

Full Length Research Paper

Abundance and impact of *Parthenium hysterophorus* L., an alien invasive herb on plant species diversity in invaded areas of Queen Elizabeth National Park, Uganda

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Parthenium hysterophorus is an alien annual herb that aggressively threatens biodiversity of Queen Elizabeth National Park (QENP) in Uganda. Occurrence, abundance and impact of *P. hysterophorus* on plant species diversity were examined. An observational inspection survey assessed the occurrence of *P. hysterophorus* while Quadrats sampled vegetation in *P. hysterophorus* invaded and uninvaded sites of Mweya Peninsula and along Kazinga Channel Track. Plant species richness, dominance, evenness and diversity of invaded and uninvaded sites were statistically different at $P < 0.05$. Species richness (R) and dominance (D) were higher in invaded sites ($R = 58$, $D = 0.62$) than uninvaded sites ($P = 0.043$; $R = 39$, $P = 0.04$; $D = 0.46$). Consequently, species diversity of other plants became less ($1-D = 0.38$) in invaded than uninvaded ($P = 0.039$; $1-D = 0.55$). Also, *P. hysterophorus* significantly starts to reduce species diversity and richness at very low levels of abundances, as low as (4.6%) and (7.7%), respectively, and dominates at a relatively higher level (40.2%). It was concluded that *P. hysterophorus* in QENP, negatively affects the plant species diversity at low levels of abundances through dominance.

Key words: *Parthenium hysterophorus*, environmental impact, species abundance, species richness, weed spread.

INTRODUCTION

Parthenium hysterophorus is an alien annual herb that belongs to the Asteraceae family (Meena et al., 2017). Currently, it is aggressively threatening the biodiversity of Queen Elizabeth National Park (QENP) in Uganda. It originated from Southern United States of America (Thapa et al., 2018) and due to its high colonization vigour (Steven and Shabbir, 2014), it has reached as far

as East Africa in general and Uganda, in particular (Wabuye et al., 2014). In Uganda, *P. hysterophorus* has been recorded in the Eastern districts of Jinja and Busia, Central districts of Kampala and Masaka, Western districts of Mbarara and Kasese and the Northern district of Pader (Wabuye et al., 2014).

P. hysterophorus is an erect plant that attains a mean

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height of 2 m (Sahrawat et al., 2018). Its life cycle exhibits rosette and reproductive distinct growth stage. In rosette stage, the plant develops large simple leaves that create a wide cover which prevents undergrowth (Kaur et al., 2014). They later become multi-branched, forming bipinnate leaves at reproductive stage (Sahrawat et al., 2018). A single mature *Parthenium* plant produces a minimum of 25000 (Kaur et al., 2014) and a maximum of 100,000 seeds (Bobo and Abdeta, 2016). The seeds are then dispersed by vehicles, wind, water, machinery, animals, and along with fodders and grains (Meena et al., 2017; Birhanu and Khan, 2018). Seed germination takes place throughout the year since it is not limited by moisture availability (Kaur et al., 2014). Soon after the seedlings' emergence, the plant forms a dense canopy and then flowers within a month (Bobo and Abdeta, 2016). *P. hysterophorus* requires an average of 180-240 days to complete its life cycle (Kaur et al., 2014; Meena et al., 2017).

The negative effects of *P. hysterophorus* are not limited to plant species diversity but also impacts on animals (Bobo and Abdeta, 2016; Meena et al., 2017) that inhabit that same locality. Direct contact with the dry parts of *P. hysterophorus*, causes asthma and skin irritations (Kumar et al., 2012). Body dehydration, inflammation of soft body membranes, miscarriage and headache have also been reported (Shrestha et al., 2019). An amount of 10-50% of *P. hysterophorus* in the animals' fodder kills livestock and buffaloes (Sahrawat et al., 2018). *P. hysterophorus*' invasion reduces plant species diversity within national parks (Etana et al., 2015) which propels game animals to search for food beyond park boundaries, creating food insecurity in neighbouring communities (Abdulkerim-Ute and Legesse, 2016; Horo et al., 2020).

Although, *P. hysterophorus* is spreading rapidly (Thapa et al., 2018) and its occurrence impacting negatively on plant composition of rangelands (Khaket et al., 2015; Hassan et al., 2018), no documentation exists on how it has influenced the vegetation composition in Queen Elizabeth National Park (QENP). Thus, the examination of abundance for *P. hysterophorus* and how it impacts on plant species diversity, can help in monitoring of the habitat of QENP as an important aspect of wildlife and biological conservation (Pilliod and Arkle, 2013). It will also inform on detection of vegetation changes (Phillippoff and Cox, 2017), especially when such changes become detrimental to species (Nkoa et al., 2015). In this study, therefore, the occurrence and abundance of *P. hysterophorus* and its impact on plant species diversity of QENP were documented.

MATERIALS AND METHODS

Study area

The study was carried out between June 2014 and December 2015 in Mweya peninsula and along the Kazinga channel track located

in QENP. The Park is the largest protected area that lies within the Albertine rift valley in Western Uganda (Figure 1). QENP directly spans the equator line (00° 15'S, 30° 00'E) between lakes Edward and George. These two lakes are connected by a 35 km Kazinga channel at an oval land mass, the Mweya peninsula (4.22 km²), located at (0° 11' 40"S 29° 53'57" E and 890 meters above sea level. The park which is under the management of Uganda Wild Authority (UWA), covers an area of 1978 km². QENP receives mean maximum precipitation of 1390 mm and minimum of 750 mm annually. The mean annual maximum temperature is 28°C and minimum is 18°C (UWA, 2012). The original vegetation of the study area is typically savanna grassland, predominated by herbs, grasses, shrubs and trees. However, UWA (2012) reported that the park also inhabited other invasive species such as *Lantana camara*, *Dichrostachys cinerea*, *Imperata cylindrica*, *Opuntia vulgaris*. Thus, in QENP, adverse impacts of *P. hysterophorus* are aggravated by the existence of other invasive plant species.

QENP is Uganda's most popular tourist destination centre, which provides a rich habitat for 95 mammalian and 619 avian species. It is a haven for antelope species like Uganda kobs, duikers, Topis and sitatunga, as well as big mammals like lions, elephants, buffaloes and hippopotamuses. According to UWA (2012), an estimated human population of 30,000 people lives within the park in 11 fishing villages; while 50,000 people live in 52 parishes bordering it. This human population together with the UWA staff and tourists crisscross the park on a daily basis.

Study sites selection

Study sites were selected using two methods. These were based on preliminary information provided by QENP-invasive species management team on *P. hysterophorus* invasion, and guidelines given by Nkoa et al. (2015). Using the QENP-invasive species management team, hot spots of *P. hysterophorus* occurrence were located, and the clumpy spatial distribution pattern exhibited by *P. hysterophorus* within the located study sites necessitated stratification of the hot spots (herein termed as sampling sites), according to Nkoa et al., (2015).

Data collection methods

Occurrence, hotspots and spread of *P. hysterophorus* in QENP

An observational inspection survey was conducted to assess the occurrence of *P. hysterophorus* as an indicator of its hotspots and spread in the park. Guided by the presence of at least a single *Parthenium* plant, occurrence of *P. hysterophorus* was measured in a 1-m² randomly thrown quadrat within (50 x 50) m plots of each hot spot following survey procedure by Maszura et al. (2018). The number of spots for a specific hotspot inhabited by *P. hysterophorus* were recorded, and *P. hysterophorus* occurrence computed as percentage presence in each hot spot for comparisons (Bhusal et al., 2014).

Plant species abundance in *P. hysterophorus* invaded and uninvaded sites of QENP

A quadrat method was employed to generate the plant species abundances, for examination of *P. hysterophorus*' impact on species diversity (Arne et al., 2018; Maszura et al., 2018; Zereen et al., 2018). Three spots per hotspot with > 50% *P. hysterophorus* area cover, were considered for sampling (Bhusal et al., 2014).

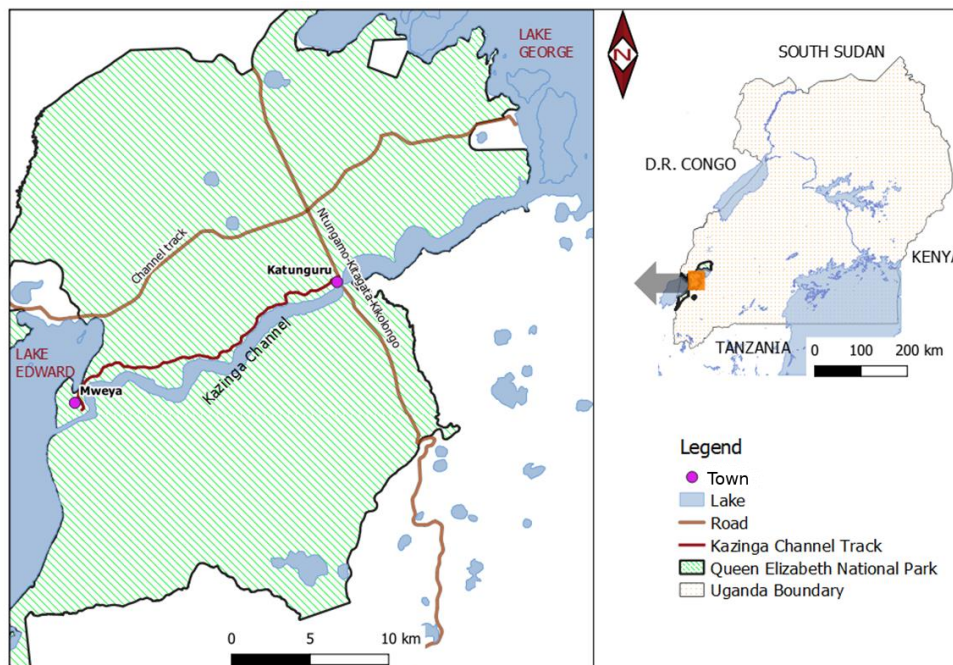


Figure 1. A map of Uganda showing the Location of the study areas in Queen Elizabeth National Park, Uganda. (Developed in QGIS 3.4.13).

Nine pairs of (10 m X 10 m) plots at 2 meters apart were demarcated for each hotspot; in a manner that nine plots were demarcated in *P. hysterothorus* invaded and other nine in uninvaded sites. A 1-m² quadrat was then randomly thrown in triplicate in each plot. Thus, a total of fifty-four (54) quadrats were placed in invaded and an equal number placed in uninvaded plots. All plant species within each quadrat were counted, recorded, collected and taken to Makerere University herbarium for identification. Plant species abundance was calculated as per a formula by Mahajan and Fatima (2017):

$$\text{Percentage abundance} = \frac{\text{Total count of an individual species}}{\text{Total number of all species recorded}} \times 100$$

Plant species diversity indices in *P. hysterothorus* invaded and uninvaded sites of QENP

Determination of plant species diversity indices; Species Simpson's index of diversity, dominance, and evenness for *P. hysterothorus* invaded and uninvaded sites were computed from plant species abundance using PAST computer software version 4.03, 2020 while species richness was compiled based on the number of plant species collected.

Data analyses

We analyzed data using Student's t-test for independent samples which compared the mean differences of Simpson's index of diversity, dominance, evenness, and richness between *P. hysterothorus* invaded and uninvaded sites while One Way ANOVA compared the computed indices between sampling sites at 0.05 level of significance using IBM SPSS Statistics 21, 2020.

A Principal Component Analysis (PCA) was run to correlate the plant species with *P. hysterothorus* abundance. Effects of *P. hysterothorus* abundance on species diversity indices were correlated by linear regression models.

RESULTS AND DISCUSSION

Occurrence, spread and hotspots of *P. hysterothorus* in QENP

From the survey with the invasive species management committee, the hot spots for *P. hysterothorus* were found to be motor-mechanical workshops, water drainage trenches, campsites, homesteads, trash burning sites located in Mweya Peninsula and spots along Kazinga channel track. *P. hysterothorus* percentage occurrences were generally high and ranged from 59.1 to 100%. Occurrence was highest in motor-mechanical workshops (100%), followed by burnt sites (85.7%), homesteads (77.1%), campsites (75.0%) then water drainage trenches (60.0%), and lastly, spots along Kazinga channel track (59.1%) as presented in Figure 2. It is evident that incoming vehicles were the most probable means of introduction of *P. hysterothorus* in these areas and its spread was further enhanced by crisscrossing of more vehicles. Mweya Peninsula once hosted the management headquarters for QENP and it is where vehicle washing and mechanical repairing of the vehicles took place. Thus, water from vehicle washing could have

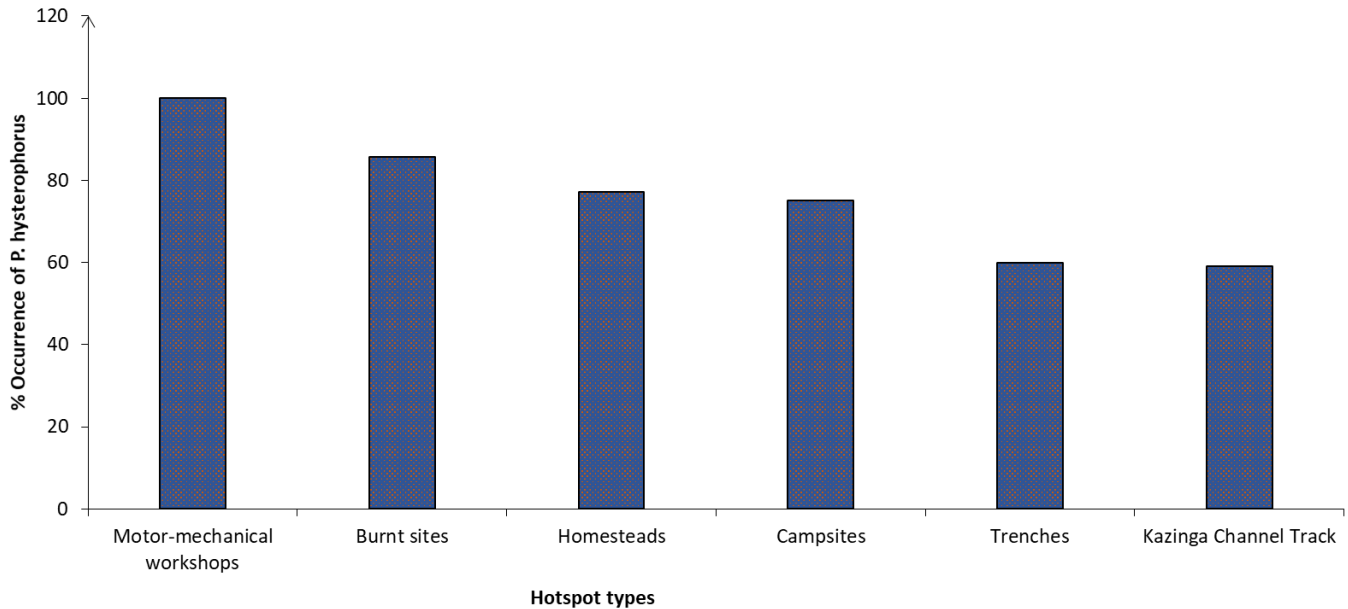


Figure 2. *P. hysterophorus* percentage occurrence for different hot spots.

spread and facilitated the seed germination of this noxious weed. The study findings are in line with CLIMEX simulation results that recorded *P. hysterophorus* in drainage trenches, dumpsites, abandoned buildings, construction sites, residential areas, rangelands and crop fields (Wabuye et al., 2014 ; Horo et al., 2020). The results also agree with a report from the distribution survey made in Nepal, where *P. hysterophorus* dispersal was directly associated with vehicle movements (Shrestha et al., 2019). Water channels were highly infested with Parthenium weed in Awash National Park in Ethiopia; thus, water was one of the dispersing agents of this weed (Etana et al., 2015). Tracks regularly used by animals to the peninsula were also observed to be lined by *P. hysterophorus*. These tracks included the visible ones made by hippopotamuses and elephants as they leave the waters of Kazinga channel. Therefore, animals' movements especially the big mammals such as elephants, buffaloes and hippopotamus are likely to be playing a big role in spreading the weed by carrying its seeds in their hooves, which can cause rapid spread of the weed and difficulty in its management.

Consistent with the findings of this study, Kuldip et al. (2011) noted that increased tourism and transportation intensified the spread of *P. hysterophorus* in North-Western Indian Himalaya. *P. hysterophorus* invasion was found in internally displaced people's camps in Pader district of Uganda, and near residential and worshipping places in Kampala (Wabuye et al., 2014) and in Malaysia (Maszura et al., 2018). It is highly likely that the spread of this weed is facilitated by human movements accidentally or due to its ornamental value such as

wreath making and wedding decorations in churches. It is possible that *P. hysterophorus* has spread in the same ways into the neighbouring communities of the QENP.

Plant abundance in *P. hysterophorus* invaded and uninvaded sites

In this study, plants species collected belonged to 27 genera and 16 families. Members of family Asteraceae were the most abundant (83.2%) in invaded sites, followed by Poaceae (11.6%) while members of other families that included Verbenaceae, Tiliaceae, Solanaceae composed of 5.4% are shown in Table 1. The table shows only plant species with percentage abundance ≥ 0.01 . Conversely, members of other plant families (48.8%) dominated the uninvaded sites followed by Poaceae (46.6%), whereas those of Asteraceae (4.2%) were the least abundant. In other studies, Poaceae (14.28%) and Asteraceae (9.52%) were among top three rich families in *P. hysterophorus* invaded sites (Gebrehiwot and Berhanu, 2015; Gadisa et al., 2019). Annual herbs of Asteraceae family have a high fecundity (Chauhan et al., 2019), that could have enabled them to compete favourably with members of other families for growth requirements. Moreover, invaded sites were characterized with bare soil patches due to disturbance, that could have allowed sunlight for secondary colonizers of Asteraceae family to grow.

We found that *P. hysterophorus* was the most abundant (79.0 %) among the flora in invaded sites followed by *Cyperus rotundus* (7.2%). *Cynodon dactylon* was

Table 1. Plant species abundances and their ranks in *P. hysterothorus* invaded and uninvaded sites.

Plant family/species	Plant origin	Counts		% Abundance		Rank	
		Invaded	Uninvaded	Invaded	Uninvaded	Invaded	Uninvaded
Acanthaceae							
<i>Hypoestes trifora</i>	IS	41	-	0.63	-	19	-
Amaranthaceae							
<i>Amaranthus spinosus</i> (L.)	IS	420	-	1.35	-	4	-
Asteraceae							
<i>Parthenium hysterophorus</i> (L.)	AN	24440	-	79.01	-	1	-
<i>Bidens pilosa</i> (L.)	IS	712	1	2.3	-	3	32
<i>Tagetes erecta</i> (L.)	IS	289	-	0.93	-	8	-
<i>Conyza bonariensis</i> (L.)	IS	235	-	0.76	-	9	-
<i>Conyza stricta</i> (Willd.var.)	IS	27	-	0.09	-	24	-
<i>Gnaphalium luteo-album</i> (L.)	IS	21	39	0.07	-	25	12
<i>Argeratum conyzoides</i> (L.)	IS	13	66	0.04	-	29	66
Capparaceae							
<i>Cleome monophylla</i> (L.)	IS	51	-	0.16	-	18	-
Convolvulaceae							
<i>Dichondra repens</i> (L.)	IS	10	43	0.03	1.69	30	10
Cyperaceae							
<i>Cyperus rotundus</i> (L.)	IS	2234	656	7.22	25.05	2	1
Malvaceae							
<i>Sida ovata</i> (Forssk.)	IS	219	24	0.71	0.94	10	15
Oxalidaceae							
<i>Oxalis corniculata</i> (L.)	IS	66	-	0.21	-	17	-
Fabaceae							
<i>Indigofera spicata</i> (Forssk.)	IS	35	339	0.11	13.28	22	3
Poaceae							
<i>Digitaria scalarum</i> (Schweint.) Chiov.	IS	395	0	1.28	-	5	-
<i>Cynodon dactylon</i> (Pers.)	IS	296	260	0.96	10.29	7	4
<i>Datylactenium aegyptium</i> (L.) Willd.	AN	219	547	0.71	21.4	10	2
<i>Eleusine indica</i> (L.) Gaertn	AN	149	13	0.48	0.48	13	16
<i>Chloris gayana</i> (Kunth.)	IS	104	188	0.34	7.37	14	5
<i>Eleusine jaegeri</i> (Var.)	IS	103	41	0.33	1.61	14	11
<i>Sporobolus africanus</i> (Poir.)	IS	20	26	0.06	1.02	26	14
<i>Hyparrhenia rufa</i> (Nees.) Stapf.	IS	10	82	0.03	3.21	30	7
<i>Cynodon nlemfuensis</i> (Vanderyst.)	IS	2	28	0.01	1.1	42	13
Polygonaceae							
<i>Oxygonum sinuatum</i> (Meisn.) Dammer	IS	213	140	0.69	5.48	12	6
Primulaceae							
<i>Anagallis arvensis</i> (L.)	IS	41	-	0.13	-	19	-
Solanaceae							
<i>Datura stramonium</i> (L.)	IS	33	-	0.11	-	22	-
Tiliaceae							
<i>Triumfetta rhomboidea</i>	AN	393	53	1.27	2.07	6	9
Verbenaceae							
<i>Lantana camara</i> (L.)	AN	102	-	0.33	-	14	-
Zygophyllaceae							
<i>Tribulus terrestris</i> (L.)	IS	38	6	0.12	0.23	21	22
Total counts		30931	2552				

Bolded, Family names; IS, Indigenous; AN, Alien.

recorded in all *P. hysterophorus* invaded sites, but with a low abundance (0.96%). Similarly, a report on weed survey done in Khyber Pakhtunkhwa in Pakistan, revealed that *P. hysterophorus* dominated the study sites with the highest abundance (63.4%) among the weeds and was followed by *C. dactylon* (11.37%) at most locations (Ali and Khan, 2017). *P. hysterophorus* abundance was also the highest (85.2%) at Kuala Muda in Malaysia (Maszura et al., 2018). In another related study, highest mean important value index (IVI) of (76.15%) was recorded for *P. hysterophorus* (Gebrehiwot and Berhanu, 2015) in Ethiopia. Musese et al. (2020) recorded the highest abundance (43.0%) of the same alien invasive species in Tanzania. High abundances of *P. hysterophorus* have been attributed to its allelopathic effects on native species (Meena et al., 2017; Birhanu and Khan, 2018), short life span and high fecundity (Bobo and Abdeta, 2016; Meena et al., 2017), vegetative regeneration (Rwomushana et al., 2019), absence of natural enemies (Meena et al., 2017) and diverse means of dispersal; which could have enhanced its rapid spread and fast colonization (Abdulkerim-Ute and Legesse, 2016).

Co-existence of plant species with *P. hysterophorus* at different sampling sites

Analysis of plant species that co-existed with *P. hysterophorus* at different sampling sites revealed a strong association of *P. hysterophorus* abundance with *Cyperus rotundus* and *Tribulus terrestris*. They clustered more closely with *P. hysterophorus* on negative axis of PC1 in Trenches (T). Other plant species such as *Bidens pilosa*, *Indigofera spicata*, *Cynodon dactylon*, *Oxalis corniculata*, *Portulaca oleracea*, and *Triumfetta rhomboidea* also showed a strong association and clustered close to negative axis of PC1 in motor-mechanical workshops (MW). *Digitaria scalarum*, *Cida ovata*, *Oxygonum sinuatum*, *Eleusine indica*, *Chloris gayana* clustered close to negative axis of PC2 around homesteads (HS), showing a weak association with *P. hysterophorus* abundance. *Datyloctenium aegyptium* and *Eleusine jaegeri* clustered on positive axis of PC2 at burnt sites (BA), also showing a weak association with abundance of the invading weed. *Galinsoga parviflora*, *Dichondra repens* clustered close to negative axis of PC2 showing a weak relationship (Figure 3). *C. rotundus*, which inhabits wet environments, co-existed in trenches where the Parthenium seeds could have dispersed by water currents. Secondary colonizers such as *B. pilosa* could have existed in motor-mechanical workshops following soil disturbance. *T. terrestris* was also recorded in high and low *P. hysterophorus* infested clusters of Simanjaro Rangeland in Tanzania (Musese et al., 2020). The co-existence can also be explained from

morphological perspective. For example, *C. dactylon* develops stolons and rhizomes which enhance its rapid vegetative growth that enables it to compete favourably with *P. hysterophorus*. Also, the stolons and rhizomes already in the soil could have been spread into fresh areas by a grader while making drainage systems. Furthermore, a study by Kruk and Satorre. (2008), reported that *C. dactylon* reproduces by seeds that have a low primary seed dormancy. Thus, seeds emerge from the soil faster than seedlings of other plants, which makes them strong competitors (Donato et al., 2019). Therefore, *C. dactylon* is a potential candidate for suppressing *P. hysterophorus* and is recommended for vegetation restoration in *P. hysterophorus* invaded sites. In other studies, *C. dactylon* was also found in *P. hysterophorus* invaded sites (Kumari et al., 2014) in India and Woreda in Ethiopia (Gadisa et al., 2019).

Plant species diversity indices in *P. hysterophorus* invaded and uninvaded sites in QENP

Generally, the study results showed a significant difference in species richness, dominance, evenness and diversity between *P. hysterophorus* invaded and uninvaded sites with $P < 0.05$ (Table 2). Although invaded sites were richer ($P = 0.043$, $R = 58$) in plant species than uninvaded ($R = 39$), uninvaded sites had more evenly distributed plant species ($P = 0.04$, $E = 0.63 \pm 0.02$) than invaded ($E = 0.23 \pm 0.08$). Species dominance was also found to be higher in invaded ($P = 0.04$, $D = 0.62 \pm 0.19$) than uninvaded sites ($D = 0.46 \pm 0.25$). Consequently, species diversity became significantly less ($P = 0.039$, $1-D = 0.38 \pm 0.19$) in invaded than uninvaded ($1-D = 0.55 \pm 0.25$). Reviewed impacts of *P. hysterophorus* on species diversity in India revealed a decrease (46.1%) in grass cover and a loss (398.1) g m^{-2} in dry biomass of Poaceae family (Birhanu and Khan, 2018). Assessment of *P. hysterophorus* impact on herbaceous plant diversity of Awash National Park in Ethiopia (Etana et al., 2015), attributed the difference in species richness to high regeneration of plant species that follow soil disturbance.

Effect of *P. hysterophorus* abundance on plant species diversity, dominance, richness and evenness in invaded sites of QENP

It was found that increasing relative abundance of *P. hysterophorus* causes a significant decline in plant species diversity ($R^2 = 0.9972$; $P < 0.001$), and plant species richness ($R^2 = 0.7377$; $P < 0.001$), but increases dominance in invaded sites ($R^2 = 0.9962$; $P < 0.001$). However, it does not contribute to species evenness in invaded sites ($R^2 = 0.0081$; $P = 0.643$) as indicated in

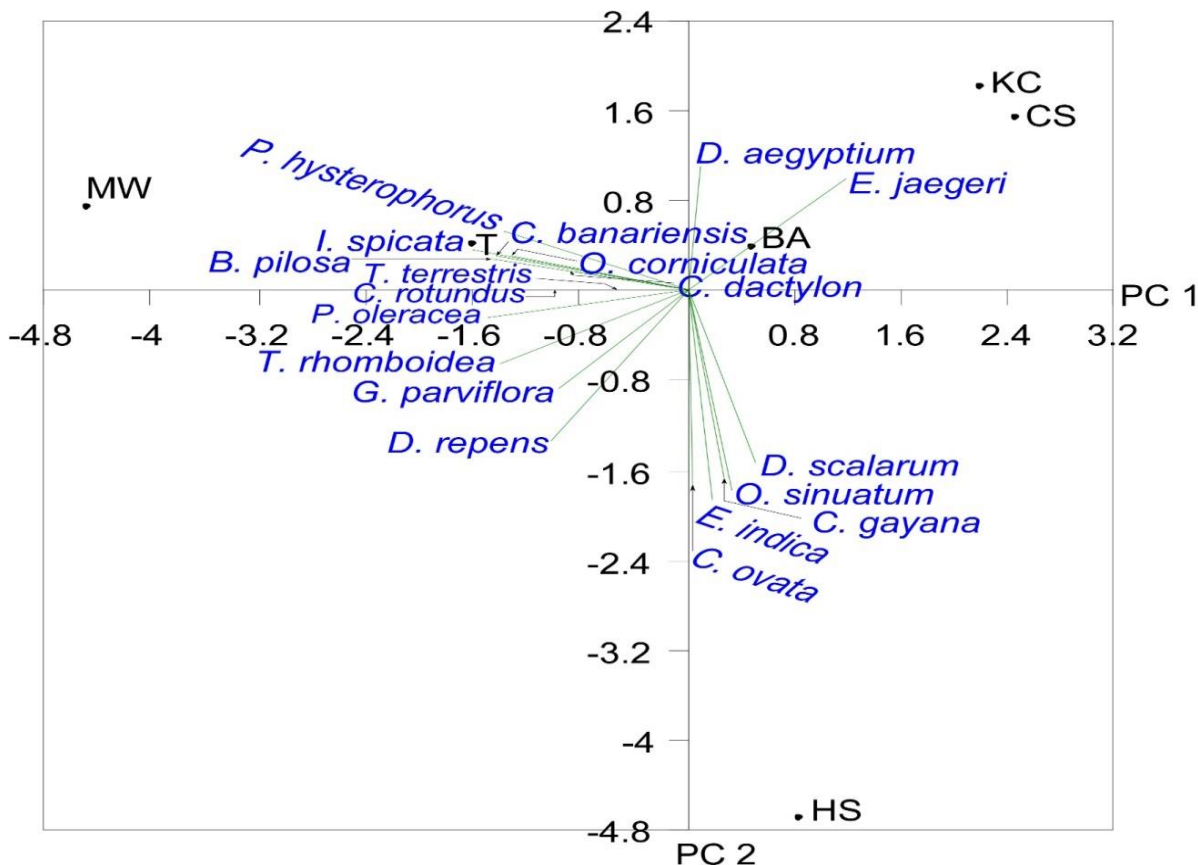


Figure 3. Scatter diagram showing plant species that co-exist with *P. hysterothorus* at Queen Elizabeth National Park.

Table 2. Means of species richness, dominance, evenness and Simpson’s diversity in *P. hysterothorus* invaded and uninvaded sites.

<i>P. hysterothorus</i> invasion status	No. of sampling sites	No. of quadrats	Diversity Indices			
			Species richness (R)	Dominance (D)	Evenness (E)	Simpsons iversity (1-D)
Invaded sites	6	54	*58	(Mean±SD) *0.62±0.19	(Mean±SD) *0.23±0.08	(Mean±SD) *0.38±0.19
Uninvaded sites	6	54	*39	*0.46±0.25	*0.63±0.21	*0.55±0.25

*Mean value is significant at P < 0.05.

Figure 4A to D. Furthermore, extrapolation of the generated linear regression models, based on linear equations ($y = -0.014x + 1.465$) in 4A, and ($y = -0.8896x + 106.87$) in 4B, the abundance at which *P. hysterothorus* starts to significantly reduce species diversity and richness is at very low percentage of 4.6 and 7.7% respectively. However, its effect on dominance according to ($y = 0.014x - 0.4631$) in 4C, was exerted at relatively higher percentage abundance (40.2%).

This confirms that *P. hysterothorus* reduced the

species diversity and richness of plant species and agrees with the documented impact of *P. hysterothorus* that also revealed a reduction of 80-90% carrying capacity of pasture in Central West Asia (Rwomushana et al., 2019). In addition, *P. hysterothorus* frequency was inversely proportional to species diversity and a significant shoot growth reduction (47.9%) and root growth inhibition (59.3%) was recorded on grassland species of Australia (Birhanu and Khan, 2018). The dominating effect of *P. hysterothorus* was attributed to

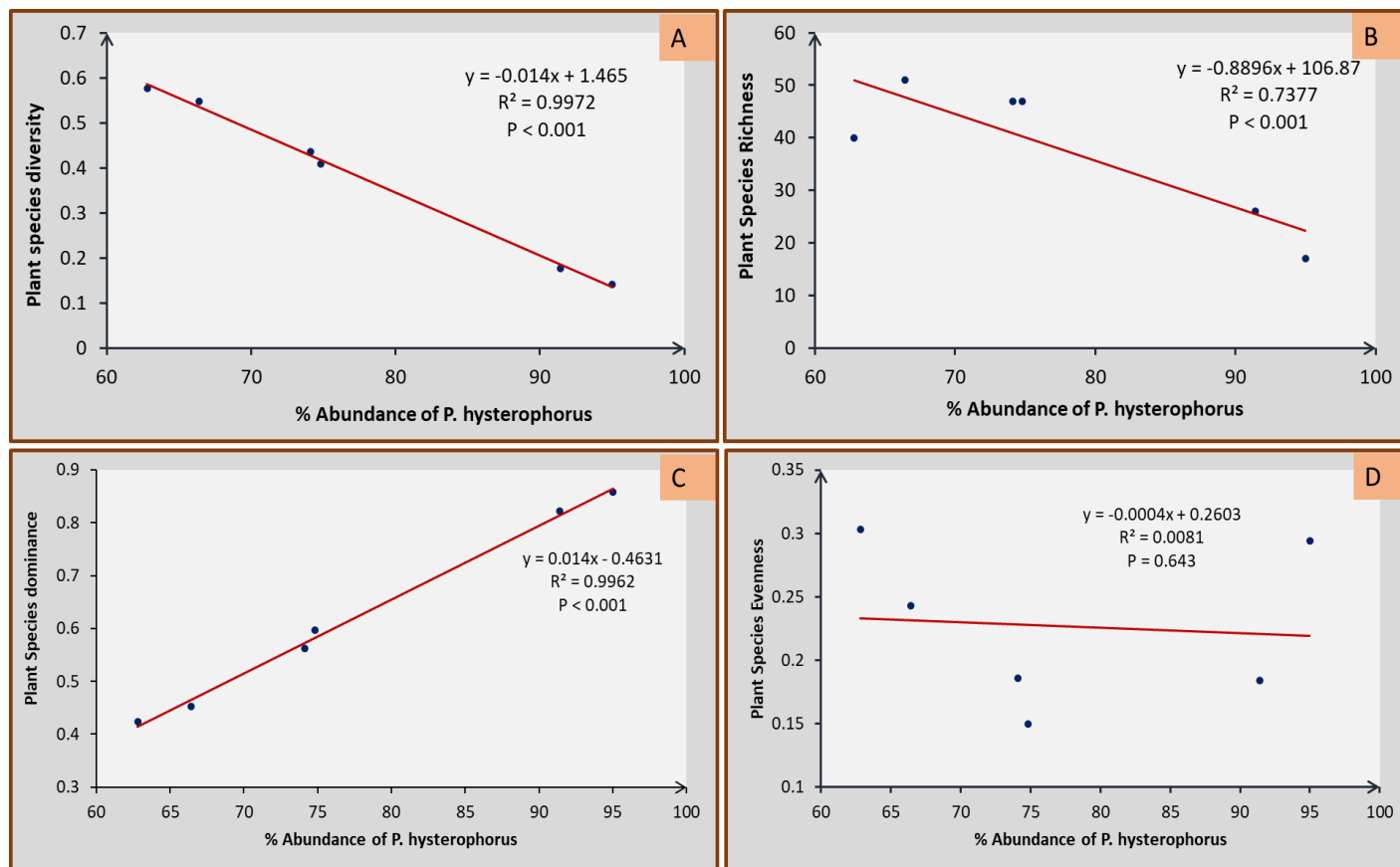


Figure 4. Effect of *P. hysterophorus* relative abundance on plant species diversity (A), richness (B), dominance (C) and evenness (D) at invaded sites in Queen Elizabeth National Park.

allelopathic nature of monoterpenes it contains (Belgeri and Adkins, 2015). Over 73.7% reduction in species richness in invaded areas as shown in Figure 4B, was accounted to *P. hysterophorus*. The same trend was reported by Gadisa et al. (2019), further confirming the detrimental effect of the weed especially in protected areas like QENP. Similarly, a decline (90%) in forage production was attributed to inhibitory potentials of *P. hysterophorus* on plant germination (Birhanu and Khan, 2018).

Conclusion

P. hysterophorus invasions in QENP, significantly reduces species diversity and richness, even at very low levels of abundance through its dominance at a relatively higher level.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

- Abdulkerim-Ute J, Legesse B (2016). *Parthenium hysterophorus* (L.): Distribution, Impact, and Possible Mitigation Measures in Ethiopia. *Tropical and Subtropical Agroecosystems* 19:61-72.
- Ali S, Khan IA (2017). Distribution of *Parthenium hysterophorus* (L.) in the Swabi District of Khyber Pakhtunkhwa. *Sarhad Journal Of Agriculture* 33:269-275.
- Arne W, Tim B, Wilgen BW (2018). An Assessment of the Distribution and Potential Ecological Impacts of Invasive Alien Plant Species in Eastern Africa. *Transactions of the Royal Society of South Africa* 73(3):217-236.
- Belgeri A, Adkins SW (2015). Allelopathic Potential of Invasive Parthenium Weed (*Parthenium hysterophorus* L.) Seedlings on Grassland Species in Australia. *Allelopathy Journal* 36(1):1-14.
- Bhusal, K, Devkota MP, Shrestha BB (2014). Vulnerability Assessment of Different Land Use Types to Invasion by *Parthenium hysterophorus* (L.) in Western Chitwan, Nepal. In: Thapa GJ, Subedi N, Pandey MR, Chapagain NR, Thapa SK, Rana A (eds.)

- Proceedings of the International Conference on Invasive Alien Species Management. Kathmandu: National trust for Nature Conservation, Nepal, pp. 61-69.
- Birhanu A, Khan PR (2018). The Distribution, Status and Mitigation Methods of *Parthenium hysterophorus* (L.) in Ethiopia: A Review. *Journal of Medical Plants Studies* 6(4):5-10.
- Bobo A, Abdeta C (2016). Distribution, Biology and Management Practices of Parthenium Weed, (*Parthenium hysterophorus* (L.) in Ethiopia. A Review: *Journal of biology, Agriculture and Healthcare* 6(5):136-145.
- Chauhan BS, Hafiz HA, Singarayer F (2019). Seed Germination Ecology of *Bidens pilosa* and Its Implications for Weed Management. *Scientific Reports* 9(1):1-9.
- Donato L, Stefano C, Anderito TPC (2019). Germination of *Chloris barbata*, *Cynodon dactylon*, and *Cyperus rotundus* from Angola at Constant and Alternate Temperatures. *MDPI. Agronomy* 9(615):1-11.
- Etana A, Ensermu K, Teshome S (2015). Impact of *Parthenium hysterophorus* (L.) (Asteraceae) on Soil Chemical Properties and Its Distribution in a Reserve Area: A Case Study in Awash National Park (ANP). *Journal of Soil Science and Environmental Management* 6(5):116-124.
- Gadisa D, Fitamo D, Kebede F (2019). Socioeconomic and Ecological Consequences of Parthenium Weed (*Parthenium hysterophorus* L.) in Boset Woreda, Ethiopia. *African Journal of Agricultural Research* 14(34):1921-1942.
- Gebrehiwot N, Berhanu L (2015). Impact of Parthenium on Species Diversity in Gamo. *Scholarly Journal of Agricultural Science* 5(7):226-231.
- Hassan G, Rashid HU, Amina A, Khan IA, Shehzad N (2018). Allelopathic effects of *Parthenium hysterophorus* on Germination and Growth of Some Important Crops and Weeds of Economic Importance. *Planta Daninha* 2016:1-11.
- Horo JT, Gudisa T, Worku E, Tilahun D (2020). Distribution and Abundance of *Parthenium hysterophorus* (L.) in Metekel Zone, Northwest Ethiopia. *American Journal of Plant Sciences* 11(07):1101-1110.
- Kaur M, Neeraj KA, Vikas K, Romika D (2014). Effects and Management of *Parthenium hysterophorus*: A Weed of Global Significance. *International Scholarly Research Notices* 2014:1-12.
- Khaket TP, Himanshu A, Drukshakshi J, Suman D (2015). *Parthenium hysterophorus* in Current Scenario: A Toxic Weed with Industrial, Agricultural and Medicinal Applications. *Journal of Plant Science* 10(2):42-53.
- Kruk BC, Satorre EH (2008). Soil Water Availability Affects Green Area and Biomass Growth of *Cynodon dactylon*. *European Weed Research Society Weed Research* 48(1417):248-256.
- Kuldip SD, Sarvesh KS, Romita S (2011). Distribution, Biology and Ecology of *Parthenium hysterophorus* L., (Congress Grass) an Invasive Species in the North-Western Indian Himalaya (Himachal Pradesh). *African Journal of Plant Science* 5(11):682-687.
- Kumar S, Khandpu S, Rao DN, Wahaab S, Khanna N (2012). Immunological Response to *Parthenium hysterophorus* in Indian Patients with Parthenium Sensitive Atopic Dermatitis. *Immunological Investigations* 41(1):75-86.
- Kumari P, Pankaj KS, Madhu YS, Poonam A (2014). Impact of *P.hysterophorus hysterophorus* (L.), Invasion on Species Diversity of Cultivated Fields of Bilaspur (C.G.) India. *Agricultural Sciences* 05(08):754-764.
- Mahajan M, Fatima S (2017). Frequency, Abundance and Density of Plant Species by List Count Quadrat Method. *International Journal of Multidisciplinary Research III(Vii):21-28.*
- Maszura CM, Karim SMR, Norhafizah MZ, Kayat F, Arifullah M (2018). Distribution, Density, and Abundance of Parthenium Weed (*Parthenium Hysterophorus* L.) at Kuala Muda, Malaysia. *International Journal of Agronomy* 2018:1-8.
- Meena RK, Kunaujia G, Tiwari A (2017). Impact and Management of Parthenium hysterophorus. Review Article. *Global journal of Bio-Science and Biotechnology* 6(1):15-18.
- Musese LJ, Andrew JM, Shirima DD, Witt A, Kilewa R (2020). Effects of the Abundance of *Parthenium hysterophorus* on the Composition and Diversity of Other Herbaceous Plant Species in Simanjiro Rangeland, Tanzania. *International Journal of Engineering Technologies and Management Research* 7(5):11-20.
- Nkoa R, Micheal DKO, Clarence JS (2015). Weed Abundance, Distribution, Diversity, and Community Analyses. *Weed Science* 63(SP1):64-90.
- Phillippoff J, Cox E (2017). Measuring Abundance: Transects and Quadrats. Concepts: estimation, percentage, error and zonation. Lesson Developments. pp. 1-5. Available at: <https://www.hawaii.edu/gk-12/opihi/classroom/measuring.pdf>
- Pilliod DS, Arkle RS (2013). Performance of Quantitative Vegetation Sampling Methods across Gradients of Cover in Great Basin Plant Communities. *Rangeland Ecology and Management* 66(6):634-647.
- Rwomushana I, Constantine K, Godwin J, Makale F (2019). Parthenium: Impacts and Coping Strategies in Central West Asia. In Parthenium- Evidence Note 1-43. <https://www.invasive-species.org/wp-content/uploads/sites/2/2019/04/Parthenium-evidence-note-Final.pdf>.
- Sahrawat, Jyoti S, Siddarth NR (2018). Parthenium hysterophorus: Current Status and Its Possible Effects on Mammals- A Review. *International Journal of Current Microbiology and Applied Sciences* 7(11):3548-3557.
- Steven A, Shabbir A (2014). Biology, Ecology and Management of the Invasive Parthenium Weed (*Parthenium hysterophorus* (L.)). *Pest Management Science* 70(7):1023-1029.
- Shrestha BB, Pokhrel K, Paudel N, Poudel S, Shabbir A, Adkins SW (2019). Distribution of *Parthenium hysterophorus* and one of Its Biological Control Agents (Coleoptera : Zygogramma bicolorata) in Nepal. *Weed Research: An international Journal of Weed Biology, Ecology and Vegetation Management* 59:467-478.
- Thapa S, Vishwas C, Srijana JR, Neha B, Bharat BS (2018). Understanding the Dynamics in Distribution of Invasive Alien Plant Species under Predicted Climate Change in Western Himalaya. *PLoS ONE* 13(4):1-16.
- UWA (2012). Ministry of Tourism, Wildlife and Antiquities.
- Wabuye E, Jenifer B, Agnes L, Andrew JM (2014). A Roadside Survey of the Invasive Weed *Parthenium hysterophorus* (Asteraceae) in East Africa. *Journal of East African Natural History* 103(1):49-57.
- Zereen S, Ahmad I, Ali I, Khan HA (2018). Distributions of Invasive Weed Parthenium (*Parthenium hysterophorus* (L.) in the University Campus Peshawar, Pakistan. *European Journal of Experimental Biology* 08(03):1-9.