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Effects of the invasive *Hedychium gardnerianum* on the diversity of native vegetation species in Bvumba Mountains, Zimbabwe

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ABSTRACT

Wild ginger (*Hedychium gardnerianum*) poses a threat to biodiversity conservation because of its high competition for nutrients, water and light. This study aimed at assessing the effects of the *H. gardnerianum* on native vegetation species in the Bvumba Mountains, Zimbabwe. A purposive random sampling technique was adopted to sample 24 sites. The results show that there was a significant difference between plant species diversity in uninvaded compared to invaded sites with ($P < 0.05$). The study concluded that there is a need to develop and implement an invasive species management programme for *H. gardnerianum* for both protected and communal areas before high species losses occur.

KEYWORDS

Invasive species; *Hedychium gardnerianum*; native species

Introduction

Biological invasions threaten biodiversity conservation worldwide [1]. People have often facilitated the spread of invasive alien species by introducing them for ornamental purposes [2, 3]. *Hedychium gardnerianum* (*H. gardnerianum*) commonly known as wild ginger or Kahili ginger is native to the Himalayas in eastern India and Nepal [4]. This rhizomatous herbaceous plant species was first discovered in the 1950s in the Indian Himalayas region and was later introduced as an ornamental plant species into parts of the tropical region such as the Hawaii Mountains, the Azores, Reunion, Madeira, South Africa and New Zealand [5]. Wild ginger becomes dominant and displaces native vegetation [1, 6, 7]. *H. gardnerianum* invaded over 500 hectares of Hawaii Volcanoes National Park and it is negatively affecting the growth of indigenous plant species [8, 9]. This invasive plant species can significantly modify ecosystem functions and services [10, 11].

Previous studies in Hawaii reported that *H. gardnerianum* grows well in forest margins, open areas, forest understorey and in undisturbed environments forming thickets, preferably at an altitude of 1000–1300 m [5, 9]. This is in accordance with the edge effect theory which states that the number of alien species decreases with

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an increase in distance from forest edge [12]. *H. gardnerianum* inhibits the regeneration of native vegetation whilst facilitating the colonisation and replacement of native ecosystem by alien species [1]. The invasion by *H. gardnerianum* occurs by high seed production, quick seed dispersion by birds, fast growth and the ability to spread through rhizomes compared to native species [8, 9, 13–16] (Figure 1). This plant species outcompetes native plant species for nutrients, water and sunlight, thus replacing indigenous forests [17].

The effects of *H. gardnerianum* on the survival of indigenous plant species of montane forests prompted research to prevent further invasion [9, 18]. Various control methods (mechanical, biological and chemical) have been tested in *H. gardnerianum* infested areas. The use of bacterial wilt caused by the ginger strain of *Ralstonia solanacearum* on mechanically wounded *H gardenerianum* species successfully resulted in wilting of infected plant species [9, 18]. Studies in Hawaii forests tested the uses of chemical control agents (Escort) on *H. gardnerianum* infested sites and the experimental results show that it is an effective and reliable

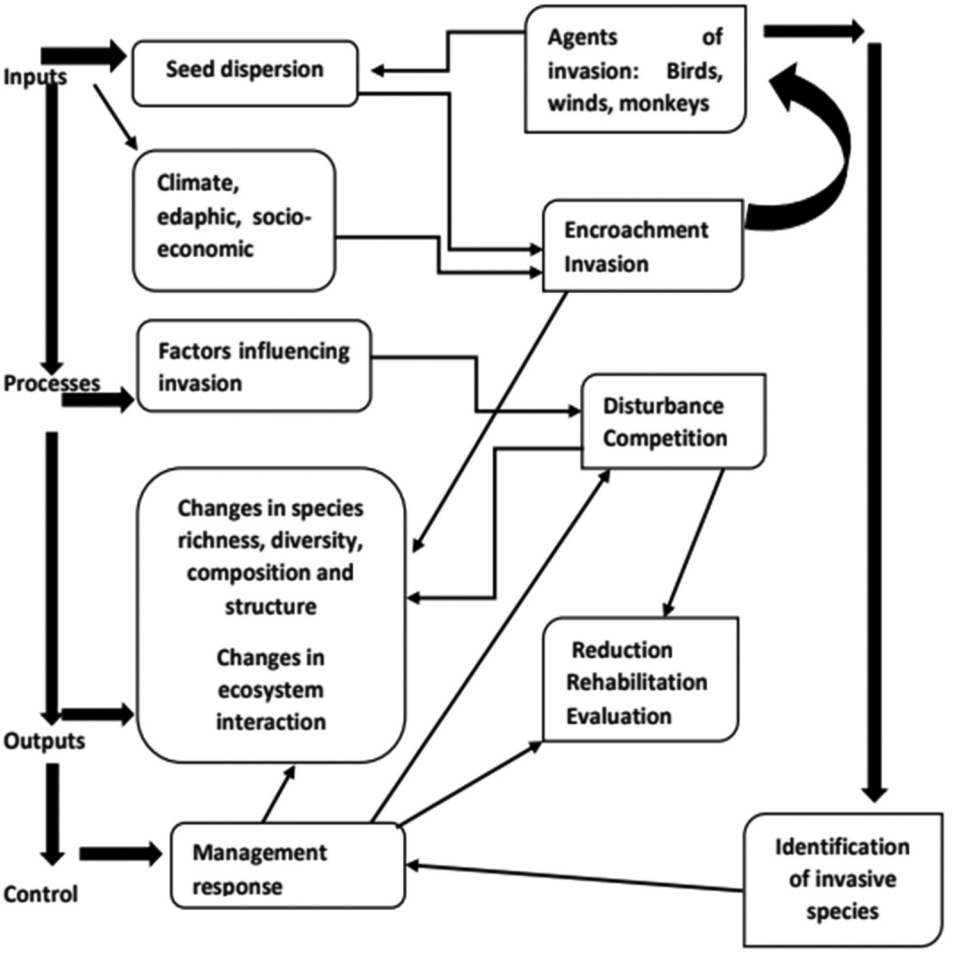

Figure 1. Conceptual framework of plant species invasion and management.

method of controlling *H. gardnerianum*. The use of environmentally friendly and target specific chemicals in control of *H. gardnerianum* is critical to protecting native species from invasive species [6, 19].

In Zimbabwe, the status of invasion by *H. gardnerianum* is not well documented and knowledge of its effects on native Afromontane species is rudimentary. The continuous spread of *H. gardnerianum* in the Bvumba Mountains of Zimbabwe and the extent of its invasiveness are not well documented. The effects of *H. gardnerianum* on indigenous flora are not well known given the overwhelming evidence of its impact on native vegetation in other areas similar to this ecoregion. There is a trend to biodiversity loss as a result of invasive species in (nominally) protected Afromontane regions, the home to over 5000 endemic species [20]. Our study contributes to developing strategies to reduce further invasion in Afromontane forests. The objectives of the study were to determine the effect of *H. gardnerianum* on the diversity of native plant species and determine the relationship between the abundance of *H. gardnerianum* and native species diversity in the Bvumba Mountains, Zimbabwe.

Methods

The study was conducted in the Bvumba Mountains located in the Eastern highlands of Zimbabwe (Figure 2). The Bvumba Mountains are situated (19°4′60 S, 32°45′0" E) 10 km south-east from Mutare, rising to an altitude of 1 911 m at the Castle Beacon (Bvumba heights).

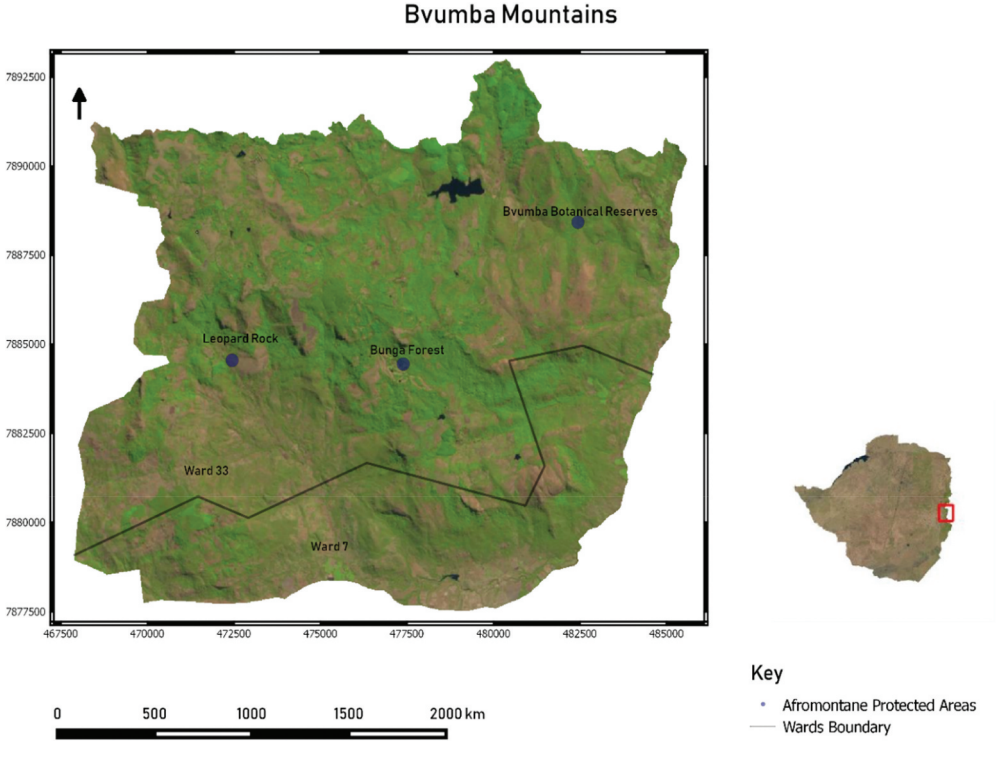

Figure 2. Showing the map of the Bvumba Mountains, Zimbabwe.

Bvumba area is characterised by a range of mountains that stretch along the eastern border of Zimbabwe up to Mozambique. This mountain range is made up of granite rocks, rounded hills and steep slopes [21]. Nature reserves found in the Bvumba Mountains includes Bvumba botanical gardens, Bunga Forests and Leopard Rock National Park. The area experiences mist throughout the year [22]. It has a seasonal humid climatic pattern since much of the rainfall is received from November to March, followed by a cool dry season that extends from April to July and the hot dry season from August to October [23]. The mean annual rainfall is 647 mm, with great spatial and temporal variability. This mountainous area can receive rainfall above 3 000 mm per year [23]. Annual temperatures range from a minimum of 9°C to 12°C to a maximum of 25°C to 28°C [23]. The temperature varies spatially and temporally across the mountainous area. The vegetation type is categorised into moist evergreen forests, sub-montane forests, dry montane forests, shrublands and grasslands.

A purposive random sampling of quadrants in both invaded and uninvaded areas in the Bvumba Mountains, Zimbabwe was done. Twenty-four (24) sampling plots were established (12 invaded plots and 12 uninvaded plots). Quadrants of 5 × 5 m were used in both invaded and uninvaded areas. The study measured the Diameter at Breast Height (DBH) at 1.5 m using a diameter tape. The researchers measured the height of the first tree using a measuring graduated poll and later used it as a reference point when estimating the height for other trees in each quadrant. The estimated height of shrubs using the aforementioned method counts the number of non-native and native plant species and counts the number of saplings in each quadrant. Global Position System (GPS) device was used to record the location at the centre of each quadrat. A digital camera was used to take photos of *H. gardnerianum* invaded sites. Biodiversity indices were calculated to evaluate native species diversity in areas that are invaded by *H. gardnerianum* and those which were not invaded using the Shannon-Wiener index.

The Shannon-Wiener index was calculated using: $H = -\sum piLnpi$ formula. Whereas H is the Shannon-Wiener index, ∑ is the sum of calculation in a sample, pi is the proportion of individuals of particular species found divided by the total number of individuals found. Ln is the natural log. Before all statistical analyses, data were tested for normality using SPSS version 23. Since the samples size was less than 50 the Shapiro-Wilk test was used to test for data normality. The data for Shannon-Wiener and species richness with $P = 0.05$. Parametric tests (One-way ANOVA) were conducted to determine if there is a significant difference between *H. gardnerianum* invasion and the diversity of species in invaded and uninvaded sites. Therefore, a non-parametric test (Kruskal Wallis test) was used to determine if there were significant differences between *H. gardnerianum* invasion and the abundance of plant species in invaded.

Results

Native species ranged from 1 to 481 and ginger abundance ranged from 0 to 73 at each sampling plot. The study recorded an average of 47 native species and 22 ginger plants on sampled plots. The Kruskal–Wallis test on the effect of *H. gardnerianum* invasion on plant species diversity (Shannon-Wiener) results show that there is a statistically significant difference between species diversity in areas that were invaded by *H. gardnerianum* as compared to those areas which were not invaded, with $x^2(1) =$

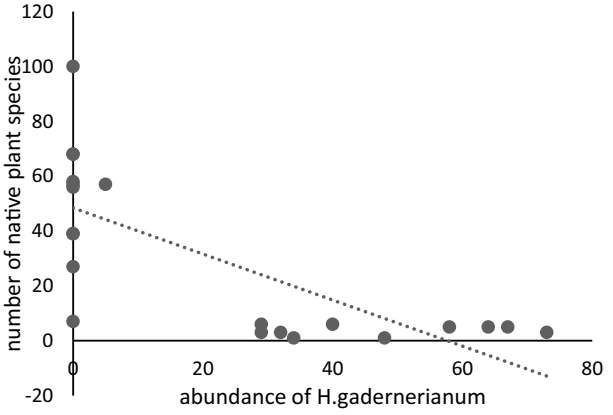

Figure 3. Scatterplot showing the relationship between *H. gardnerianum* abundance and the number of native plant species.

16.309, P = 0.000. There was a significant relationship between *H. gardnerianum* abundance and native species richness ($P < 0.05$). Analysis of scatter plot results shows that there is a strong negative relationship between the abundance of ginger and the number of native plant species (Figure 3). This is shown by the equation $y = -0.8398x + 48393$ and the direction of the R. Figure 3 shows that as the number of ginger plants increases the biodiversity decreases by 54.5%.

Discussion

H. gardnerianum species is affecting the diversity of plant species in the Bvumba Mountains, Zimbabwe as is shown by a statistically significant difference between plant species diversity in invaded compared to uninvaded sites. In highly invaded areas, few or no native species were found in some sampled sites causing high dominance index close to 1 and at some instances equal to 1. This is supported by an inverse relationship between the abundance of *H. gardnerianum* and the number of native plant species since an increase in its abundance results in a 54.5% decrease in native vegetation in the Bvumba Mountains, Zimbabwe. This invasive plant species forms thickets in the understorey forest layer threatening the growth of shrubs and saplings. Research findings show that the number of native plant species decreases with an increase in the abundance of *H. gardnerianum* [24]. This is because this invasive plant species has a larger leaf area that suppresses the penetration of sunlight required for the growth of shrubs and saplings of native plant species (Figure 4a) [25]. Besides, it outcompetes native juvenile tree species for nutrients and sunlight. These findings are in line with previous studies conducted in other areas with similar characteristics such as Hawaii and New Zealand [1, 8, 9]. *H. gardnerianum* can result in the death of mature trees since it grows parasitically on other trees, e.g. it grows on the stem of the tree fern, a protected plant in the Bvumba botanical garden (Figure 4b). The parasitic interaction between *H. gardnerianum* and native species is striking since no study documented it. *H. gardnerianum* species invaded *hydrangea* species, an ornamental plant species

Figure 4. (a) *H. gardnerianum* broad leaves (b) *H. gardnerianum* growing on a tree trunk. (Photo credit: Cally-ann Furamera, 2019).

in the Bvumba botanical garden, affecting its regeneration. In Bvumba, *H. gardnerianum* species is mainly found on forest margins and its population decreases with an increase in the distance into thick forests. This is consistent with previous studies conducted in areas with similar vegetation types, climatic and geological characteristics, for instance in the Hawaiian region [5, 9]. The invasion by this species could be facilitated by seed dispersal agents such as wind, birds and monkeys. If these plant species remain unchecked it can significantly modify the ecosystem structure, nutrient cycling, functioning and biodiversity since it replaces native ecosystems [24, 26]. *H. gardnerianum* distorts the scenic views of tourism sites by invasion and this negatively impacts tourism within the Bvumba Mountains.

Conclusion

H. gardnerianum adversely affects the diversity of native plant species, vegetation patterns and species composition in the Bvumba Mountains, Zimbabwe. This invasive species is mainly found in protected areas on the understorey layer of montane forest and its population decreases with increasing distance into thick montane forests. *H. gardnerianum* grows parasitically on other trees, outcompetes native juvenile plant species for nutrients and sunlight and suppresses regeneration of native plant species. The establishment of this species alters the vegetation pattern, composition and diversity. The study recommends the need to develop a management programme to control and manage *H. gardnerianum* in protected and communal areas. Further researches should be conducted on the factors influencing invasion, identifying potential areas to be invaded by *H. gardnerianum* and devising environmentally friendly control measures.

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