LAIKIPIA UNIVERSITY JOURNAL OF SCIENCE AND APPLIED TECHNOLOGY

Effects of Parthenium Weed (*Parthenium hysterophorus* L.) on Biodiversity of Native Plant Species in Nakuru County, Kenya

Boniface Muli Mutua, *[1]Wanjiku Chiuri, [1]Veronica Ngure[2] and Veronica Kimani[1]

[1]Earth Sciences Department, [2]Biological Sciences Department,

Laikipia University, 1100-20300, Nyahurru, Kenya

***Corresponding author email: bonifacemutua4@gmail.com**

Abstract

Invasive Alien Species (IAS) are organisms that are introduced into new areas where they establish and have adverse effects on the environment and human livelihoods. Worldwide IAS are considered the second most serious threat to biodiversity after habitat destruction. Among the notable IAS in Kenya is parthenium weed (*Parthenium hysterophorus* L.). *Parthenium hysterophorus* is an annual plant native to South and Central America considered to occur as an invasive invader in Africa, Asia and Australia. It is one of the worst weeds because it produces allelochemicals which inhibit the germination and growth of other species resulting in habitat change. In Kenya, high colonies of the weed are threatening the existence of native plant species, especially in the western, Lake Victoria Basin and the Rift Valley. Therefore, this study investigated the effects of *P. hysterophorus* on the biodiversity of native plant species in Nakuru County, Kenya. The study was carried out in Gilgil sub-county using the quadrants method whereby all the herbaceous plants were counted and identified. Data on the effects of *P. hysterophorus* on the density of native plant species was analyzed using correlation analysis at a 1 % level of significance. The Shannon-Weiner Diversity Index and Evenness Index were used to determine species diversity. The results of this study established that high densities of *P. hysterophorus* significantly reduced the abundance of the native plant species ($r = -0.367$, $p = 0.001$). It was also established that the presence of *P. hysterophorus* in the study area lowered the diversity of native plant species according to the low values of both the Shannon-Weiner Diversity Index (1.78) and Evenness Index (0.20085). According to the results of this study, *P. hysterophorus* significantly lowered both the diversity and abundance of the native plant species in the study. Therefore, urgent control measures should be put in place to avert further damage to the vegetation cover which is likely to compromise the availability of pasture species in a county whose main activities include agriculture. In addition, the findings of this research can be used to inform policy formulation on invasive weed control in Kenya.

Keywords: Abundance, diversity, *Parthenium hysterophorus*, policy formulation

Introduction

Parthenium weed (*Parthenium hysterophorus* L.) is an invasive plant species, first reported in Kenya in 1975. The plant releases allelochemical compounds that inhibit the germination and growth of other plant species. High densities of *P. hysterophorus* threaten the biodiversity of native plant species. Therefore, this study sought to investigate the effects of *P. hysterophorus* on the abundance and diversity of native herbaceous plant species in Gilgil sub-county. It was revealed that *P. hysterophorus* adversely affected the abundance and diversity of native herbaceous plant species and therefore control measures should be prioritized to avert further damage to biodiversity.

Invasive Alien Species refers to those living organisms including plants, animals, fungi and microorganisms that spread beyond their natural habitat where they threaten biodiversity (Shiferaw et al., 2018; Shine et al., 2009). Globally, invasive alien Species are ranked the second major threat to biodiversity after habitat loss (UNEP, 2001). In Kenya, notable invasive alien species include the Larger Grain Borer (*Prostephanus truncates*), Water hyacinth (*Eichhornia crassipes*), Mathenge (*Prosopis spp.*), Prickly pear (*Opuntia* spp.), Striga weed, and parthenium weed (*Parthenium hysterophorus* L.) (Kedera & Kuria, 2005). This study focused on *Parthenium hysterophorus*, an invasive alien plant species first reported in Kenya in 1975 (Njoroge, 1986).

In Kenya, the plant occurs in the Rift Valley, the Lake Victoria Basin, central, and western parts of the country (Wabuyele et al., 2014). However, *P. hysterophorus* is likely to spread further because the country is climatologically favourable for new invasions (McConnachie et al., 2011). Apart from its native habitat in South and Central America, the weed has invaded Australia, Asia and Africa (Bajwa et al., 2016). In Africa, the weed occurs in Ethiopia, Somalia, Uganda, Tanzania, Kenya, Mauritius, Eritrea, Rwanda, Djibouti, Mayotte, Comoros, Seychelles, Swaziland, Mozambique, Zimbabwe, South Africa, Botswana and Egypt (Adkins et al., 2018).

The worldwide distribution of *P. hysterophorus* has been facilitated by wind, water, animals, movement of contaminated food grain and feed and seed lots, floral bouquets, attachment to vehicles and machinery, and packaging materials (Mao et al., 2021b; Adkins et al., 2018). Besides, *P. hysterophorus* exhibits phenotypic and geographical plasticity that contributes to its invasiveness and expansion in different habitats (Mao et al., 2021a). *Parthenium hysterophorus* grows in regions with more than 500 mm of annual rainfall, and germination takes place between 10 and 25 degrees Celsius (Adkins et al., 2018). However, the invasion of *P. hysterophorus* is predicted to get worse as a result of climate change as higher levels of atmospheric carbon dioxide, hotter temperatures, floods, heatwaves, and droughts are likely to boost the establishment, habitat expansion, and the adverse effects of this invasive plant species while complicating management efforts (Mao et al., 2021a).

Parthenium hysterophorus is an annual herbaceous plant species that belong to the family Asteraceae. It has an erect stem that can grow to a height of two metres when weather conditions are favourable. It has deeply serrated leaves that have soft hair and are pale green. The tips of the stems bear small white flowers (Adkins et al., 2018). *Parthenium hysterophorus* is a prolific seed producer with a single plant capable of producing up to 20,000 seeds. The seeds are small, flattened, dark brown to black and have two thin spoon-shaped appendages (Adkins et al., 2018). Due to the production of high quantities of seeds, *P. hysterophorus* can build massive seed banks of about 200,000 seeds per m^2. The seeds can survive for four to six years, thus creating a prolonged life seed bank, which is a challenge to eradicate (Bajwa et al., 2016).

The success of *P. hysterophorus* as an invasive seed lies in its ability to reproduce. The plant produces up to four succeeding generations of seedlings in a season, and flowering may begin as soon as four weeks after seedling emergence (Adkins et al., 2018). The plants continue to flower for about six to eight months under favourable climatic conditions (Bajwa et al., 2016). These properties render the control of *P. hysterophorus* a major challenge, especially for small-scale farmers. Control options include manual removal, mechanical removal, burning, synthetic herbicides, cover crops, competition and suppression, and biological agents (Adkins et al., 2018).

The plant has been ranked as one of the most problematic weeds in the world since it poses serious challenges to biodiversity, food security and human well-being (Singla, 1992). *Parthenium*

Volume 1, Number 2, 2022 ISSN N0 2791-1926

hysterophorus releases allelochemicals which inhibit the germination and growth of a variety of crops, including grazing grasses, cereals, vegetables, and native plant species (Adkins et al., 2018). These properties are important for its invasion and survival in a wide range of native and non-native habitats resulting in ecosystem change (Adkins et al., 2018). Several studies have documented the effects of *P. hysterophorus* on the diversity and abundance of native plant species. For instance, in a study carried out in Ethiopia to investigate the impact of *P. hysterophorus* on grazing land communities using the cover class method, regression analysis showed that the diversity (r^2 = 73%) and evenness (r^2 = 69.5%) of native plant species reduced as the density of *P. hysterophorus* increased, implying that the heterogeneity of the community was significantly affected (Nigatu et al., 2010). In another study conducted in Ethiopia to access the effects of *P. hysterophorus* on herbaceous and woody species diversity by applying sampling plots along a line transect, a strong negative relationship between the density of *P. hysterophorus* and the species richness (r = -0.82, p = 0.013) and abundance (r = -0.917, p = 0.001) was recorded (Boja et al., 2022).

In Kenya, in a study to determine the effects of *P. hysterophorus* on herbaceous plant species diversity using the quadrant method, Abuto et al. (2018) reported that *P. hysterophorus* significantly reduced the species diversity (r = -0.075, p = 0.029) and richness (r = -0.924, p = 0.001) of the native plant species. These adverse effects of *P. hysterophorus* on plant species diversity and abundance are likely to lower the availability of pasture species as reported by Nguyen et al. (2017). The presence of high densities of *P. hysterophorus* in Nakuru County threatens plant biodiversity. This study investigated the effects of *P. hysterophorus* on the abundance and diversity of native plant species since such information is limited for the study area. Even though similar studies have been done in other places where *P. hysterophorus* occurs, there is a need to conduct this study in Nakuru County because the impacts and successful invasion of this weed are dependent on the amount of rainfall, temperature and altitude which vary geographically.

Methodology

This study was carried out in Gilgil sub-county, Nakuru County, Kenya in September 2021 using the total count method whereby every individual of all herbaceous plant species rooted within a

Volume 1, Number 2, 2022 ISSN N0 2791-1926

quadrant was counted (Sutherland, 2006). A total of 7 line transects measuring 1 Km long were laid out systematically to cover the sample area. Eleven quadrants ($1m^2$) were laid out at 100 m interval along the line transects to collect the required data. Plant identification and naming was done according to the binomial nomenclature.

Data Analysis

Data on the effect of *P. hysterophorus* on the relative density (abundance) of the native plant species was determined using correlation analysis at a 1 % level of significance with the aid of the computer software; IBM SPSS V. 28 statistical tool (SPSS Inc., Chicago, IL) and Ms Excel 2013. Data on the effects of *P. hysterophorus* on species diversity was determined using the Shannon-Weiner Diversity Index (*H*) as proposed by Baliton et al. (2020) and the Evenness Index (*E*) as proposed by (Hill, 1973).

$$H = -\sum_{i=1}^{S} pi \ln(pi)$$

Where;

H = Shannon-Weiner Diversity Index

S = number of species encountered

ln = natural log

$\sum$ = sum from species 1 to species S

Pi = proportion of the entire population belonging to species i

Shannon-Weiner Diversity Index (*H*) runs from 1.5 to 3.5 and hardly ever exceeds 4. A higher index value denotes species diversity and community heterogeneity, whereas a lower number denotes homogeneity in the community.

$E = \frac{H}{Ln(S)}$ where,

E = Evenness Index

H = Shannon-Weiner Diversity Index

S = number of species encountered

This index assumes a value between zero (0) and one (1), with one denoting complete evenness or a healthy ecosystem and zero meaning that only a single species is dominating the region.

Relative density was determined using the formulae by Krebs, (1985, 2014) as follows;

$$\text{Relative density of species y} = \frac{\text{Total individual of species y}}{\text{Total individual of all species}} \times 100$$

Results

This study identified 37 plant species in the 77 quadrats sampled (Table 1). These plants included *Amaranthus blitum* (purple amaranth), *Anisantha sterilis* (barren brome), *Bidens pilosa* (black jack), *Chenopodium album* (white goosefoot), *Commelina benghalensis* (wandering jew), *Commicarpus pedunculosus*, *Conyza bonariensis* (hairy fleabane), *Cucumis prophetarum* (wild cucumber), *Cynodon dactylon* (couch grass), *Datura stramonium* (thorn apple), *Digitaria sp*.(crabgrass), *Dysphania pumilio* (clammy goosefoot), *Eleusine sp*. (goose grass), *Erucastrum arabicum* (wild kales), *Euphorbia prostrata* (prostrate sandmat) *Fuerstia Africana*, *Galinsoga parviflora* (gallant soldier), *Heliotropium longiflorum*, *Hypoestes forskaolii* (white ribbon bush), *Indigofera spicata* (creeping indigo), *Ipomoea lepharophylla* (morning glory), *Leonotis nepetifolia* (Christmas candlestick) *Nicotiana glauca* (tree tobacco), *Oxalis stricta* (yellow oxalis), *Oxygonum sinuatum* (star stalk) *Parthenium hysterophorus* (parthenium weed), *Pavonia senegalensis*, *Pennisetum clandestinum* (Kikuyu grass), *Psiadia punctulata* (sticky psiadia), *Salsola sp.*, *Schkuria pinnata* (dwaft arigold) *Setaria verticillata* (bristly foxtail) *Sida sp. Solanum incanum* (Sodom apple) *Sonchus oleraceae* (sow thistle) *Tagetes minuta* (marigold) and *Withania somnifera* (winter cherry).

Table 1. Plant species identified in the study area

Species	Common name	Family	No. of individuals
Amaranthus blitum	Purple amaranth	Amaranthaceae	29
Anisantha sterilis	Barren brome	Poaceae	2
Bidens pilosa	Black jack	Asteraceae	2
Chenopodium album	White goosefoot	Amaranthaceae	76
Commelina benghalensis	Wandering jew	Commelinaceae	3
Commicarpus pedunculosus	-	Nyctaginaceae	3
Conyza bonariensis	Hairy fleabane	Asteraceae	1
Cucumis prophetarum	Wild cucumber	Cucurbitaceae	4
Cynodon dactylon	Couch grass	Poaceae	3561
Datura stramonium	Thorn apple	Solanaceae	11
Digitaria sp.	Crabgrass	Poaceae	397
Dysphania pumilio	Clammy goosefoot	Amaranthaceae	109
Eleusine sp.	Goose grass	Poaceae	142
Erucastrum arabicum	Wild kales	Brassicaceae	2
Euphorbia prostrata	Prostrate sandmat	Euphorbiaceae	52

Fuerstia africana		Lamiaceae	74
Galinsoga parviflora	Gallant soldier	Asteraceae	198
Heliotropium longiflorum	-	Boraginaceae	10
Hypoestes forskaolii	White ribbon bush	Acanthaceae	535
Indigofera spicata	Creeping indigo	Fabaceae	10
Ipomoea blepharophylla	Morning glory	Convolvulaceae	5
Leonotis nepetifolia	Christmas candlestick	Lamiaceae	20
Nicotiana glauca	Tree tobacco	Solanaceae	2
Oxalis stricta	Yellow oxalis	Oxalidaceae	3
Oxygonum sinuatum	Star stalk	Polygonaceae	34
Parthenium hysterophorus	Parthenium weed	Asteraceae	1268
Pavonia senegalensis	-	Malvaceae	5
Pennisetum clandestinum	Kikuyu grass	Poaceae	1
Psiadia punctulata	Sticky psiadia	Compositae	42
Salsola sp.	-	Amaranthaceae	17
Schkuria pinnata	Dwaft marigold	Asteraceace	5
Setaria verticillata	Bristly foxtail	Poaceae	147
Sida sp.	-	Malvaceae	36
Solanum incanum	Sodom apple	Solanaceae	46
Sonchus oleraceae	Sow thistle	Asteraceae	1
Tagetes minuta	Marigold	Asteraceae	40
Withania somnifera	Winter cherry	Solanaceae	30
Total number of individuals			6923

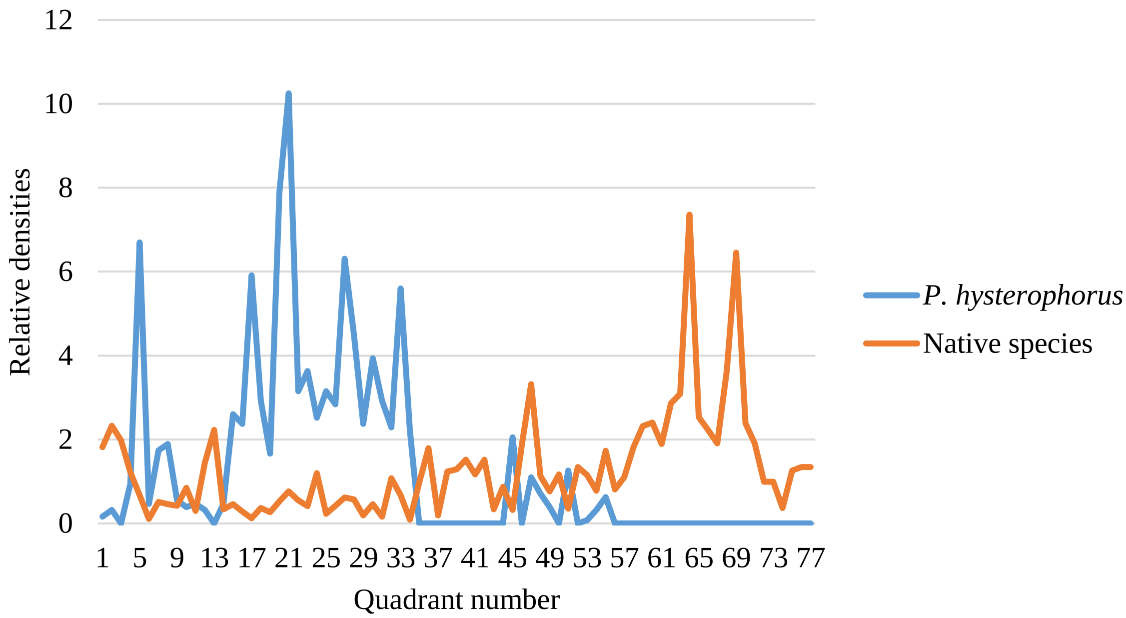
Correlation analysis indicated a highly significant negative relationship (r = -0.367, $p = 0.001$) between the relative density of *P. hysterophorus* and the relative densities of all native plant species combined (table 2). The results of this study imply that higher densities of *P. hysterophorus* lowed the abundance of native plant species in the study areas. Quadrants that had few or no individuals of *P. hysterophorus* had a higher abundance of the native species as shown in figure 1.

Table 2: Effects of *Parthenium hysterophorus* on the abundance of native plant species

		Parthenium weed _ RD	Other plant species _ RD
Parthenium weed _ RD	Pearson Correlation	1	-.367**
	Sig. (2-tailed)		.001
	N	77	77
Other plant species _ RD	Pearson Correlation	-.367**	
	Sig. (2-tailed)	.001	
	N	77	77

**. Correlation is significant at the 0.01 level (2-tailed). RD = Relative Density

Volume 1, Number 2, 2022 ISSN N0 2791-1926



.

Fig. 1: Effects of *P. hysterophorus* on the abundance of native plant species

Shannon-Weiner Diversity Index and Evenness Index (E) indicated that *P. hysterophorus* negatively affected the species richness in the study area. The low value of the Shannon-Weiner Diversity Index (1.78) denoted a homogenous community dominated by *P. hysterophorus* as shown in table 2. In addition, the Evenness Index (0.20085) also indicated that the study areas had low species diversity with *P. hysterophorus* dominating the community.

Discussion

This study revealed that *P. hysterophorus* negatively affected the abundance and diversity of native plant species. Few or sometimes no other plant species were observed in *P. hysterophorus*-dominated quadrats. In contrast, higher plant species diversity was observed in non-invaded quadrats. These results were confirmed by a negative correlation (r = -0.367, p = 0.001) between the relative density of *P. hysterophorus* and the total relative density of all the native species within a quadrat. This implies that quadrats that had a high density of *P. hysterophorus* had a low density of the native plant species. These results agree with Abuto et al., (2018) that high densities of *P. hysterophorus* resulted in a decline in the diversity of native plant species in Kenya (Abuto et al., 2018).

Similar results were reported in Tanzania where *P. hysterophorus* accounted for a 40% decline in the number of native plant species. In the same study *P. hysterophorus* significantly reduced the native plant richness (r = -0.82, p = 0.013) and diversity (r = -0.917, p = 0.001) (Boja et al., 2022). These results were confirmed by the low Shannon-Weiner Diversity Index (1.78) and Evenness Index (0.20085). These indices suggest that the study area was dominated by *P. hysterophorus*. These findings are consistent with those of Boja et al. (2022), who reported a high Shannon-Wiener diversity index (3.38 +0.1365) in areas not invaded by *P. hysterophorus* and low diversity index (1.724 +0.045) in highly invaded areas. This is due to the inhibitory responses exhibited by *P. hysterophorus. Parthenium hysterophorus* releases allelochemicals in the soil that inhibit the germination and growth of a variety of crops, including grazing grasses, cereals, vegetables, and native plant species (Adkins et al., 2018).

Conclusions and Recommendations

This study established that high densities of *P. hysterophorus,* decreased the density of native plant species. In Nakuru County, the management of *P. hysterophorus* should be prioritized as the plant has the potential to reduce the abundance and diversity of native plant species which is likely to reduce the availability of pasture. Further, the findings of this research can be used to inform policy formulation on the management of *P. hysterophorus* in Kenya.

Acknowledgement

The completion of this work was made possible through the help and collaboration of many people. First, I would like to express my gratitude to my supervisors, Prof. Wanjiku Chiuri, Dr. Veronica Ngure and Dr. Veronica Kimani, for their advice and support during the research process. The staff members in the School of Science and Applied Technology cannot go unmentioned; Prof. Nguta, Dr. Barbabus Kurgat, and Dr. Daniel Pande. Thank you so much.

References

Abuto, J. O., Murono, D. A., Wabuyele, E., & Mouria, P. K. (2018). Distribution of *Parthenium hysterophorus* Linn. and its impacts on biodiversity in Nyando sub-county, Kisumu County, Kenya. *European Academic Research, 7*, 2888-2910.

Adkins, S. W., Shabbir, A., & Dhileepan, K. (Eds.). (2018). *Parthenium weed: biology, ecology and management* (Vol. 7). CABI.

Bajwa, A. A., Chauhan, B.S., Muhammad, F., Shabbir, A., & Adkins, S.W. (2016). What do we really know about alien plant invasions? A review of the invasion mechanism of one of the world's worst weeds. *Planta, 244,* (1), 39-57.

Baliton, R., LANDICHO, L., Cabahug, R. E., Paelmo, R. F., Laruan, K., Rodriguez, R., ... & Castillo, A. K. A. (2020). Ecological services of agroforestry systems in selected upland farming communities in the Philippines. *Biodiversitas Journal of Biological Diversity*, *21*(2).

Boja, M., Girma, Z., & Dalle, G. (2022). Impacts of *Parthenium hysterophorus* L. on Plant Species Diversity in Ginir District, Southeastern Ethiopia. *Diversity*, *14*(8), 675.

GoK (Government of Kenya) (2010). *The Suppression of Noxious Weed Act (CAP. 325), Kenya Gazette Vol. CXII-No 44*. Nairobi: National Council for Law Reporting.

Hill, M. O. (1973). Diversity and its evenness, a unifying notation and its consequences. *Ecology*, *54* (2), 427–432.

Kedera, C., & Kuria, B. (2005). Invasive alien species in Kenya: Status and management in IPPC Secretariat (2005). In Identification of risks and management of invasive alien species using the IPPC framework. Proceedings of the workshop on invasive alien species and the International Plant Protection Convention, Braunschweig, Germany, 22-26 September 2003, *Food and Agriculture Organisation,* 199-204.

Mao, R., Bajwa, A. A., & Adkins, S. (2021a). A superweed in the making: adaptations of *Parthenium hysterophorus* to a changing climate. A review. *Agronomy for Sustainable Development*, *41*(4), 1-18.

Mao, R., Shabbir, A., & Adkins, S. (2021b). *Parthenium hysterophorus*: A tale of global invasion over two centuries, spread and prevention measures. *Journal of Environmental Management*, *279*, 111751.

McConnachie, A. J., Strathie, L. W., Mersie, W., Gebrehiwot, L., Zewdie, K., Abdurehim, A., Abrha, B., Araya, T., Asaregew, F., Assefa, F., Gebre-Tsadik, R., Nigatu, L., Tadesse, B., & Tana, T. (2011). Current and potential geographical distribution of the invasive plant *Parthenium hysterophorus* L. (Asteraceae) in Eastern and Southern Africa. *Weed Research*, *51*, 71–84.

Nguyen, T., Bajwa, A. A., Belgeri, A., Navie, S., O'Donnell, C., & Adkins, S. (2017). Impact of an invasive weed, Parthenium hysterophorus, on a pasture community in south east

Queensland, Australia. *Environmental Science and Pollution Research*, *24*(35), 27188-27200.

Nigatu, L., Hassen, A., Sharma, J., & Adkins, S. (2010). Impact of *Parthenium hysterophorus* on grazing land communities in north-eastern Ethiopia. *Weed Biology and Management*, *10*, 143-152.

Njoroge, J. M. (1986). *New* weeds in Kenya coffee. *Kenya Coffee*, 51, 333–335.

Shiferaw, W., Demissew, S., & Bekele, T. (2018). Invasive alien plant species in Ethiopia: ecological impacts on biodiversity a review paper. *Int J Mol Biol*, *3*(4), 171-178.

Shine, C., Kettunen, M., Genovesi, P., Gollasch, S., Pagad, S., & Starfinger, U. (2009). Technical support to EU strategy on Invasive Alien Species (IAS). *Institute for European Environmental Policy*, 35.

Singla, R. K. (1992). Can parthenium be put to use? *The Tribute*, *112*, 294.

UNEP. (2001). *Status, impacts and trends of alien species that threaten ecosystems, Habibat and Species*. UNEP/CBD/SBSTTA/6/INF/5 Annex II.

Wabuyele, E., Lusweti, A., Bisikwa, J., Kyenune, G., Clark, K., Lotter, W. D., McConnachie, A. J., & Wondi, M. (2014). A roadside survey of the invasive weed *Parthenium hysterophorus* (Asteraceae) in East Africa. *Journal of East African Natural History*, *103*(1), 49-57.

Sutherland, W. J. (Ed.). (2006). *Ecological census techniques: a handbook*. Cambridge University Press.