The role of the National Botanic Garden of Namibia in plant species conservation

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Abstract

This study was aimed at determining and comparing plant species diversity, species composition and species richness in the National Botanic Garden and Aloe Trail areas in Windhoek, Namibia. Floristic data were collected following standard random plot sampling procedure, where 1m × 1m plots were nested in the 20m x 20m plots to measure herbaceous and woody plant species respectively. A total of 50 and 40 plots were sampled at the Botanic Garden and Aloe Trail areas respectively. The Shannon-Wiener diversity index was used to compute the species diversity of each plot sampled in each area. The Shapiro-Wilk test was used to test the data for normality. The Jaccard index of similarity revealed a 64% percentage similarity in species composition between the two sites. However, there was no significant difference in the herbaceous cover (Mann-Whitney statistic, $Z = -1.314, p = 0.189$) between the two areas. The Botanic Garden showed a significantly higher species richness than the Aloe Trail (t-test, p= 0.000). In addition, the Botanic Garden was found to be significantly more diverse (Mann-Whitney statistic, U=478, p=0.000) than the Aloe Trail because it is a protected area that is fenced and with minimal disturbances. The higher species diversity in the National Botanic Garden is attributable to the role of these living collections in the conservation of plant species.

Keywords: Botanic Garden; conservation; plant species; Namibia.

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1 Introduction

Botanic Gardens are institutions comprising documented living collections and displays of a wide range of plants, kept and used mainly for scientific research, conservation, recreation and educational purposes (Sharrock et al., 2011; Hulme, 2011; Ward et al., 2010). These gardens are often linked to universities or other scientific research organizations, and often have associated herbaria. Globally, Botanic Gardens constitute up to one-third of all known plant species (Sharrock et al., 2011). Botanic Gardens around the world are gaining considerable recognition for their instrumental role in the conservation of plant taxa (Hulme, 2011, Crane et al., 2009). According to the International Union of the Conservation of Nature (IUCN) version 2010.4 Red List of Threatened Species, cited in Sharrock et al., (2011), global plant species extinction would be 34% higher than currently, in the absence of conservation efforts of Botanic Gardens. Because of their scientific basis, collections in Botanic Gardens have contributed significantly to the body of knowledge on threatened species and their conservation (Donaldson, 2009). *Ex-situ* conservation, as a practice of supporting conservation in the wild is an active area of research in Botanic Gardens (Donaldson, 2009).

Namibia is well-endowed with a rich botanical diversity of more than 4200 taxa (Klaassen and Kwembeya, 2013), that is well adapted to the prevailing semi-arid climate. With the country's economy being heavily dependent on biodiversity and natural resources through the tourism, fisheries and agricultural sectors and given that about 70% of the population depend directly on natural resources for their livelihoods, conservation is recognized as a viable landuse in Namibia (MET, 2014). This, coupled with the emerging commercialization potential of indigenous plant species (MAWF, 2014) as well as the unpredictable climatic conditions, characterized mainly by highly variable rainfall and temperatures further demand for biodiversity research and conservation.

The land where the National Botanic Garden of Namibia (NBGN) is located was donated to the Government of the Republic of Namibia by the City Council of Windhoek in October 1969. It was earmarked to be a nature reserve, and developed into a Botanic Garden in 1993 (NBRI, 2015). Since then, the NBGN has transformed into a botanical paradise of Namibian indigenous plant species. The NBGN is a section of the National Botanical Research Institute (NBRI), which falls under the Ministry of Agriculture, Water and Forestry (MAWF). In comparison with Botanic Gardens elsewhere in the world, the NBGN is unique because it only cultivates, conserves and promotes Namibian indigenous plant species. Furthermore, this garden is a water-wise garden with minimal landscaping and periodic watering of plants that have been planted there. This approach allows for conservation of water resources and promotes the appreciation of plants in their natural environment (NBRI, 2015; MAWF, 1999). The NBGN is involved in taxonomic research, the development of propagation methods to explore the potential of indigenous plants as ornamentals, as well active participation in rescue operations of sensitive and protected plant species that face negative impact from

development of infrastructure or other habitat destructing activities such as mining (NBRI, 2015; MAWF, 1999). Being the only Botanic Garden in the entire country, and given its convenient location in the city, the NBGN is a prominent tourist attraction for the general Namibian public and visitors alike.

Within the context of the above, this study was conducted to investigate the impact of *Ex-situ* conservation efforts in the NBGN and thus the role of the NBGN in plant species conservation in Namibia. The specific objectives of this study were to determine and compare plant (1) species richness, (2) species composition, (3) species diversity and (4) herbaceous cover between the NBGN and the adjacent Aloe Trail, also known as the Hoffmeyer Trail.

2 Methods

2.1 Study site description

The study was carried out at the National Botanic Garden (S22°.571149, E017°.094375) and Aloe Trail (S22°.56 775, E017°.09 488). The two areas are adjacent to each other and are recognized as urban green-spaces within the city centre of Windhoek, located behind the Parliament Gardens, on top of a mountain that overlooks the city from the eastern direction. The Aloe Trail covers an area of about 9 ha while the NBGN stretches over some 12 ha.

The climate in the Windhoek area is generally described as semi-arid and is characterized by hot, wet summer months (December - February), and mild, sunny winter months (June - August). Average maximum temperatures range between 30°C and 32°C while average minimum temperatures range between 4°C and 6°C. Average annual rainfall ranges between 300-360 mm (Mendelsohn et al., 2002). The geology of central Namibian region is dominated by the Kuiseb Formation schists Damara Sequence, with biotite schist as the main rock type (Mannheimer, 2012; Mendelsohn et al., 2002). Soils in this area are predominantly Lithic Leptosols and Eutric Regosols, which are generally shallow and contain very little organic matter, which has been attributed to low organic litter input and rapid mineralization (Bertram and Broman, 1999). The vegetation in the study area has been described as highland savanna (Giess, 1971), with a relatively low cover of trees and shrubs, predominantly *Senegalia* and *Vachellia* species and an assortment of gramminoid and herbaceous species.

2.2 Data collection

Species diversity which relates to the type, number of the different species (species richness) and the proportion of individuals representing each species (species evenness or heterogeneity) within a given community is usually calculated and expressed as an index (Purvis and Hector, 2000; Rosenzweig, 1995). Species diversity is useful as an indicator of the biological health of a given ecosystem, as it reflects the complexity of food webs, prevailing conditions, ecosystem functions and environmental change (Purvis and Hector, 2000). A higher species diversity index value may thus indicate positive conservation efforts promoting healthy ecosystems while low diversity may reflect poor efforts towards conservation. Biodiversity measurements therefore yield useful information necessary for the development of conservation strategies.

A modified nested quadrat design was used to record data on woody and non-woody plants in randomly selected 20m × 20m quadrats. In these plots, all woody plant species were identified to species level using field guides and the number of individuals counted and noted. The 1m × 1m plots were nested in each corner of the 20m × 20m plots where herbaceous plant cover was estimated and expressed as a (%). Tape measures were used to demarcate the plots. A total of fifty (50) and forty (40) plots were sampled at the NBGN and Aloe Trail respectively. Plant species that could not be identified were prepared and lodged at the National Herbarium of Namibia (WIND), located on the same premises as the NBGN. The data were collected in the month of June 2015.

2.3 Data analysis

Plant species diversity was calculated for each plot using the Shannon-Wiener Diversity index (H'):

$$H' = -\sum(p_i)(lnp_i)$$

where p_i is the proportion of individuals found in the i-th species, ln is the natural logarithm (Krebs, 1994).

A Shapiro-Wilk test was used as the normality test for species diversity, species richness and herbaceous % cover data. The Mann-Whitney U test was used to test for significant differences in species diversity and herbaceous % cover, while the Independent t-test was used to compare species richness between the NBGN and Aloe Trail. All statistical analyses were performed in SPSS (version 22). Furthermore, the Jaccard's index of similarity was used to compare the species composition between the NBGN and Aloe Trail.

The Jaccard's index of similarity is given by the formula:

$$S_j = \frac{a}{a+b+c}$$

where S_j = Jaccard's similarity coefficient
a=Number of species common to both sample A and sample B
b=Number of species in sample B but not in sample A
c=Number of species in sample A but not in sample B
The coefficient is multiplied by 100 to give a percentage figure (Kent, 2012).

3 Results

3.1 Species composition

The study recorded a total of sixty-seven (67) and forty-six (46) plant species belonging to twenty-eight (28) and twenty (20) plant families from the NBGN and Aloe Trail respectively. These species exclude plants that have been planted in the NBGN from elsewhere in the country. Generally, the plant families Poaceae, Fabaceae, Malvaceae, Amaranthaceae and Aloaceae were the most dominant. Plant families represented at the NBGN but were absent from the Aloe Trail include Oxalidaceae, Crassulaceae, Euphorbiaceae, and Verbenaceae.

The Jaccard's index of similarity showed a 64 % similarity in the species composition between the two areas. The two sites are adjacent to each other, thus under the same climatic conditions and share similar geological and soil features.

3.2 Species richness

The Independent t-test ($t = 3.639, p < 0.001$) showed a significant difference in the mean plant species richness between the NBGN and Aloe Trail, at alpha level 0.05. The average number of species recorded in this study per 400 m^2 at NBGN and Aloe Trail was thirteen (13) and eleven (11) respectively (Figure 1).

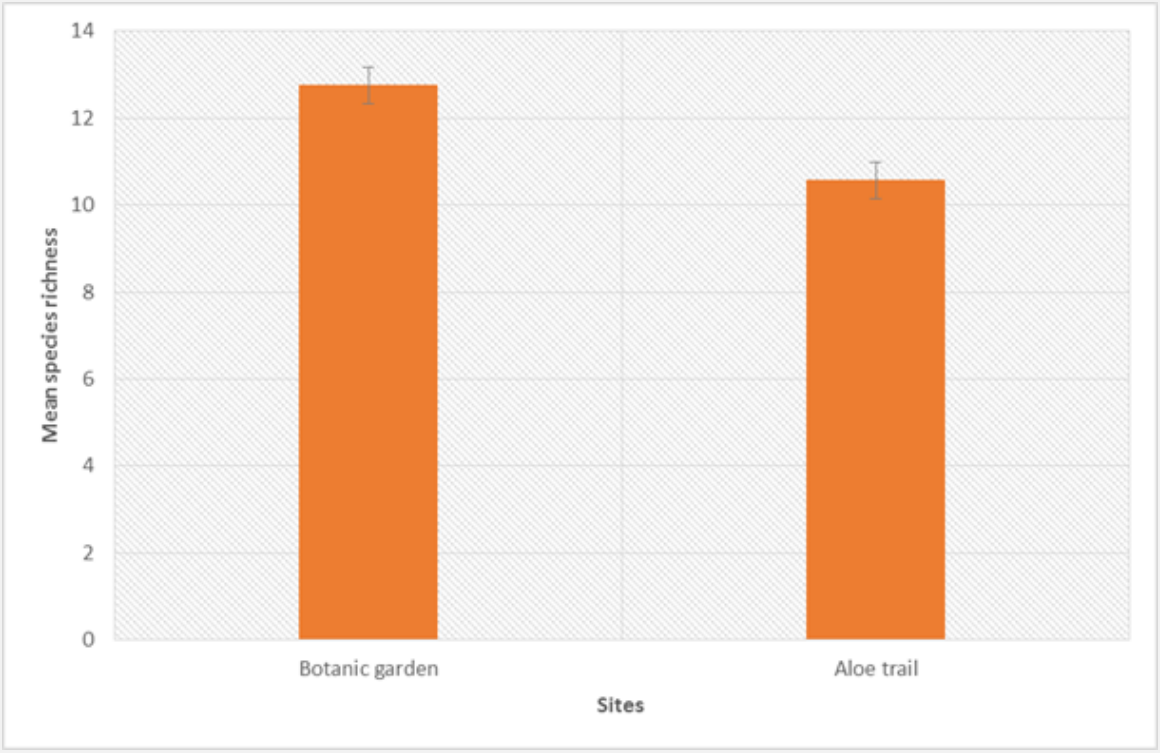

Figure 1: Comparison of mean plant species richness (± SE) between the NBGN and Aloe Trail.

3.3 Plant species diversity

The Mann-Whitney U test showed a significant difference in plant species diversity between the NBGN and Aloe Trail (Mann Whitney U, $Z = -4.239, p < 0.001$) at alpha level 0.05. The median species diversity ($H' = 2.24$) in the NBGN was thus significantly higher than the median species diversity ($H' = 1.86$) at the Aloe Trail (Figure 2).

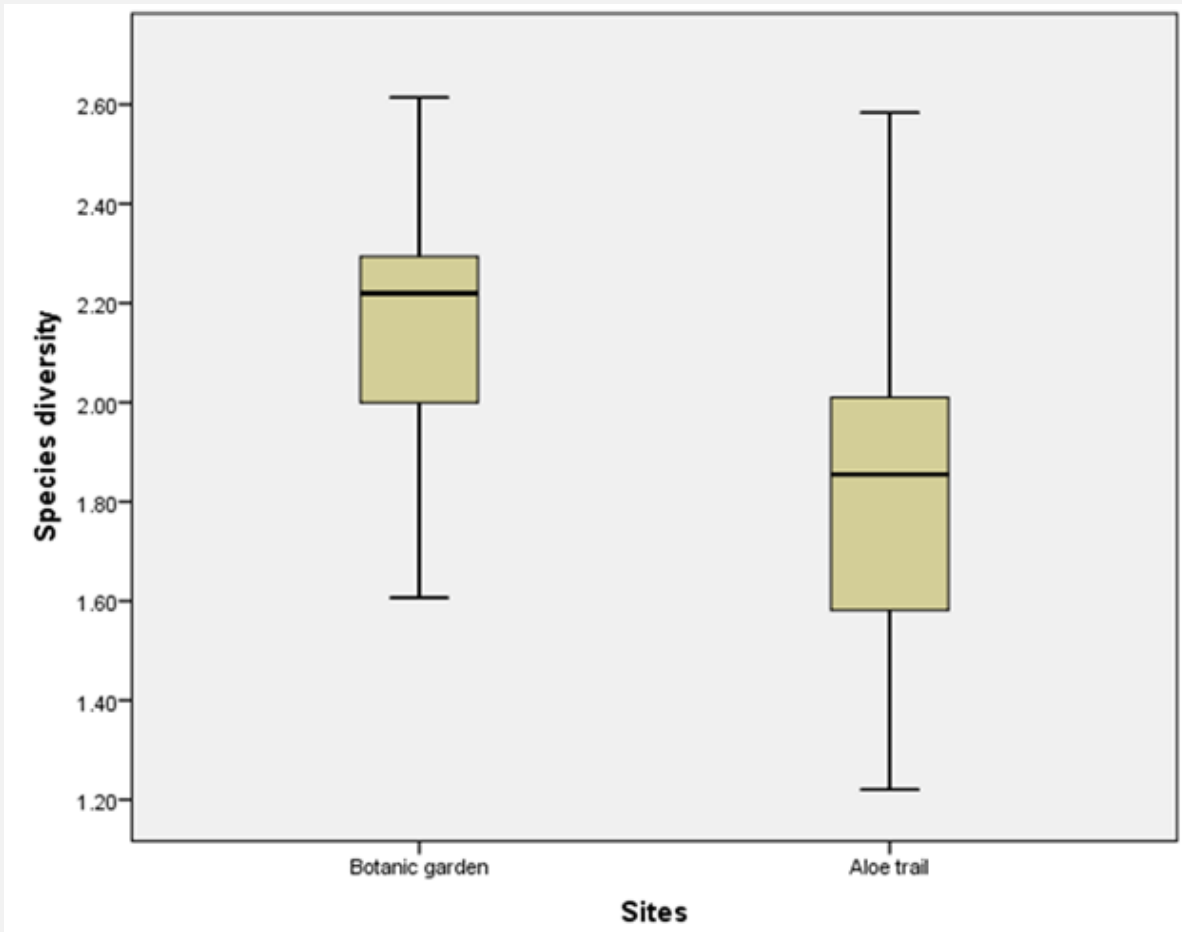

Figure 2: Comparison of plant species diversity between the NBGN and Aloe Trail.

3.4 Herbaceous percentage cover

The Mann-Whitney U test showed no significant difference in herbaceous cover between the NBGN and Aloe Trail (Mann-Whitney U, $Z = -1.314, p = 0.189$) at alpha level 0.05. Figure 3 displays the graphical variability.

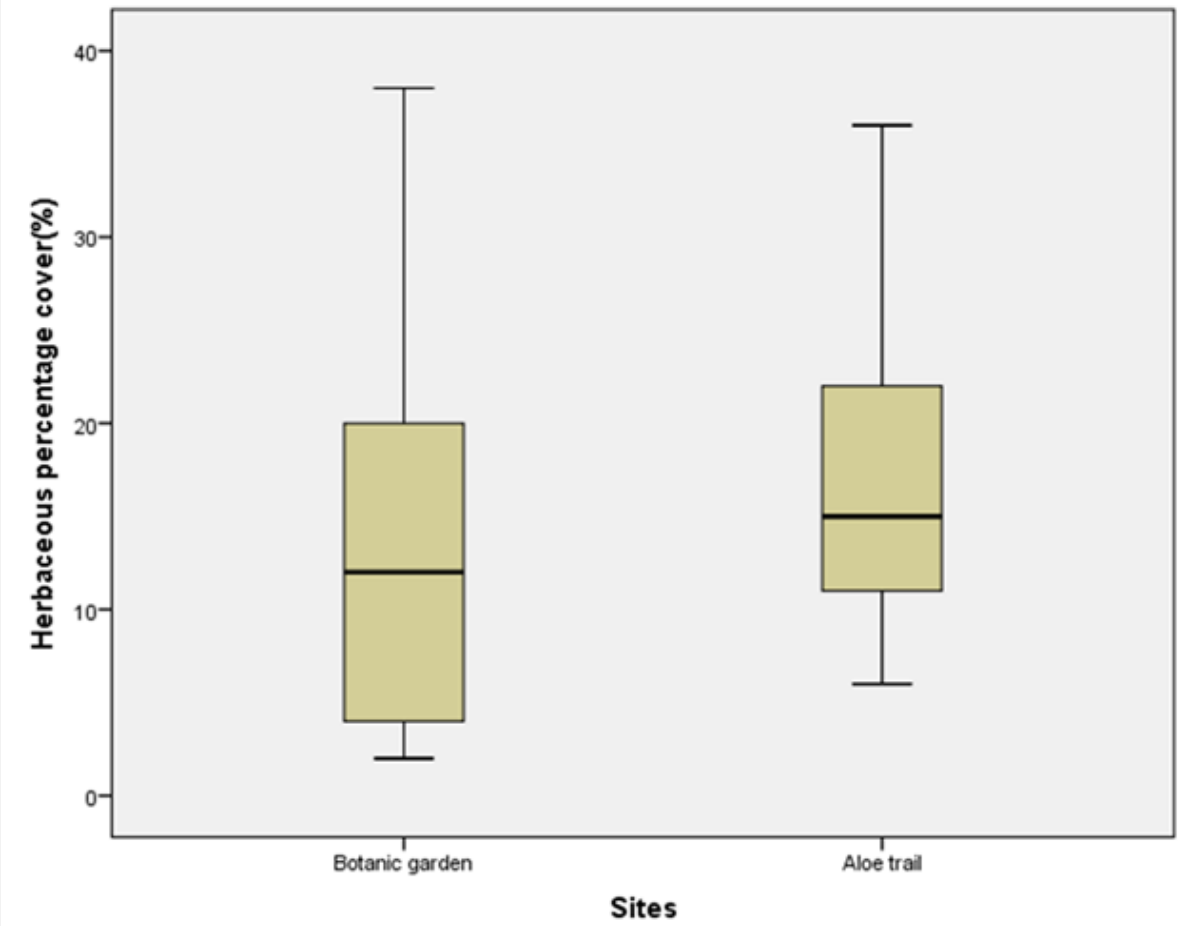

Figure 3: Comparison of herbaceous cover between the NBGN and Aloe Trail

4 Discussion

This study aimed to compare plant species diversity and components that of between the NBGN and the Aloe Trail in Windhoek, Namibia to investigate the role of Botanic Gardens in plant conservation. The study found that the NBGN hosts a significantly greater number of species than the Aloe Trail (Figure 1). Moreover, plant species diversity also differed significantly between the two sites (Figure 2). Since the NBGN is a protected area, it experiences minimal disturbances, unlike the Aloe Trail which has open access to the public and where collection of natural materials is not strictly prohibited. This explains the higher plant species diversity in the Botanic Garden. Plant species in the NBGN are better

conserved than those occurring outside this nature reserve. Although some plant species e.g. *Aloe dichotoma* Masson and *Euphorbia virosa* Willd. subsp. virosa were planted in the NBGN from elsewhere in the country, these species were not included in the present study.

The lower species diversity in the Aloe Trail could be explained by the presence of uncontrolled alien invasive species and unregulated plant collecting by the public. Alien invasive species are known to negatively impact biodiversity through displacing and outcompeting other species for natural resources (water, light, nutrients), altering habitats, evolutionary relationships, ecosystem function and other ecological processes (Shirley et al., 2004, Alpert et al., 2000). The intense invasion of alien invasive species at Aloe Trail such as the cactus species *Opuntia aurantica* Lindl., which form dense mats on the ground and may prevent the establishment of other species thus altering plant species richness and diversity.

While some Botanic Gardens elsewhere in the world have been implicated in the introduction and cultivation of alien invasive species (Hulme, 2011), the National Botanic Garden of Namibia is exclusively a nature reserve (conserving plant species in their natural environment). Moreover, the regular alien invasive clean-up campaigns in the NBGN as facilitated through coupled efforts with the Botanical Society of Namibia. The Botanical Society of Namibia conducts "Annual Alien Invasives" clean-up operations in the National Botanic Garden in which environmental enthusiasts, the general public, students, scouts and other environmental groups participate to remove invasive cacti. The Botanical Society of Namibia strives to promote the understanding, appreciation and conservation of Namibian flora through community awareness and education (Botanical Society of Namibia, 2016).

There was no significant difference in herbaceous cover between the two locations (Figure 3). Generally, the herbaceous cover was low (less than 40%) in both locations. Low herbaceous cover is a characteristic of late succession and undisturbed reference standard conditions. High percentage cover of herbaceous plants can indicate an early stage of succession. High percentage of herbaceous cover also indicate recent, intense or frequent disturbances (Caratti, 2006). The NGBN and the Aloe Trail revealed no significant difference in herbaceous species (Figure 3). With records and relatively high abundance of the climax grass species *Anthephora pubescens* Nees, *Cenchrus ciliaris* L. and *Panicum maximum* Jacq. (MÃijller and van Eck, 2007), in this well-established highland savanna and given the absence of large herbivore influence at both locations, late succession conditions prevail.

Although, in *situ* conservation of species is the preferred conservation option, as this allows species to satisfy their ecological roles, there's a need to consider *ex situ* conservation to reduce extinction of species (Oldfield, 2009). The current conservation approach employed at the NBGN is largely ex situ conservation efforts of indigenous plant species, in which plant species are protected as living and seed collections (Oldfield, 2009). This contributes to maximized conservation benefits of the local flora. Indigenous plant species could provide water-wise and climate-smart ornamental options as well as new and alternative medicinal

and natural products, if explored adequately. This would particularly in turn relief some pressure off our precious and scarce water resources. The development of propagation methods for this purpose and efforts to promote indigenous plants at NBGN, therefore need to be supported.

This study documented sixty-seven (67) and forty-six (46) plant species in the NBGN and Aloe Trail respectively. The study further revealed 64% similarity in species composition between the two areas. The plant species richness and diversity was significantly higher in the National Botanic Garden than the Aloe Trail because it is a protected area that is fenced off and experiences minimal disturbances. This validates the existence and importance of Botanic Gardens in plant conservation. Furthermore, the results of this study underscore national efforts invested towards the requirements and expectations of Multilateral Environmental Agreements, particularly the Convention of Biological Diversity (CBD) and International Trade in Endangered Species of Wild Fauna and Flora (CITES) to which Namibia is a signatory state (MET, 2014). In addition, the plant species inventory produced in this study will be useful in the updating of existing checklists of plant species occurring in the NBGN and Aloe Trail.

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