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EFFECTS OF THE ABUNDANCE OF *PARTHENIUM HYSTEROPHORUS* ON THE COMPOSITION AND DIVERSITY OF OTHER HERBACEOUS PLANT SPECIES IN SIMANJIRO RANGELAND, TANZANIA

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Abstract:

Parthenium hysterophorus is an annual herbaceous plant native to tropical America; and an invasive plant in Africa causing distressing effects on natural flora. This study investigated the effects of P. hysterophorus on the composition and diversity of native herbaceous plant species in Simanjiro rangeland, Tanzania. Plant species count data were collected from 60 (1m2) quadrats. Using generalized linear models (GLM), the abundance of P. hysterophorus was regressed against the abundance and diversity of the native herbaceous plants. Also, Jaccard's similarity index was used to compare species composition. Results showed that there were 14 herbaceous plant species belonging to 13 genera and 10 families in the study area. Parthenium hysterophorus was the most dominant species recorded. The abundance of P. hysterophorus has a substantial negative effect on the abundance and diversity of other herbaceous plant species. Moreover, Jaccard's similarity index showed a slightly significant difference between the infested and non-infested areas. This finding suggests that P. hysterophorus has a substantial potential threat on other herbaceous flora which are sources of food and nutrients to livestock and wild animals in the area. Thus, integrated management strategies are required to control the weed from spreading to other nearby rangelands.

Keywords: Dominant Species; Evenness; Invasive Weed; Richness.

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1. Introduction

An expansion on international trade, travel and tourism has resulted into a significant increase in invasive species (Etana *et al*., 2011). These invasive species create a major threat to biodiversity globally (Preisser *et al*., 2008). According to Dogra *et al.* (2009), these species affects ecosystem

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processes by decreasing species diversity and hence altering community composition. Therefore, in order to reduce biodiversity loss, it is important to monitor ecological effects and spread of these species (Andrew *et al*., 2014). However, to achieve this, we must understand the effect of invasive species on other plant species in an ecosystem (Ehrenfeld, 2008).

An invasive species is one that establishes itself in a new habitat, spread freely and establishes a population (Simberloff, 2010). Currently, one of the main challenges in conservation which causes extinction of many other species is species invasion (Simberloff, 2003). This is because invasive species compete with resident species for light, moisture and nutrient (Vila and Weiner, 2004); and hence dominating an area through displacement of the resident species thus decreasing resident species diversity (Hejda *et al*., 2009). The majority of invasive species are introduced from away, although some native species have become invasive in newly occupied habitats (Simberloff, 2010). These native species in newly occupied habitat can be categorized into two groups and each one of the groups involves human activities. The first group, a native species that is rather restricted in range and habitat is supplemented with introductions from afar that have new genotypes, and the new genotypes, or recombinants involving the new genotypes, become invasive. The second group arises from human modification of the environment. For instance, in western Europe, the grass *Elymus athericus*, previously a minor component of high intertidal vegetation, began spreading seaward because of increased nitrogen in both aerial deposition and runoff, and it now occupies most of the intertidal in many areas (Valéry *et al*. 2004).The greatest effects of invasive species is the alteration of the whole ecosystems which affects the resident species hence negative consequences on ecosystem goods and services delivered by plant communities (Yurkonis *et al*., 2005). However, the effects of invasive species vary basing on the biological traits of the invader and characteristics of the invaded community and therefore effects of invasion should not be generalized (Andrew *et al*., 2014).

Parthenium hysterophorus L. (Asteraceae) is an aromatic annual and noxious herb native to tropical America (Veena and Shivani, 2012) and one of the most damaging invasive alien plant species. It can dominate native plants rapidly (Ayele *et al.*, 2014) and therefore threatens biodiversity (Anil, 2014). In most tropical and subtropical parts of Africa, Asia and Oceana *P.hysterophorus* was accidentally introduced with cereal and grass seed shipments from America during the 1950s (Bhowmik and Sarkar, 2005).

Studies on the effects of *P. hysterophorus* have been done in different parts of Australia, Asia and Africa but we cannot generalize the effects as the effects depends on the biological traits of the invader and characteristics of the invaded plant communities. Therefore, for the finest restoration strategies, it is important to conduct studies focusing on the effects of invasive species on composition and diversity of other plant communities in areas where the invader has established itself (Andrew *et al*.,2014).

This study aimed at assessing the effect of *P. hysterophorus* on other herbaceous plant species within a rangeland in Simanjiro District in Tanzania. Specifically, this study addresses the following question: Does *P. hysterophorus* abundance affects the composition and diversity of other herbaceous plants?

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1. Materials and Methods

1.1. Study Area

The study was conducted in Terrat rangeland in Simanjiro District in northern Tanzania at 36.6^{0}28'42"S; 3.9^{0}43'09"E and 36.6^{0}08'83"S;3.8^{0}85'94"E and 36.6^{0}17'65"S;3.9^{0}12'4"E (Figure 1). It is a semi-arid area which lies within the Maasai Steppe with a land area of 20,591 km^2 of which 600 km^2 is fertile land, 12,682 km^2 is comprised of hunting blocks and the rest is hilly area (Nyaruhucha *et al.*, 2006). The rangeland is adjacent to the Tarangire National Park in northern Tanzania within the semi-arid Tarangire-Manyara ecosystems, one of the most diverse and complex grasslands savanna ecosystems on the planet (Msoffe *et al*., 2010). The soil of the area is also characterized by high levels of phosphorus. Furthermore, the area is characterized by high variability in bimodal rainfall with long rain between January - March and short rains between September-December and frequent droughts (Nyaruhucha *et al*., 2006). The rangeland supports member of Bovidae family, blue wildebeest (*Connochaetes taurinus*) and member of family Elephantidae, elephants (*Loxodanta africana*) as well as member of family Felidae, lions (*Panthera leo*), leopards (*Panthera pardus*), family Hyaenidae, spotted hyena (*Crocuta crocuta*) and family Canidae, wild dogs (*Lycaon pictus*) (Msoffe *et al.*,2010).

According to the National Census of 2012 the dominant communities in the area are the Maasai with a human population of 178,693 who depends on livestock husbandry for their livelihood.

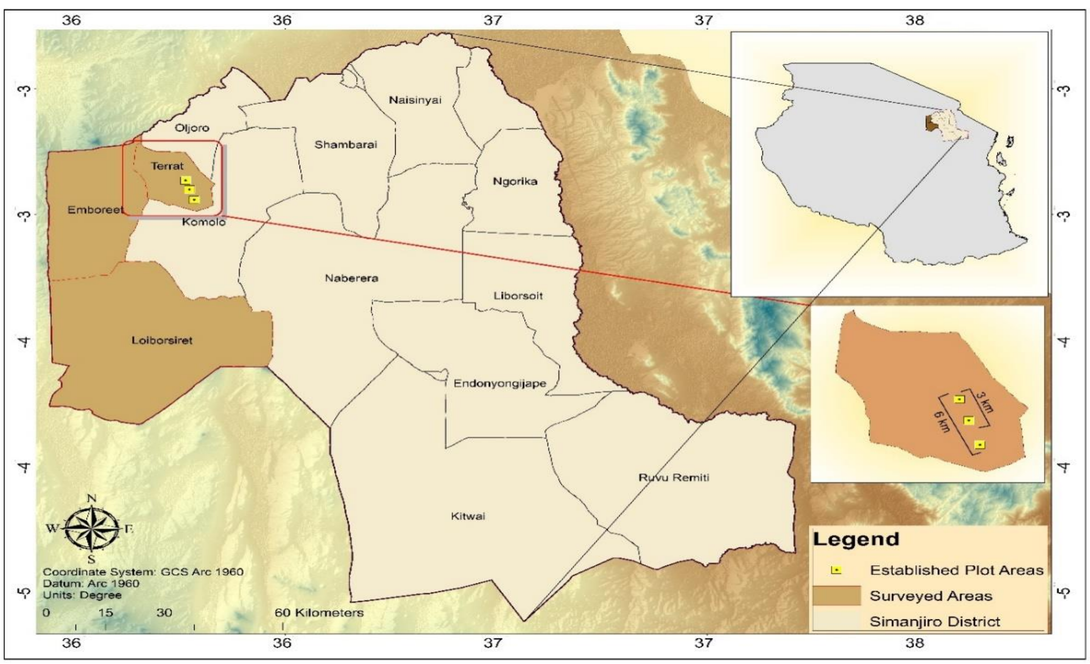

Figure 2.1: Map showing three clusters in Terat rangeland within Simanjiro District, Tanzania
Study species *(Parthenium hysterophorus)*

Parthenium hysterophorus commonly known as 'altamisa', carrot grass, bitter weed, star weed, white top, wild feverfew, the ''Scourge of India'' and congress grass; it is an upright, ephemeral herb with a vigorous growth and high fecundity especially in warmer climates, native to north-east

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Mexico (Patel, 2011). It is one of the world's seven most devastating and hazardous weeds (Patel, 2011) thought to be introduced into Asia, Africa and Oceania with cereal and grass seed shipment from America during the 1950s (Bhowmik and Sarkar, 2005). Major biological and morphological characteristics that contribute to its severe invasiveness are its adaptability to wide climatic and soil conditions, its production of allelopathic chemicals and its ability to produce large numbers of seeds (10,000 - 25,000 per plant; Bekeko, 2013). Currently, it is found in some parts of Tanzania and therefore its management is of high concern. Thus, this study attention has focused on its effects as a weed on range lands specifically in Simanjiro District.

1.2. Sampling Design and Data Collection

After the reconnaissance survey, the focus was only given to *P. hysterophorus* infested areas as the study interest was to look on the effects of it on other herbaceous species within the rangeland. The study adopted lower sampling intensity since *P. hysterophorus* had only infested a small portion of the rangeland, the area was categorized into three clusters with a distance of 3km apart from each (Figure 1), clusters were: i) *P. hysterophorus* high infested cluster (HIC) ii) *P. hysterophorus* low infested cluster (LIC) and iii) *P. hysterophorus* non-infested cluster (NIC). The distance of 3km apart between clusters has also been successfully used by Kumari *et al*. (2014), when studying the effect of *P. hysterophorus* on species diversity in India. Quadrat method and line transect methods were applied in each cluster, whereby a line transect of 100m long was laid out in *P. hysterophorus* high infested cluster, low infested cluster and non-infested cluster. Along each line transect in every cluster, 20 quadrats measuring 1m x 1m ($1m^2$) were demarcated systematically at 5 m interval along one side of the line transect. A 1m x 1m quadrat is a reasonable quadrat for assessing herbaceous plants and the method has also been used successfully by Gebrehiwot and Berhanu (2015) when assessing the effects of *P. hysterophorus* on species diversity in Gamo Gofa, Ethiopia. Within each quadrat, individuals of different plant species were identified, counted and recorded. Most of the plant species collected were identified in the field while those that could not be identified were collected, pressed and transported to Arusha National Herbarium for subsequent identification.

1.3. Data Analysis

Species richness (S), Shannon-Wiener diversity index (*H*'), evenness (E) and abundance were computed for each quadrat. Species richness (S) was estimated as total number of species in a quadrat. Species abundance for *P. hysterophorus* and other species were estimated as the relative presence of a species. Species diversity was computed using Shannon Diversity Index. This index accounts for both the abundance and the evenness of the species in natural environment as shown by the equation below (Shannon, 1948). The Shannon index is explained as $H'=-\Sigma p_i \ln p_i$ where H'= Shannon diversity index, pi= the importance value of the i^{th} species in quadrat. Species evenness was calculated as suggested by (Hill, 1973) as $E = H`/\ln S$ where S is the number of species in a quadrat. Species evenness index explains how equally abundant each species would be in the plant community. And when there is no single species dominating the ecosystem the evenness is always high evenness and it is a sign of ecosystem health. Also, species importance value index (IVI %) for each species was estimated as the sum of relative frequency (%) and relative density (%) (Curtis and McIntosh, 1950). Importance Value Index for all species was estimated in order to comprehend the dominance species. IVI %=Relative Density (%) + Relative Frequency (%).

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Additionally, a similarity index was developed to compare infested and non-infested areas according to Jaccard's formula. This coefficient has been recognized to be strong and unbiased even with a small sample size as compared with other similarity indices (Ludwing and Reyonlds, 1988).The similarity index of Jaccard between infested and non-infested area, i and j is given by the following formula: S_{ij}= a/ (a + b + c) where: (a) represents the number of species present in both i and j, (b) represents the number of species in i but not in j and (c) represents the number of species present in j but not in i. The coefficient has a value from 0 to 1, where 1 reveals complete similarity and 0 complete dissimilarity.

Generalized linear models (GLM) were then used to examine the relationship between community species abundance, diversity, evenness and richness and *P. hysterophorus* abundance. Given that those tests with no significance difference were automatically removed from the model.

2. Results

2.1. Species Composition and Dominance

The most dominant species within the study area was *Parthenium hysterophorus* followed by *Eleusine indica* (Table 2.1). A total of 14 species belonging to 13 genera and 10 families were recorded in the study area (Table 2.2). In *P. hysterophorus* infested cluster we recorded ten different species belonging to nine families.

Table 2.1: Importance Value Index (IVI) for recorded species in areas with high, low and non-infestation of *Parthenium hysterophorus*

High Infested Cluster		**Low Infested Cluster**		**Non-Infested Cluster**	
Species name	**IVI (%)**	**Species name**	**IVI (%)**	**Species name**	**IVI (%)**
Parthenium hysterophorus	43	*Parthenium hysterophorus*	36.2	*Eleusine indica*	35.4
Eleusine indica	25	*Eleusine indica*	7.9	*Tribulus terrestris*	8.1
Amaranthus spinosus	10	*Tribulus terrestris*	2.8	*Cynodon dactylon*	7.4
Tribulus terrestris	7.9	*Tephrosia purpurea*	1.9	*Cyperus rotundus*	6.7
Portulaca oleracea	6.21	*Cynodon dactylon*	1.2	*Portulaca oleracea*	6.5
Calotropis gigantean	5.7	*Portulaca oleracea*	0.2	*Calotropis procera*	6.5
Cynodon dactylon	4.4	*Calotropis gigantea*	0.2	*Echinocloa colona*	6.4
Solanum campylacanthum	3.2	*Cyperus rotundus*	0.06	*Solanum campylacanthum*	6.1
Cyperus rotundus	2.3	*Solanum campylacanthum*	0.03	*Eragrostis aspera*	5.9
		Amaranthus spinosus	0.02	*Ipomoea hildebrandtii*	3.7
				Amaranthus spinosus	0.3

Table 2.2: Name and families of species recorded in all three clusters studied

Species name	**Genus**	**Family**
Parthenium hysterophorus	Parthenium	Asteraceae
Eleusine indica	Eleusine	Poaceae
Amaranthus spinosus	Amaranthus	Amaranthaceae

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Tribulus terrestris	Tribulus	Zygophyllaceae
Portulaca oleracea	Portulaca	Portulaceae
Calotropis gigantean	Calotropis	Apocynaceae
Cynodon dactylon	Cynodon	Poaceae
Solanum campylacanthum	Solanum	Solanaceae
Cyperus rotundus	Cyperus	Cyperaceae
Tephrosia purpurea	Tephrosia	Fabaceae
Ipomoea hildebrandtii	Ipomoea	Convolvulaceae
Echinoclea colona	Echinoclea	Poaceae
Eragrostis aspera	Eragrostis	Poaceae
Calotropis procera	Calotropis	Apocynaceae

2.2. Comparison Between Infested and Non- Infested Areas

The results from Jaccard's similarity coefficient showed a value of 0.6 in a comparison between *P. hysterophorus* high infested cluster and non-infested cluster. Similarly, a coefficient showed a value of 0.6 when *P. hysterophorus* low infested cluster was compared with and non-infested.

2.3. Effect of *P. Hysterophorus* on Other Herbaceous Plant Species

There was a significant negative relationship between the abundance of *P. hysterophorus* and the abundance and diversity of other herbaceous species (Table 2.3). Furthermore, the abundance of *P. hysterophorus* showed no significance difference with the evenness and richness of other herbaceous plants and hence removed from the Generalized linear Model.

Table 2.3: Effect of the abundance of *P. hysterophorus* on diversity and abundance of other herbaceous plants

	Estimate	**Standard Error**	***P*-value**
(Intercept)	6.093	0.034	0.001
Diversity	-0.9423	0.033	0.001
Abundance	-0.0023	0.0002	0.001

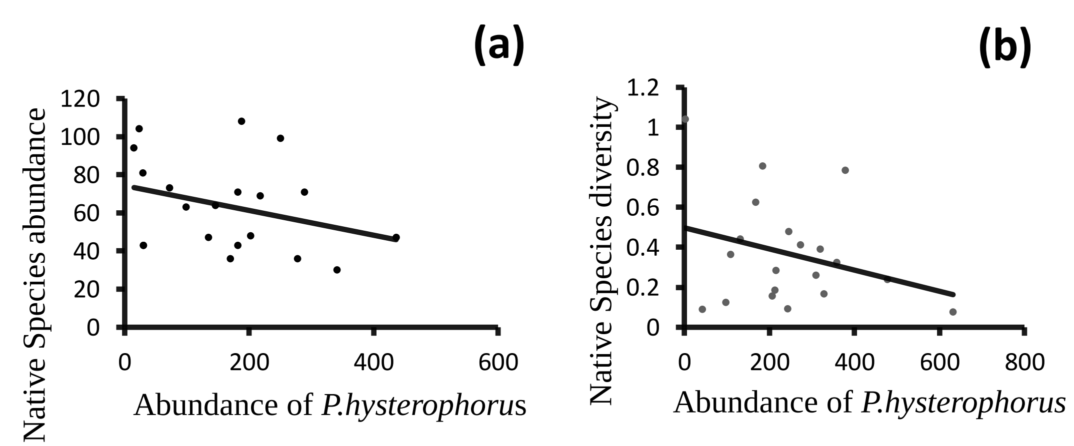

Figure 2.2: The relationships between *P. hysterophorus* abundance and native herbaceous species (a) native species abundance, (b) native species diversity in Simanjiro rangeland, Tanzania.

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3. Discussion

3.1. Species Composition and Dominance

The number of 14 species recorded is relatively low this might be due to the fact that the area is semi-arid in nature. Among all the species recorded *P. hysterophorus* was the most dominant species (Table 2.1) with greater Importance Value Index (IVI) as compared to all other plant species. Similar results were found by Huy and Seghal (2004) who found greater IVI on *P. hysterophorus* an indication of the domination character of the weed. Also, Khan *et al*. (2014) confirmed that the importance value index (IVI) showed the superiority of *P. hysterophorus* in Peshawar valley, Pakistan. The domination of *P. hysterophorus* could be due to its high invasive capacity, allelopathic properties, short life cycle and prolific character (Dalip *et al*., 2013). This might be due to its high growth rate and hence ability to hinder the growth of other species. Similarly, Belachew and Tessema (2015) showed that *P. hysterophorus* was the most competitive species in Ethiopia.

3.2. Comparison Between Infested and Non-Infested *P. Hysterophorus* Areas

Results showed a high similarity between the infested and non-infested area, this indicated that there is no fundamental change in species composition within the area. Similarly, Kumari *et al*. (2014) observed no major difference in species composition between *Parthenium* weed infested and non-infested area in cultivated fields of Bilaspur, India. The similarity between infested and non-infested area might be due to a short time since the introduction of the weed in the area as *P. hysterophorus* achieved a major weed status in India and Australia after decades (Bhowmik *et al*. 2007). Therefore, with time if *P. hysterophorus* remains uncontrolled fundamental changes in species composition within the area are expected to occur.

3.3. Effects of The Abundance of *P. Hysterophorus* on Community Structures of Other Herbaceous Plants

There was a negative significance relationship between the abundance of *P. hysterophorus* and the abundance and diversity (Table 2.3). This suggests that *P. hysterophorus* significantly decreased the abundance and diversity of other species (Fig. 2.2(a)-(b). Similarly, Mekonnen (2017) who reported the reduction in species diversity as the result of the high abundance of *P. hysterophorus* in Ethiopia. Studies in Australia (Grice 2006) and India (Kohli *et al.*,2004) have also found a decrease in plant diversity as the result of *P. hysterophorus* invasions.

There was no significance difference between the abundance of *P. hysterophorus* and species richness. This finding is contrary to that of Kohli *et al*. (2004) who reported a significant decrease in species richness from 68 to 32% in invaded areas in the lower Himalayas, India. Lower than expected effect of the abundance of *P. hysterophorus* on species richness in our study may be due to the semi–arid nature of the study area which makes the area poor in species richness. Furthermore, *P. hysterophorus* is also a recent introduction to Tanzania (Clark and Lotter 2011), so the long-term effects of it on species richness will only become evident in the long term.

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The present study has also revealed that there was no significance difference between species evenness and the abundance of *P. hysterophorus.* This could elucidate that *P. hysterophorus* has not established itself in the manner that has affected the ecosystem health, which is also an evident that the weed is still in the initiation stage of infesting the area. As Belachew and Tessema (2015) supported that the evenness of species declined with increasing spread of *P. hysterophorus* which suggests negative influence that *P. hysterophorus* had on the status of species evenness. Seta *et al*. (2013) and Dalip *et al*. (2013) reported that *P. hysterophorus* has negative significance difference on species evenness in Mehari Sub-Watershed of Rajouri Forest Range, India and in Gedeo Zone, Southern Ethiopia respectively.

4. Conclusion and Recommendation

The study has revealed that *Parthenium hysterophorus* is a dominant weed and has negative effect on the diversity and composition of other native herbaceous plant species. On one hand, monitoring of the species spread rate and its impact on native flora is important in order to develop management control strategy. On the other hand, there should be deliberate efforts on the ground to contain its spread and establishment into protected areas in Northern Tanzania. Additionally, these are preliminary results and more intensive monitoring are required to come up with appropriate control measures.

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