually and then added to get total basal ar for the plant.

Density (plants/ha) for each plot was calculat using the formula:

Density (plants/ha) = Number of plants × 10 000 m Plot area (m^2) (Meffe *et al.,* 1997).

Percentage *L. camara* cover was estimated for ea plot by estimating the proportion of the plot under *camara* cover.

Data Analysis

Analysis of variance (ANOVA), classification a ordination were used for data analysis. Grou truthing was done to affirm the validity of the mod that was used to map the distribution of *L. camara* the northern part of GNP. Variables included in da analysis were number of species per plot (S Shannon Index of Diversity (H^1), species evenne (E), herbaceous cover, woody plant height, bas area, density, canopy cover, species frequency, *camara* cover and altitude.

Shapiro-Wilks W test for normality was perform on vegetation data to test for the normali assumption of ANOVA using STATISTICA versi 7. One-way ANOVA was used to test for significa differences in vegetation variables among the thr categories of *L. camara* intensity. Differences height and basal area size class distributions amo the three categories were also tested using ^{2} MINITAB. Descriptive statistics (means a standard errors) were calculated usi STATISTICA for all the measured variables.

The Shannon Index (H') was calculated using the formula:

$H' = -\sum pi \ln pi$ where p_i is the proportion of species i and ln is the natural logarithm.

Evenness was calculated using the formula:

$E = \frac{H'}{\ln S}$ where S is species richness (Meffe *et al.*, 1997).

Hierarchical Cluster Analysis (HCA) using the average linkage method was performed on a matrix of plots by species, using species presence/absence data as described by ter Braak and Smilauer (1998) in MINITAB. This was done to produce a classification identifying similarities among the plots based on species composition. Species data were analysed using ordination Canonical Correspondence Analysis (CCA). Since comparison of results provides information beyond what CCA analysis alone can provide, CCA was carried out using CANOCO for Windows (version 4) (ter Braak and Smilauer, 1998). The statistical significance of the ordination was tested using an unrestricted Monte-Carlo permutation test available in CANOCO.

Results

Distribution of *L. camara*

A map showing distribution of *L. camara* in the northern part of Gonarezhou National Park is shown in Figure 2. A regression model at 5% level of significance was constructed and validated by ground-truthing. This revealed that the model was about 87% (13 out of 15 sites visited had *L. camara*) reliable in predicting the occurrence of *L. camara* in the park.

Lantana camara was found to be most prevalent among riparian vegetation and in low-lying areas, especially along the Save, Mwenezi and Runde rivers (Figure 2). (*see picture on next page*).

Vegetation Classification

A total of 41 woody and 27 herbaceous plant species were identified in the twenty plots assessed. The most common woody species identified in the study area were *Lonchocarpus capassa* Rolfe, *Dichrostachys cinerea* L, *Tabernaemontana elegans* Hochst.ex A. DC, *Diospyros mespiliformis* Hochst. Ex A. DC and *Grewia monticola* Sonder in decreasing order of dominance. Hierarchical cluster analysis separated the plots into three distinct groups with respect to species presence/absence data (Figures 3 and 4). The three clusters corresponding to plots from the uninvaded (Group 1), moderately invaded (Group 2) and heavily invaded (Group 3) categories (Figure 3) were produced based on differing floristic associations.

Distinct groups of the floristic associations were produced when woody species frequency was used (Figure 3). These groups were however distorted with the inclusion of herbaceous species. The categories of *L. camara* intensity could not be clearly defined when herbaceous species frequency was included in the clustering (Figure 4).

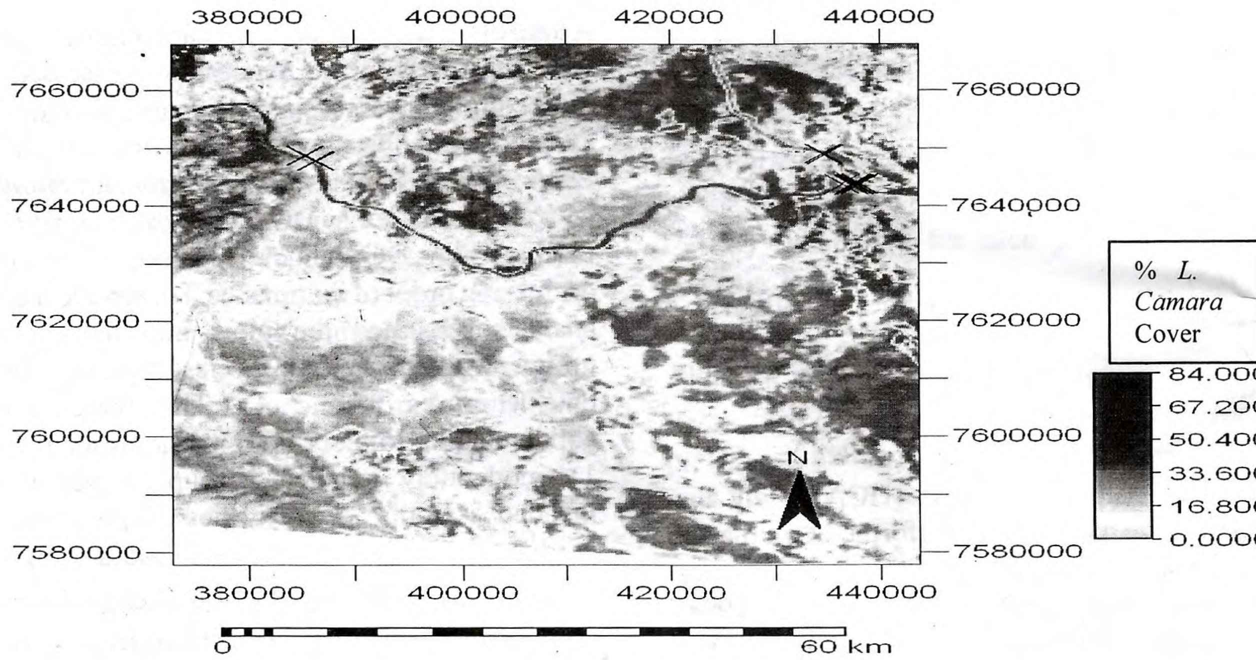

Figure 2: Modelled Spatial Distribution of Percentage *L. camara* cover in Northern Gonarezhou National Park.

The heavily invaded category was dominated by *Lonchocarpus capassa, Dichrostachys cinerea, Tabernaemontana elegans, Grewia monticola* and *Phyllanthus reticulates* Poiret. *Panicum maximum* dominated the herbaceous layer followed by *Achyranthes aspera var. sicula* and *Setaria incrassate.*

Achyranthes aspera var. sicula was most dominant in the heavily invaded category followed by *Panicum maximum. Panicum maximum* was present in almost all the sampled plots except in two plots from the heavily invaded category.

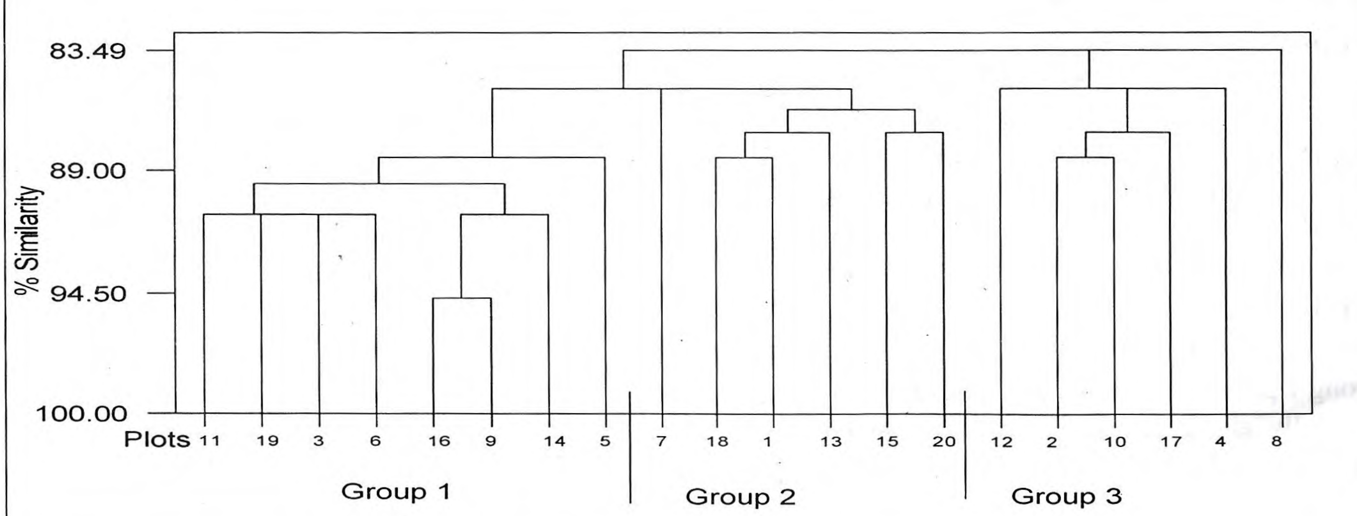

Figure 3: Hierarchical Cluster Analysis dendrogram of plots based on woody species presence/absence in northern GNP.

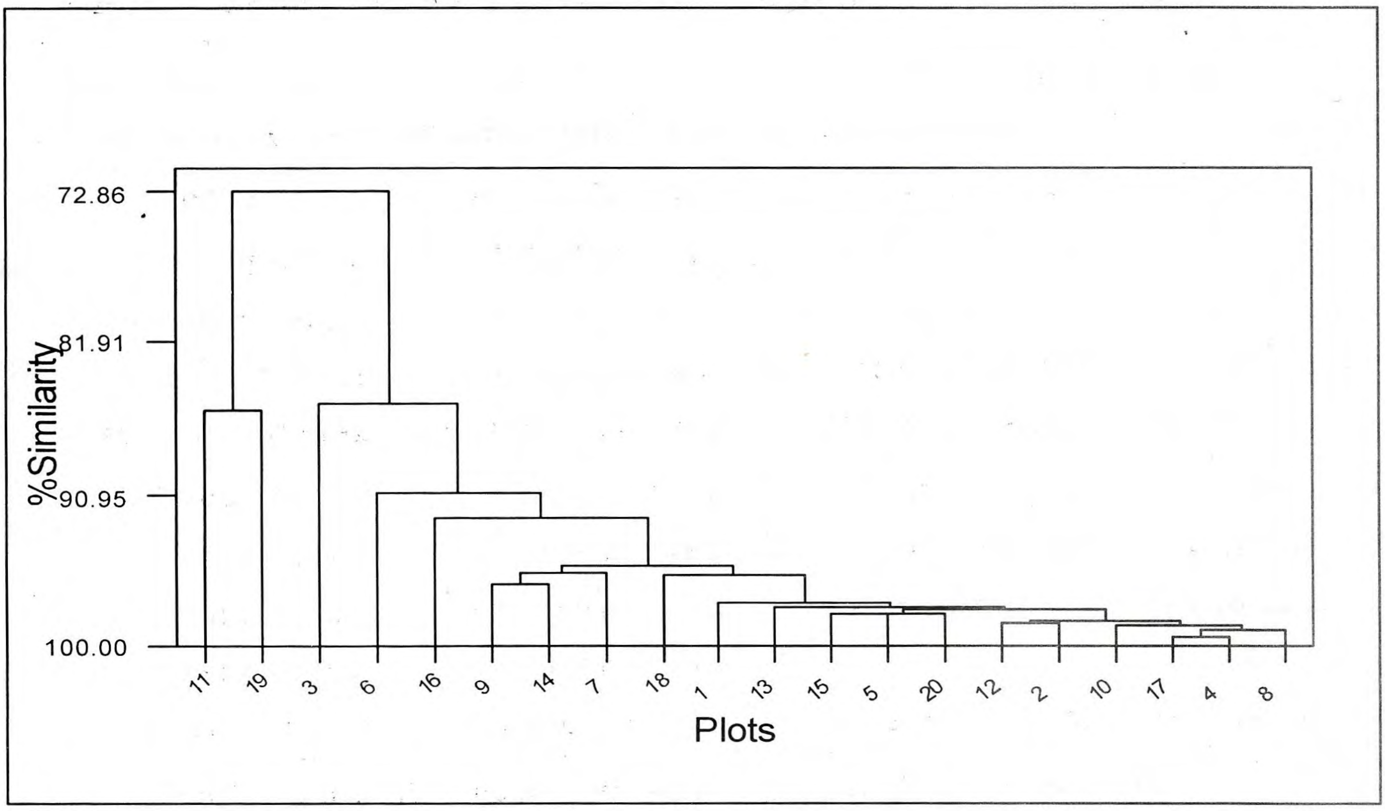

Figure 4: Hierarchical Cluster Analysis dendrogram of plots based on woody and herbaceous species presence/absence in northern GNP.

Basal Area

There were significant differences in mean woody vegetation basal area among the three *L. camara* intensity categories (F=8.5026, P<0.05). The ^{2} tests showed significant differences in size class distributions of woody species basal area among the three categories (^{2} =14.513, Df =6, P =0.025).

Table 1: Means and standard errors of the vegetation attributes in the different intensities of *L. camara* in northern GNP. *SE.*

Variable	Uninvaded ±SE	Moderately Invaded ±SE	Heavily Invaded ±SE
H'	1.875 ± 0.084	1.621± 0.084	1.334 ± 0.090
S	14.571 ± 0.670	9.571 ± 0.700	8.167 ± 0.756
E	0.707 ± 0.035	0.723 ± 0.035	0.636 ± 0.0382
Tree Density/ha	857.143 ± 69.065^{a}	542.857 ± 69.065^{b}	533.333 ± 74.598^{c}
Shrub Density/ha	4375.000 ± 237.712^{a}	3482.143 ± 237.712^{b}	2812.500 ± 256.758^{c}
Herb cover (%)	70.114 ±2.612^{a}	48.229 ± 2.612^{b}	36.150 ± 2.821^{c}
Tree height (m)	10.016 ± 1.188^{a}	9.487 ± 1.188^{b}	9.331 ± 1.283^{b}
Shrub height (m)	2.363 ± 0.098^{a}	2.128 ± 0.098^{b}	2.302 ± 0.106^{a}
Basal area (m^2)	1.380 ± 0.174^{a}	0.896 ± 0.174^{b}	0.322 ± 0.188^{c}
Canopy cover (%)	254.271 ±26.254^{a}	105.415 ± 26.254^{b}	76.016 ± 28.358^{c}

^{ab}Means within the same row with different superscripts are significantly different at $p<0.005$

The uninvaded recorded the highest frequency of the smaller size class woody plants (<100 cm^2) with the heavily invaded recording the lowest frequency (Figure 5). However, the smallest size class (<100 cm^2) dominated in all the three categories (Figure 5).

The basal area size classes showed a reverse J-shap in all the three categories. The larger size clas (>1000 cm^2) was dominated by *Trichilia emetic* Vahl, *Lonchocarpus capassa, Diospyro mespiliformis* and *Combretum imberbe* Wawra.

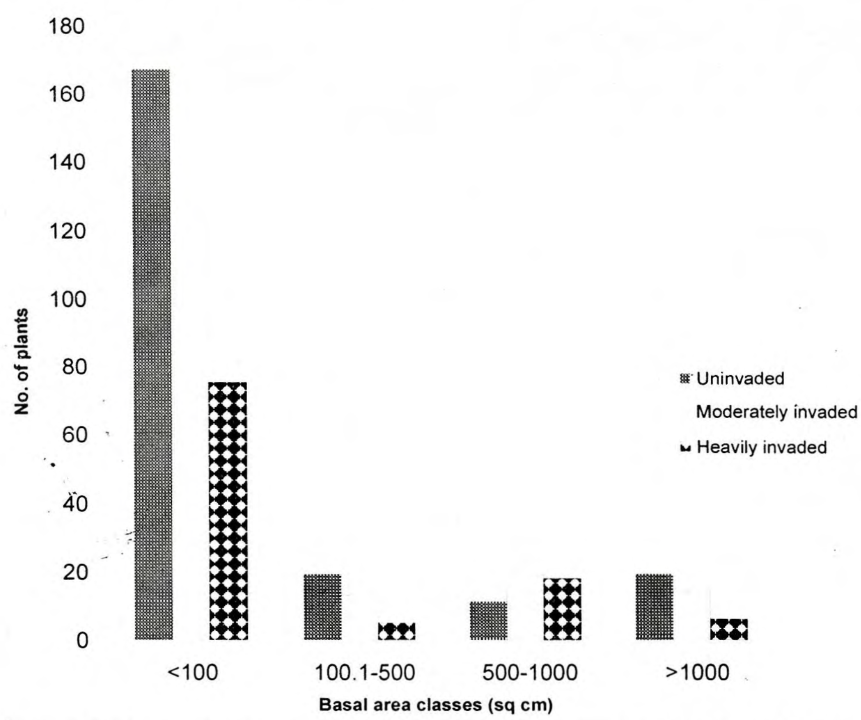

Figure 5: Basal area size class distribution of woody species in the three levels of *L. camara* invasion in northern GNP.

Both mean tree and shrub heights were not significantly different among the three levels of *L. camara* invasion (P >0.05). However, height classes differed significantly among the three levels of *L. camara* invasion with the uninvaded recording the highest frequencies of plants less than 2 m in height (χ^2 =26.738, Df =8, P =0.001) . The heavily invaded recorded the lowest frequencies of plants less than 2 m in height (Figure 6).

Faidherbia albida Delile, *Trichilia emetica, Diospyros mespiliformis, Ficus capensis* Thunb, *Lonchocarpus capassa* and *Combretum imberbe* dominated the size class greater than 20 m. Height size class distributions also revealed a reverse J-shape in all the categories.

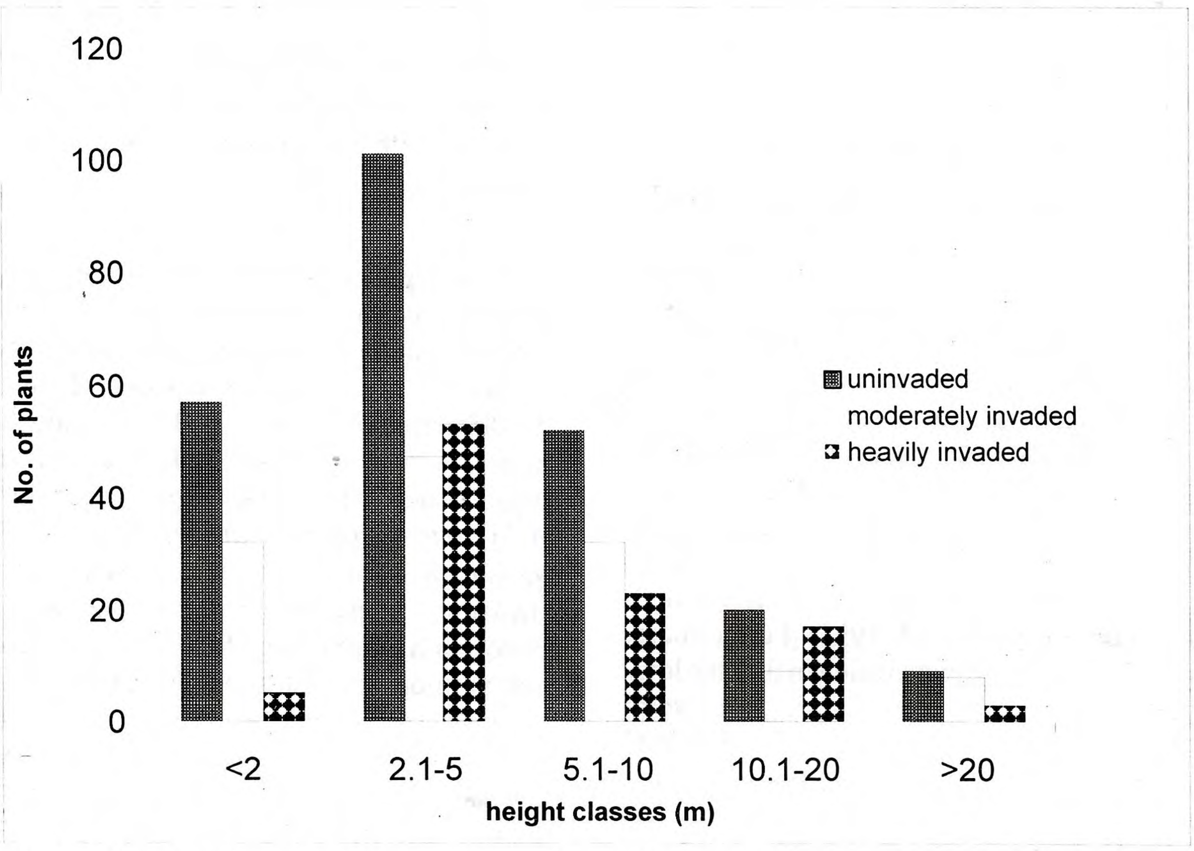

Figure 6: Height size class distribution of woody species in the three levels of *L. camara* invasion in northern GNP.

Species Density, Diversity and Richness

Species diversity and richness varied significantly among the three levels of *L. camara* infestation as revealed by the Shannon-Wiener Index of Diversity (H') and species richness (S) (F= 9.616, P< 0.05; F=22.103, P<0.05, respectively). The uninvaded category had the highest species diversity and species richness followed by the moderately invaded, while the heavily invaded was the least diverse amongst the three categories (Table 1). Species evenness showed no significant differences among the categories (P>0.05).

Analysis of variance on both mean tree density and mean shrub density showed significant differences among the *L. camara* levels (F=6.9241, P<0.05; F=10.1400, P<0.05, respectively). The heavily invaded category recorded the lowest mean densities with the uninvaded recording the highest densities of woody plants (Table 1).

Canopy Cover and Herbaceous Cover

Mean canopy cover and mean herbaceous layer cover decreased with increase in *L. camara* invasion (Table 1). The two variables showed significant differences with change in *L. camara* cover ($F=12.23$, $P<0.05$; $F=40.60$, $P<0.05$, respectively). In the uninvaded categories canopy cover was well above 200, and slightly more than 100 in the moderately invaded but was below 100 in the heavily invaded category.

Discussion

Distribution of *L. camara* in northern GNP

Figure 2 shows that more than 50 of Northern GNP has been infested with *L. camara* especially along riparian areas, which implies that the area is already threatened by the invasion to the detriment of wildlife forage. Thomas and Ellison (2000) also found that *Lantana camara* is mainly distributed within the riparian vegetation, especially along the Save, Runde and Mwenezi rivers and the low-lying areas. The dispersal mechanism of *L. camara*, which is mainly through birds and floods could account for such a distribution since riparian areas in the Park are associated with floods and a high diversity of birds (DNPWLM, 1998). Furthermore, GNP has a dry and hot climate which makes the low-lying areas and riparian zones with high moisture levels, the most favourable habitats for dispersal agents and provides ideal conditions for the proliferation of *L. camara*. *Lantana camara* also has the ability to reproduce vegetatively giving it greater advantage over most species of the savannah woodlands. Therefore, the invasion by L. *camara* in the Park as indicated by this study poses a severe threat to the riparian and aquatic ecosystems, which are hot spots of biological diversity. Changes in the riverine vegetation impact negatively on aquatic and riparian food webs.

Vegetation classification

The vegetation in GNP reveals a clear-cut separation of vegetation associations according to intensity of *L. camara* invasion. Vegetation composition and abundance varied significantly along the *L. camara* intensity gradient from the uninvaded category to the heavily invaded category.

Associated with each level of *L. camara* intensity, were three main vegetation groupings defined on the basis of species composition and abundance (Figures 3 and 4). Each group had different species composition and abundance, and also varied in explanatory variables.

Separate groupings of the uninvaded plots 6 and 11 could be explained by the heterogeneity of the environment in which they are located. The distortion on the clusters with the inclusion of herbaceous species (Figure 4) could be explained by the fact that herbaceous species composition rapidly changes with any minor variations in edaphic factors (Lykke, 1998).

Dominating woody species in the heavily invaded category such as *Lonchocarpus capassa, Diospyros mespiliformis, Dichrostachys cinerea, Thilachium africanum* Lour, *Kigelia africana* (Lam.) Benth., *Xeroderris stuhlmannii* (Taub.) Mendonca & E. P. Sousa, *Gardenia volkensii* K. Schum. and *Vitex payos* (Lour.) Merr., and herbaceous plants such as *Achyranthes aspera var. sicula* and *Panicum maximum* indicate species resistant to *L. camara* invasion. These species can be used in the restoration programme of the Park as they withstand competition from the alien plant. *Colophospermum mopane* (Kirk ex Benth) Kirk ex J. Leonard, *Faidherbia albida, Acacia ataxacantha* DC, *Spirostachys africana* Sonder, *Diplorhynchus condylocarpon* (Muell. Arg.) Pichon and *Lecaniodiscus fraxinifolius* Baker were virtually absent from *L. camara*-infested sites and were found on the uninvaded sites, which could imply that they are displaced once *L. camara* invasion occurs. These fragile communities need attention as the said species can easily be displaced by *L. camara*.

Species like *F. albida* are limited by their intolerance to competition. The main factor governing the occurrence of *Colophospermum mopane* is low availability of moisture in the soil (Nyamapfene, 1988).

However, in this study, the effect of *L. camara* appeared to be outweighing the influence of moisture on occurrence of *C. mopane*. Species such as *Leucosidea sericea* Ecklon & Zeyher, *Bridelia cathartica* Bertol.f., *Grewia monticola* and *Tabernaemontana elegans* appeared to resist moderate levels of *L. camara* invasion but are displaced as invasion intensifies.

Impact of *L. camara* on Vegetation Structure

The study showed that *L. camara* invasion is negatively affecting elements of vegetation structure in northern GNP (Table 1). The principal elements of structure are growth form, stratification and coverage. Basal area decreased with increase in *L. camara* intensity. Height size class distribution showed the dominance of the 2-5 m size class. Though height was insignificantly different, the size class distribution showed significant differences among the three categories with frequency decreasing with increase in *L. camara* infestation. The alien species might have a smothering effect on native vegetation.

The basal area size class distribution of woody species in the northern Gonarezhou National Park showed a reverse-J shape (dominance of the smaller size classes) in all the three categories, which is characteristic of communities with high recruitment (Figure 5).According to Chidumayo *et al.* (1996), small size class distribution dominance indicates the potential for high regeneration. Inverse-J shape is a characteristic of species with good rejuvenation and continuous replacement of themselves, whereas flatter distributions indicate lack of recruitment and may be species composition change (Lykke, 1998). However, this might indicate species responding to high browsing pressure or invasive alien plants in this case *L. camara*. Significant differences in basal area and height size class distributions among the three categories show that recruitment decreased with increase in *L. camara* intensity (Table 1).
Macdonald *et al.* (1991) found that alien plant invaders shade out indigenous species and reduce their recruitment in India.

In this study, *L. camara* invasion affects native vegetation recruitment and regeneration negatively as revealed by decreasing dominance of smaller size class distributions with increasing *L. camara* intensity. Furthermore, Gentle and Duggin (1998) supported this by documenting the capability of *L. camara* to interrupt the regeneration processes of native species by reducing germination, reducing early growth rates, and increasing mortality.

Gentle and Duggin (1998) found a significant increase in seed germination and seedling biomass with the removal of *L. camara* thickets. The allelopathic effects of *L. camara* result in severe reductions in seedling recruitment of nearly all species under its cover. Both tree and shrub density of native species tended to decrease with the increase in *L. camara* intensity. This reduction in density could be attributed to reduced recruitment and growth rates.

Canopy cover and herbaceous aerial cover differed significantly among the three levels of *L. camara* infestation. The total cover of a plot may exceed 100 because of over layering of canopies of different heights. The heavily invaded plots recorded much less than 100% mean canopy cover. This implies a reduction in recruitment due to *L. camara* invasion resulting in decrease in woody vegetation density with subsequent low canopy cover. Fensham *et al.* (1994) observed that *L. camara* increases mid-storey fuel loads and intense fires can destroy vegetation canopy. This could be the case in GNP where an average of 5.1 fires occur every year (Gandiwa, 2006).
Presence of *L. camara* on sites with low canopy cover could be due to open canopy cover promoting *L. camara* invasion and spread. Decrease in herbaceous aerial cover with increase in *L. camara* intensity is due to the recruitment reducing, smothering or allelopathic effect of *L. camara*. These findings concur with Fensham *et al.* (1994) who found that grass cover was negatively correlated with the abundance of *L. camara* which reduces grass cover as its cover increases.

Low soil moisture levels, which were found to be associated with *L. camara* invasion could account for the decrease in herbaceous cover with the increase in *L. camara* intensity in this study. Chatanga (2003) found a decrease in herbaceous cover with a decrease in soil moisture levels.

Species diversity and richness decreased significantly with increase in *L. camara*-infestation (Table 1). The heavily invaded category was the least diverse and the poorest in species richness, as also found by Fensham *et al.* (1994). The decline in species diversity and richness is probably due to the allelopathic effect of *L. camara.* Increase in fuel loads by *L. camara* density also results in fire sensitive species being burnt. However, the current findings contradict those of Stohlgren *et al.* (199) who found a positive correlation between level of invasion and species richness.

Conclusion

Lantana camara impacts negatively on native vegetation structure and composition. The effects on native vegetation are direct, through smothering and allelopathic means. *Lantana camara* invasion reduces native species diversity and richness to the detriment of ecosystems. It also negatively affects native vegetation recruitment and regeneration capacity. Active control of *L. camara* in Gonarezhou National Park is therefore urgently required to enhance wildlife and biodiversity conservation in the area.

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