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Abundance, distribution and ecological impacts of invasive plant species in Maputo Special Reserve, Mozambique

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With a few exceptions, comprehensive assessment of invasive plants species (IPSs) list that invade Maputo Special Reserve's natural ecosystems is lacking. Some available data are either preliminary or localised, or focus on agricultural weeds that leave an ecological gap about IPSs. In order to establish this gap, a study was conducted to asses the impact of IPSs in Maputo Special Reserve. A stratified random sample was used to allocate five land use and land cover strata. Plots of 20 m diameter formed by two replicates were established in transects within plot of 160 m × 80 m and each invasive plants species number were counted and recorded. At every 10 km distance of the road side in different reserve directions, field plots of 10 m × 10 m were also established location and coordinates where invasive plants species occur recorded. With the ARCGIS 10.3 software, IPSs location coordinates were positioned on the map to create location. Data analysis was through calculation of diversity and evenness indices (Shannon-wiener (H') and Simpson (D'). Student's t -test was used to compare diversity differences between the invaded and un-invaded sites. The result indicated the occurrence of 26 IPSs across all strata with *Lantana camara* and *Eucalyptus* sp being dominant. Settlement stratum recorded the highest level of invasive plants compared to other strata. Student t test on differences in Shannon-wiener diversity (H') between invaded and un-invaded areas showed that there was significant difference in species diversity ($t\ 0.05(2)^{170}$ =1.84 0.05< P< 0.10*)*. The threat of IPSs is increasing at an alarming rate, thus control methods have to be designed to stop further spreading into Maputo Special Reserve.

Key words: Biological invasions, environmental damage, species diversity, ecosystem services.

INTRODUCTION

Invasive Plant Species (IPSs) are non-native or alien to the ecosystem whose introduction causes or is likely to cause economic or environmental harm (Kareiva, 1996). These plant species can also be understood as either indigenous or non-indigenous species that heavily colonize a particular habitat and negatively impact on it

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economically, environmentally or ecologically (Davis and Thomson, 2015). These plant species are considered one of the greatest threats to long-term conservation of biological diversity in both terrestrial and aquatic habitats (Lee and Macdonald, 2016; Wilcove et al., 2008; Mack et al., 2015). According to Cronk and Fuller (2015), IPSs pose a significant threat to many of Africa's conservation areas. Among the most widely distributed invasive plants is *Lantana camara* which occurs across many protected areas (Kareiva, 1996). The plant occurs in diverse habitats and on a variety of soil types in the Asia-Pacific region, Australia, New Zealand, Central and South America, West Indies and Africa (IUCN, 2010). Thus, its diverse and broad geographic distribution is a reflection of its wide ecological tolerance. These invasive plants, invades and impacts severely on natural ecosystems, threatening the survival of many species (Sharma and Raghubanshi, 2016). It's allelopathic qualities can selectively increase mortality of other plant species (Gentle and Duggin, 2012; Sharma et al., 2015a), resulting in reduction of species diversity as well as decline of species (Sharmer et al., 2015b).

Invasive plant species is one of the world's conservation challenge that affect protected areas (Wittenberg and Cock, 2001). However, the impact of IPSs in protected areas such as National Reserves is currently poorly understood and the magnitude of the problem is not well appreciated. In this regard, biodiversity in protected areas is adversely affected and its long-term survival is threatened by IPSs (Kareiva, 1996).

The features that are associated with invasive plants species are: (1) they show large seeding and early age of fast reproduction, (2) have unpalatable foliage, can easily establish in degraded environments, (3) have an ability to regenerate directly from seeds, stems or roots. These features make them good competitors amongst other plant species and allow their survival and abundant establishment (Ahimbisiwe, 2014). An introduced plant species might become invasive if it can out-compete native species for resources such as nutrients, light, water or food (Tilman, 1993).

Invasive species compete for space or resources, dominating the niches occupied by native species and excluding them from the natural environment. The competitive exclusion of these species can compromise the existence of rare species and even other trophic levels, keeping communities in a constant state of disruption.

Invasive plant species invasions can have devastating population, community and ecosystem impacts (Parker et al., 2013). Such impacts may include loss of native species, disruption of energy and nutrient webs and unstable production systems (Davis et al., 2015). As a potential threat to native biological diversity, IPSs need to be controlled to ensure that the food plants of all herbivores are in large supply, maximize productivity (Adcock et al., 2017) and hence sustenance of life. Perring et al. (2016), suggests that most cases of invasiveness can be connected to the intended or unintended consequences of economic activities. Therefore, social and economic applications are essential to understand the problem and provide more accurate and comprehensive assessments of the benefits and costs of control alternatives to increase the effectiveness and efficiency of public funding. Invasive species are increasingly recognized as having important impacts on landscapes, ecosystems and levels of biodiversity (Baskin, 2012). Costs are incurred if the exotic species inhibit the effective functioning of the local social and ecological systems (Pimentel et al., 2011). A quantification of the impacts of IPSs is required to substantiate an argument to control them.

The protected areas of Mozambique are not exempted from the occurrence IPSs, although they are well distributed throughout the country. These areas represent a considerable national surface with varieties of ecological systems rich in endemic species (Marulo, 2012). In these conservation areas for example Maputo special reserve, the occurrence of IPS like Lantana camara*,* *Eucalyptus* sp and others are threatening the reserve's biodiversity as these have been observed encroaching into the natural vegetation (MICOA, 2014). They are extensive and intense, thus compromising the natural regeneration process of native plants. This reduces the progress of ecological succession processes and consequently compromises the increase in the structural complexity of vegetation and the perpetuation of non-native plant species, demanding ecosystem conservation techniques (Gandolfi et al., 2017).

The presence of IPSs is not desirable in a conservation area, since they interfere with the growth dynamics of native vegetation, used as pasture by wild animals and creates food imbalance in all ecological processes (Almeida and Leão, 2011).

In Maputo Special Reserve, changes which IPSs have caused, a reduction in the abundance of environmental goods and services as well as increasing the physical threats to wildlife habitats and threatening entire ecosystem (MICOA, 2014). Many invasive plant species have enhanced frequency and intensity of fires threatening wildlife habitats and an entire ecosystem (MEWC, 2014). Previous efforts to rehabilitate Maputo Special Reserve focused on increasing the number of animals where elephants' number have been restocked and the creation of new reserve limits neglecting the rehabilitation of pastures threatened by invasive plants species. However, Brett (2013) suggests that, wildlife pasture availability and quality are also major determinants of habitat suitability in order to sustain viable wildlife populations (Muya and Oguge, 2015). Hrabar and Dutoit (2015) point out that an understanding of all factors that may affect the productivity of wildlife is crucial in order to achieve maximum productivity and decrease their vulnerability to extinction. Thus, in addition to wildlife restocking and creation of new reserve boundaries, successful management and conservation of the reserves and other protected areas can be achieved if invasive plant species are managed to allow proper pasture to wildlife and manage entire habitat health through avoiding compromising their food resource base (Adcock et al., 2017).

In Mozambique, IPSs have been introduced over the years mostly deliberately and for commercial purposes and fencing of agriculture fields, for example *Eucalyptus* sp and *Pinus.* Other invasive plants species like *Lantana camara* were utilized for ornamental purposes. Several plant species have been invading in a natural way, for example, *Parthenium hysterophorus, Ipomoea carnea*, *Opuntia ficus indica, Ipomea alba, Pinanga coronata*, *Ricinus communis* and others are observed in several regions of the country (MICOA, 2014). Some introduced plant species are not harmful and are important economically, socially and even ecologically. On the other hand, other species have caused imbalances in protected area ecosystems and caused the extinction of some species and probably reduction of genetic diversity (MICOA, 2014). Despite growing awareness of the problem of biological invasions in general, there is lack of comprehensive research on the impact of invasive plant species on conservation areas. In almost all conservation areas in tropical regions it is possible to find some IPSs. In some regions, these plant species are more prevalent in the landscape (Thapa et al., 2014). The scenario of the occurrence of invasive plant species is also currently evident in Maputo Special Reserve (MEWC, 2014).

It is widely acknowledged that good information and understanding about IPSs is the basis for sound policy and management. Therefore, there is a need for recognition that societies need to mitigate negative impacts of IPSs and find appropriate means to manage them in a way that the impacts are at least minimized. This study therefore provided an inventory of the spatial distribution of the IPSs on the reserve and tries to analyze the potential ecological impacts on Maputo Special Reserve in different parts based on the changes since the species were observed. It was also undertaken to assist decision makers to facilitate optimal allocation of resources to manage invasive plant species that are most harmful in the area.

METHODOLOGY

Study area

The study was undertaken in Maputo Special Reserve which lies in Matutuine district in Maputo province (Figure 1). The reserve covers an area of 700 km^2. It lies on 26.5048° S, 32.7157°E. The temperatures are warm wet summers (October-March varying between 26 and 30°C) and cool dry winters, April-September with temperature ranging between 14 and 26°C (MICOA, 2014). Average annual rainfall varies between 690-1000 mm. Area vegetation is characterized by a unique mosaic of varied ecosystems (MAE, 2015), including: Mangroves, Dune Vegetation, Wooded Grasslands, Sand Forest-Woodland, Sand Forest and Savannah. Three main Rivers exist in the reserve namely, Futi, Maputo and Tembe with diverse lagoons of which Piti, Chingute and Mundi are most important (Tello, 1972). The area also has significant wetland and other flooded areas that exist within (Bodasing, 2011). Surrounding it, a variety of land uses are utilized including farming (both livestock and game), tourism, trade and housing being practiced by the various communities and concessionaires (MAE, 2015). Most of these activities occur along the Maputo River, yet a few are scattered along the Ponta do Ouro – Salamanga Road with a few housing initiatives close to the tourism core areas such as Ponta do Ouro and Ponta Malongane. Various signs of human activity are still obvious across much of the reserve and are prevalent in the northern and eastern parts of the reserve (Matthews, 2008; Bodasing, 2011).

Data collection procedures

For data collection, a stratified random sampling method was used, in which the stratification used was according to the type of land use and land cover of the study area based on the use vegetation cover map of 1: 250000 of the Maputo Special Reserve. According to the stratification of the study area, five land use and land cover areas were selected, namely: agriculture area (4.34%), grasslands (25.09%), forest area (31.72%), flooded area (34.78%) and settlement (2.002%) of the study area (MICOA, 2014). The effective sampling area was (23,342.12 ha), which represented a sampling intensity of 30.03%.The number of sample units for each stratum was determined according to the stratum area. Determination of the total number of sample units per stratum was according to the procedures described by Schreuder et al. (2014). Randomization process was carried out using the package (Hawths tools extension) associated with GIS ArcGIS 9.3 (Winther and Rasmus, 2014). Location of the plots in the reserve area was done with the aid of Garmin e trex 10 GPS, in which the geographic coordinates of the sample plots were previously launched to the device. After locating the points with the aid of GPS, sixteen circular plots of 20 m diameter formed by two replicates with North orientation were established in transects within a big plot of 160 m × 80 m.

For survey of IPSs, we adapted the methodology described by Tinley (2007), which consisted of identifying all invasive species of plants in a given plot and recording them in terms of occurrence in numbers .IPSs identification was done with the help of a botanical collector and a list IPSs previously prepared based on the Compendium of Invasive plants (CABI, 2013). IPSs that were not on CABI's list were classified according to their typical characteristics and feature and later recognized by a botanist. To determine categories of disturbance related to occurrence of IPSs, detailed observations were made and the factors categorized as, a) Low - comprising up to 10%, b) Moderate - comprising between 10-30%. c), High - comprising more than 30% (Braun-Blanquet, 2014). Field plots of 10 m × 10 m were examined on both sides of Reserve routes with greater movement of employees and tourists at an interval of 10 km from the starting point. In order to capture maximum possible records on location and distribution of IPSs, some opportunistic observations were also made if encountered IPSs were not recorded in the immediate previous plot, afterwards all the co-ordinates were used to map the places of occurrence of the main IPSs. With the ARCGIS 10.3 software, IPSs location coordinates, located on map of Maputo Special Reserve to ascertain IPSs location on the ground.

Data analysis

Data analysis involved both descriptive and statistical analysis

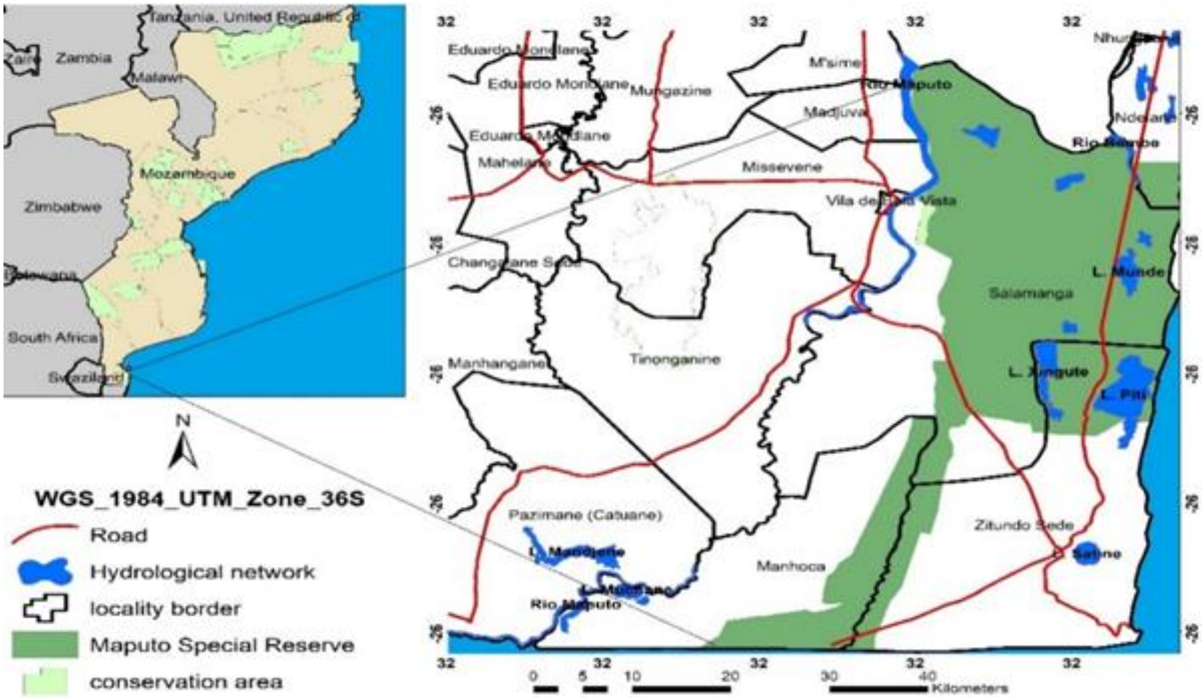

Figure 1. Map location of the study area. (Source: Generated from Arc GIS 10.5, MSR shapefile 2019.

stages. Microsoft Excel version 16.35 analytical tools were used to calculate total number of each IPSs and densities (number of individuals or area sampled) in each stratum. Statistical analysis involved determination of significance differences in species diversity between invaded and un-invaded areas using ANOVA (Zar, 2009). For data that does not require analysis, descriptive statistics were employed. Descriptive statistics such as, percentage and standard deviation were used to present the results. IPSs diversity within different sampling land use and land cover strata were calculated. In order to have an effective measure of diversity and account for richness and abundance, a Shannon-Wiener diversity (H') and Simpson (1-D') indices were calculated following the formulae described by Magurran (2004). Shannon -wiener diversity index (H*)*

(i) $$H' = -\sum_{i=1}^{s} piLn(pi)$$

(ii) Simpson Index (1-D)

$$D = 1/pi^2$$

Inferential statistical tests were performed on the data collected. In this case, Student's *t*-test was used to test for IPSs diversity differences between invaded and un-invaded areas following the formular described by Zar (2009).

Invasive plant species presence was determined by calculating absolute abundance (Ab(abs)), relative abundance (Ab(%)), absolute frequency(Fr(abs) and relative frequency (Fr(%)) as described by Eba and Lenjisa (2017).

(i) $\text{Ab (abs)} = \frac{\text{Number of individual by specie}}{\text{Area (ha)}}$

(ii) $\text{Ab (\%)} = \frac{\text{AB(abs) Species}}{\sum \text{AB(abs)}}$

(iii) $\text{Fr (abs)} = \frac{\text{Number of plot with species}}{\text{total plot number}} * 100$

(iv) $\text{Fr (\%)} = \frac{\text{FR(abs) species}}{\sum \text{FR(abs)}}$

RESULTS

Settlement land stratum

This stratum covered an area of 1.55 ha which is 2.02% of the sampling intensity. It comprised current and old settlement. Some of the areas are open while other have closed vegetation with thin canopies. Common plants are shrubs less than ten meters and trees of more than ten-meters height. In this stratum, a total of 16 IPSs were recorded with *Eucalyptus* sp, *L. camara, I. alba*, *I. indica* and *S. mauritianum* being abundant and dominant (Table 1). Shannon-wiener diversity index (H') was 2.58,with dominant IPSs contributing highly to proportions (pi) values of natural logarithm of the proportion (Lin(pi). Simpson index (1-D) indicated uneven distribution of IPSs (Table 1).

Agriculture land stratum

This comprised mainly of community current and abandoned agriculture fields. It had shrubs and short trees with few grass species. Dominant IPSs in this stratum were *Agave sisalana, Coreopsis lanceolata,*

Table 1. Invasive plant species in settlement land stratum.

Scientific name	Fr(abs)	Fr (%)	Ab(abs)	Ab (%)	Pi	ln(pi)	H''	D''
Acacia decurrens	0.28	6.89	9.89	2.95	0.030612	-3.48636	0.10	72
Agave sisalana	0.28	6.89	9.89	2.95	0.030612	-3.48636	0.1	72
Albizia lophantha	0.14	3.44	7.69	2.29	0.02381	-3.73767	0.08	42
paraserianthes lophantha	0.14	3.44	7.69	2.29	0.02381	-3.73767	0.08	42
Caesalpinia decapetala	0.14	3.44	8.79	2.62	0.027211	-3.60414	0.09	56
Cirsium vulgare	0.14	3.44	7.69	2.29	0.02381	-3.73767	0.08	42
Eucalyptus sp	0.14	3.44	48.35	14.42	0.14966	-1.89939	0.28	1892
Ipomea alba	0.57	13.79	29.67	8.85	0.091837	-2.38774	0.21	702
Ipomea indica	0.28	6.89	32.96	9.83	0.102041	-2.28238	0.23	870
Lantana camara	0.71	17.24	60.43	18.03	0.187075	-1.67625	0.31	2970
Opuntia monacantha	0.14	3.44	7.69	2.29	0.02381	-3.73767	0.08	42
Pennisetum setaceum	0.14	3.44	10.98	3.27	0.034014	-3.38099	0.11	90
Pinanga coronata	0.14	3.44	3.29	0.98	0.010204	-4.58497	0.04	6
Ricinus communis	0.28	6.89	16.48	4.91	0.05102	-2.97553	0.15	210
Solanum elaeagnifolium	0.28	6.89	18.68	5.57	0.057823	-2.85037	0.16	272
Solanum mauritianum	0.14	3.44	43.95	13.11	0.136054	-1.9947	0.27	1560
	4.14	100	335	100	1.037415	-52.9408	2.58	9030
								0.9

Datura stramonium, I. alba, I. indica, L. camara, Lilium formosanum Wallace*, Pinanga coronata, Ricinus communis, Solanum mauritianum* and *Xanthium spinosum* .Shannon-wiener index of species diversity (H') was 1.71. Invasive plant species *S. mauritianum*, *I. alba, I. indica, L. camara* and *Ricinus communis* had highest total number of recorded individuals and density, while *Agave sisalana, Coreopsis lanceolata, Datura stramonium, Lilium formosanum, Pinanga coronata*, *Xanthium spinosum* and *S. mauritianum* were most important IPSs in this stratum (Table 2).

Forest stratum

This stratum covered both artificial and natural forest. It covered an area of 26,137.51 ha or 31.72% of the study area. Some of the areas were open forest with some elements of burning characterized by short shrubs and trees. Other areas covered the artificial plantation forests that were established by the communities that lived in the study area. The main species included the *Eucalyptus* sp, *L. camara* and *S. mauritianum* while the least common species included *Cesalpinia decapetala, Acacia decurrens, Chondrilla juncea, Choromolaena odorata, Ipomoea carnea fistulosa, Solanum elaeagnifolium.* In the open forest edges, especially in areas that are used as roads by tourists and reserve workers, *Solanum elaeagnifolium and S. mauritianum* were recorded attributed to disturbances related to trampling and local nutrient enrichment through faecal-droppings, urine and salts leak. Open forest areas were mainly utilized by wildlife as resting and grazing areas. They are therefore invaded by potential IPSs. Wildlife species feed and disperse invasive species seeds through faecal droppings. The frequency and abundance of most important IPSs in this stratum indicated that they were unevenly distributed (Table 3).

Grassland stratum

The stratum was found different parts of the reserve and covered an area of 19,446.72 ha or 25% of the study area. It was mainly composed of open grassland with few woody shrubs and trees. The main invasive plant species included the following; *A triplex inflata, Cotoneaster pannosus Franch, Cuscuta suaveolens, Ipomea alba, L. camara* and *Pinanga coronata*. At the species level, *Cotoneaster pannosus, Cuscuta suaveolens, Lantana camara, Pinanga coronata* had highest number recorded and thus high diversity. The stratum is an important component of the study area as it forms the highest grazing area for wildlife and in particular the open grassland. Shannon-wiener index of species diversity (H') in the stratum was 1.65. The tabulation of plant species with the highest number of recorded individuals shows that *Cotoneaster pannosus, Cuscuta suaveolens, L. camara and P. coronata* were important IPSs in the stratum (Table 4).

Flooded stratum

This stratum covered the area of the reserve that is covered by marshes and waters. it covered 26,953.76 ha

Table 2. Invasive plant species in agriculture land stratum.

Scientific name	fr(abs)	Fr (%)	ab (abs)	ab (%)	Pi	ln(pi)	H'	D'
Agave sisalana	0.2	4.34	7.69	1.44	0.01087	-4.52179	0.04	20
Coreopsis lanceolata	0.2	4.34	15.38	2.88	0.021739	-3.82864	0.08	90
Datura stramonium	0.2	4.34	15.38	2.88	0.021739	-3.82864	0.08	90
Ipomea alba	0.8	17.39	80	14.98	0.113043	-2.17998	0.24	2652
Ipomea indica	0.6	13.04	113.84	21.32	0.16087	-1.82716	0.29	5402
Lantana camara	0.6	13.04	90.76	17.00	0.128261	-2.05369	0.26	3422
Lilium formosanum	0.2	4.34	9.23	1.72	0.013043	-4.33947	0.05	30
Pinanga coronata	0.2	4.34	23.07	4.327	0.032609	-3.42318	0.11	210
Ricinus communis	0.6	13.04	50.76	9.51	0.071739	-2.63472	0.18	1056
Solanum mauritianum	0.4	8.69	123.07	23.05	0.173913	-1.7492	0.30	6320
Xanthium spinosum	0.2	4.34	4.61	0.86	0.006522	-5.03261	0.03	6
Total	4.2	91.30	533.84	100	0.754348	-35.4191	1.71	19298
								0.83

Table 3. Most invasive plant species in the forest stratum.

Scientific name	fr(abs)	fr (%)	Ab(abs)	Ab (%)	Pi	ln(pi)	H'	D'
Acacia decurrens	0.13	4	5.12	1.93	0.019342	-3.94546	0.07	90
Cesalpinia decapetala	0.06	2	2.05	0.77	0.007737	-4.86175	0.03	12
Chondrilla juncea	0.06	2	7.17	2.70	0.027079	-3.60899	0.09	182
Chlorotoluene odorata	0.26	8	10.25	3.86	0.038685	-3.25231	0.12	380
Datura stramonium	0.06	2	2.56	0.96	0.009671	-4.6386	0.04	20
Eucalyptus sp	0.53	16	83.07	31.33	0.313346	-1.16045	0.36	26082
Ipomoea carnea	0.33	10	13.84	5.22	0.052224	-2.95221	0.15	702
Lantana camara	0.86	26	71.79	27.07	0.270793	-1.3064	0.35	19460
Opuntia monacantha	0.06	2	1.53	0.58	0.005803	-5.14943	0.02	6
Pinanga coronata	0.46	14	23.07	8.70	0.087041	-2.44138	0.21	1980
Solanum elaeagnifolium	0.06	2	10.25	3.86	0.038685	-3.25231	0.12	380
Solanum mauritianum	0.4	12	34.35	12.95	0.129594	-2.04335	0.26	4422
Total	3.33	100	265.12	100	1	-38.6126	1.88	53716
								0.79

Table 4. Invasive plant species in the grassland strata.

Scientific name	Fr (%)	Ab(abs)	Ab (%)	Pi	ln(pi)	H'	D'
A triplex inflata	14.28	7.69	3.25	0.03252	-3.42589	0.11	12
Cotoneaster pannosus	14.28	67.30	28.45	0.284553	-1.25684	0.356	1190
Cuscuta suaveolens	14.28	48.07	20.32	0.203252	-1.59331	0.32	600
Ipomea alba	14.28	26.92	11.38	0.113821	-2.17313	0.24	182
Lantana camara	14.28	38.46	16.26	0.162602	-1.81645	0.29	380
Pinanga coronata	28.57	48.072	20.32	0.203252	-1.59331	0.32	600
Total	100	236.53	100	1	-11.8589	1.65	2964
							0.80

or 34.78% of the study area. The most invasive plants were recorded in the area are at the edges of these flooded area and others in the areas that flooded during heavy rain and dry following seasons. The most recorded IPSs in this stratum were *Nephrolepis exaltata* and *Senna didymobotrya* while the one with less recorded

Table 5. Invasive plants species in the flooded area stratum.

Scientific name	fr(abs)	fr (%)	Ab(n/ha)	ab (%)	Pi	ln(pi)	H'	D'
Arundo donax L	0.08	7.14	64.10	14.45	0.144509	-1.93442	0.27	9900
Egeria densa	0.08	7.14	5.12	1.16	0.011561	-4.46014	0.05	56
Nephrolepis exaltata	0.16	14.28	192.30	43.35	0.433526	-0.8358	0.36	89700
Lantana camara	0.08	7.14	32.05	7.22	0.072254	-2.62756	0.18	2450
Pinanga coronata	0.08	7.14	32.05	7.22	0.072254	-2.62756	0.18	2450
Senna didymobotrya	0.66	57.14	117.94	26.59	0.265896	-1.32465	0.35	33672
Total	1.16	100	443.58	100	1	-13.8101	1.42	138228
								0.71

Table 6. Diversity and evenness indices in uninvaded and invaded area.

Category	Un invaded area	Invaded area	% reduction or increase
Total number of individuals recorded (N)	151	199	+13.7
Number of species	68	31	-37.37
Number of families	32	14	-39.1
Shannon-wiener index of diversity (H')	1.84	1.04	-
Simpson evenness index (D*)	0.95	0.67	-
S^2 H	0.0443	0.00233	

numbers were *L. camara, P. coronata* and *Egeria densa.* In addition*, N. exaltata* was also commonly observed at all different water point that occurred in the reserve. This was attributed to the animals that use these flooded areas as watering points. IPSs in this stratum were unevenly distributed with Shannon diversity index (H') 1.42 with *N. exaltata* contributing the highest values (Table 5).

Effects of invasive plants on indigenous plants species diversity

Assessment of plants species diversity both in the invaded and un-invaded areas showed that there was a 37.7% decline in richness at the species level in the invaded areas and a further 39.1% decline at the family level compared to the un-invaded areas (Table 6). There was higher species density in the invaded compared to the un-invaded areas but Shannon-wiener indices of diversity (H=1.84) were higher in the un-invaded areas. More plant species were recorded in the un-invaded areas (68) compared to the invaded sections (31).The high decline of species diversity is an indication of less plant and food varieties in the invaded areas for wildlife. As result, wildlife cannot exploit these areas as much as un-invaded habitats. Student *t* test on differences in Shannon-wiener diversity (H') between invaded and un-invaded areas showed that there was significant difference in species diversity (t 0.0 5(2) ^{170} =1.84 0.05< P< 0.10).

Categories of disturbance related to IPSs occurrence

Frequencies of the different factors that were recorded as associated with the occurrence of IPSs in the study area was mostly disturbances by humans. Among the abiotic factors, the probability of observing an IPS was highest in areas with disturbances related to settlements number (38%) followed by roads number (24%), edge effects such as burning and grazing of animals (22.80%), and water point number (15%) respectively (Figure 2). Anthropogenic disturbances are therefore an important related factor in the occurrence of invasive plants in the Maputo Special Reserve.

Distribution of invasive plants in the reserve

Different IPSs were observed and recorded across different transect of the reserve. The coordinates of the existence of the invasive plants were coded and put on the map of Maputo Special Reserve (Figure 3) to ascertain the location of the invasive plants. The most observed invasive plant was *L. camara, Eucalyptus* sp*, I. indica, R. communis, P. guajava, P. coronata* and *S. didymobotra*. Results show that most of the IPSs are highly concentrated along the Futi river, however *L. camara* is widely distributed throughout different points of the reserve (Figure 3).

DISCUSSION

Survey of reserve for IPS results showed that the area

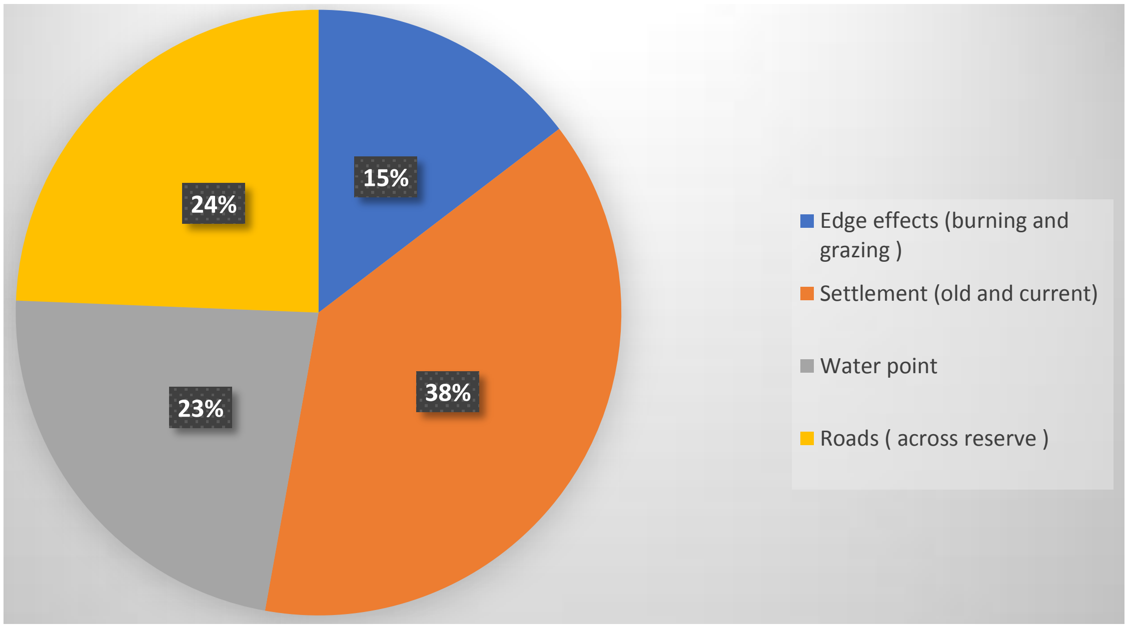

Figure 2. Percentage category of disturbance related to occurrence of IPSs.

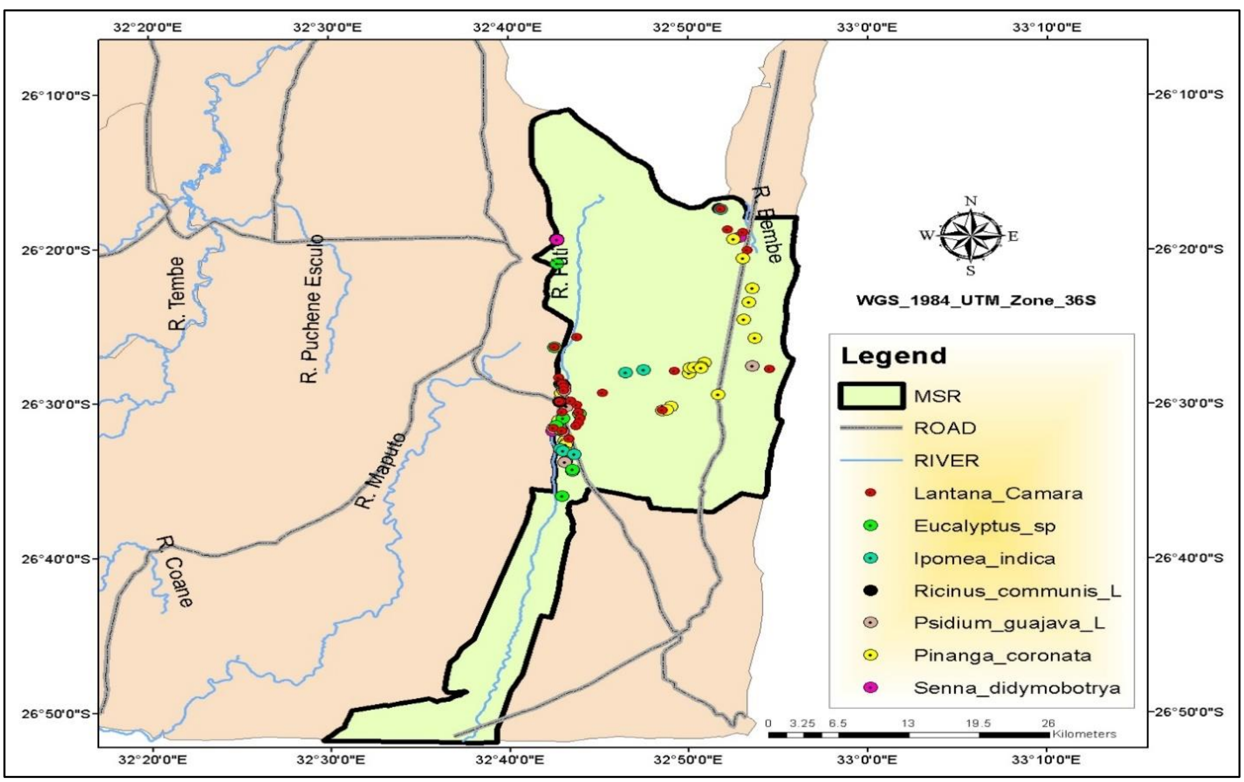

Figure 3. Distribution of invasive plants species in the study area.

was infested by a variety of IPSs. *L. camara* was the most abundant IPSs spread in four sampled strata except the flooded stratum. This agrees with IUCN (2016) Report and the study by Cronk and Fuller (2015) which found out that *L. camara* being among the most widely distributed IPSs across many protected areas, occupying diversity of habitat and on variety of soils. The diverse and broad distribution of this IPSs is a reflection of its wide ecological tolerance. *L. camara* invades and impacts severely on natural ecosystems, threatening the survival of many species (Sharma and Raghubanshi, 2016). Its allelopathic qualities can selectively increase mortality of other plant species (Gentle and Duggin, 2012; Sharma et al., 2015a), resulting in reduction of species diversity as well as decline of species (Sharma et al., 2015b). Studies have shown that *L. camara* poisons animals and destroys understory species (IUCN, 2014). It can form dense monospecific thickets which are difficult to eradicate once established, making extensive areas unusable and inaccessible, and threatening native plants as well as providing habitat to wildlife parasites. *Eucalyptus* sp had second highest number of frequencies next to *L. camara* in area where it occurred. The occurrence of *Eucalyptus* sp was due to the civil war between 1980 - 1993 that led to abandonment of the reserve and thus community encroachment that participated in growing and utilization of Eucalyptus plant (MICOA, 2014). These findings agree with Day and Witt (2020), who asserted that *Eucalyptus* sp are widely grown and utilized throughout much of the world.

Disturbances factors associated with IPSs in the study area

Percentage of disturbance factors recorded associated with the occurrence of IPSs showed that settlement both old and current contributed highest percentage of invasive plant compared to other disturbances (Figure 2). This contributed substantively to the occurrence of *L. camara* and *Eucalyptus* sp mostly. Other disturbance such as tourist roads construction across the reserve, edge effects such as burning and grazing of animals as well as water point were recorded with percentage contribution for the occurrence of invasive plants (Figure 2). During the field survey in the reserve, the probability of observing an invasive plant was high where disturbance was recorded. This observation concurs with the theory of fluctuating resource availability (Mack et al., 2015) which explains increase in invasibility following disturbance can either be due to addition of resources in a community or decline in resource uptake by resident vegetation. Plant species invasions can also be accelerated by environmental changes due to fluctuating resources (Dukes and Mooney, 2014).

High diversity values within the settlement stratum (Table 1) were also in agreement with the expected results as the species recorded within the stratum had almost equal frequency. The variation in plants species richness in the stratum was influenced by the state of the study sites that is whether they were disturbed or undisturbed. The interaction between state of the sampling site and anthropogenic disturbances influenced species richness. Based on this, human activities have an influence on species richness in the study area. The survey showed that strata prone to disturbances and were invaded had higher species richness than the undisturbed ones (Table 6). Though these had high species richness, but how useful these species are in providing key ecosystem services to the reserve is a subject to question as some of these contributing to this number are IPSs whose contribution to reserve ecosystem seems negative. Therefore, their browse capacity by wildlife needs to be investigated and quantified. In view of this, reserve managers need measures to judge the success or failure of management regimes designed to sustain biological diversity. In most conservation areas, the relationships between potential indicator species and total biodiversity are not well-established (Lindenmayer et al., 2000). Diversity indices can be useful because they provide rapid and easily calculated ecological measures. They can also enhance comparisons between similar studies, which use same indices. Though they are commonly used, they are only useful for comparison between sites, or on sites over time (Krebs, 2014). Invasive plant species recorded in the settlement (Table 1) and agriculture (Table 2) strata area are most due to disturbance by humans in the area. These results are in agreement with Ngoru et al. (2012), who cited disturbance as leading contributor to the problem of invasive plant species. Protected areas close to human settlements therefore at risk of being invaded by both native and non-native invasive plants.

Invasive plant impact on study area biodiversity

The high decline of species diversity (Table 6) is an indicator of less food varieties in the invaded areas for wildlife. Consequently, wildlife cannot exploit these areas as much as un-invaded habitats. The results are in agreement with Lwando and Russell (2015) who found out invasive plants species have a tendency of causing severe reductions in seedling recruitment of nearly all species under its influence. These invasive plant species may affect native species by introducing pathogens or parasites that cause disease or kill native species. Study by Okoth and Kapaata (2007), also confirmed that invasion of the area by invasive plant species like *L. camara* introduces an Allelopathic effect that kill native species. This results into reduced species diversity coupled with less suitable habitats for wildlife species leading to threatening of entire biodiversity of the area.

Conclusion

The spread of invasive plant species is now recognized as one of the greatest threats to the ecology of Maputo Special Reserve. A total of 26 IPSs were identified and recorded which potentially threaten area biodiversity. The findings of this study emphasize the need to eradicate invasive plants as they occupy the habitat that would otherwise have been as grazing grounds for wildlife. These invasive plants need to be controlled so that they do not reduce the diversity of native plants species and entire grazing points for wildlife through competition for resources. Maputo special reserve is particularly threatened by *Eucalyptus* sp followed by *L. camara* which is quite widespread. These invasive species have already caused negative impacts on the native species and its effects are projected to increase with time, if control measures are not taken. The problem is aggravated in disturbed areas where anthropogenic disturbances take place.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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