

**A Biogeographic Study of the KwaZulu-Natal Sandstone Sourveld patches within the  
eThekweni Municipal Area**

**By**

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## **Preface**

This research contained in this Thesis was completed by the candidate while based in the Discipline of Ecology, School of Life Sciences of the College of Agriculture, Engineering and Science, University of KwaZulu-Natal, Westville, South Africa. The research was financially supported by the eThekweni Municipality – University of KwaZulu-Natal Joint Partnership, KwaZulu-Natal Sandstone Sourveld Project as well as the Wildlands Conservation Trust.

The contents of this work have not been submitted in any form to another university and, except where the work of others is acknowledged in the text, the results reported are due to investigations by the candidate.

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- (i) The Research reported in this dissertation, except where otherwise indicated or acknowledged, is my original work;
- (ii) This dissertation has not been submitted in full or in part for any degree or examination to any other university;
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## **Abstract**

KwaZulu-Natal Sandstone Sourveld (KZNSS) is an endangered vegetation type in South Africa. Approximately 68% of KZNSS is transformed, with remaining patches existing within an urban and suburban matrix. Fragmented patches of KZNSS found within the eThekweni Municipal Area (EMA) represent a conservation priority but are often not managed/ conserved appropriately as they are sometimes misclassified as Indian Ocean Coastal Grassland Belt (IOCBG) based on their close proximity to the latter vegetation type in a number of areas. This motivated the present study which involved characterising the flora of eight grassland patches within the EMA presently categorised as follows: three KZNSS sites (viz. Giba Gorge Environmental Precinct, Inanda Mountain and Springside Nature Reserve), three IOCBG sites (viz. Spyhill Open Space, Tanglewood Nature Reserve and Edgecliff Open Space) which are currently called Ecotonal given their close proximity to KZNSS, and two IOCBG sites (viz. New Germany Nature Reserve and Roosfontein Nature Reserve).

Floristic surveys, which involved quadrats sampling were performed year round (c. 60% in the winter, 30% in the summer and the remaining quadrats performed in spring or autumn) until an 80% sampling effort was achieved. Additionally, transect sampling was performed monthly for a year at each site. Data from both methods were used to determine the vegetation composition and structure at each site. The below-ground flora of each site was also characterized by removing 30 – 35 soil samples after the two main flowering events (late November and early December as well as late April and early May) at each site and allowing germination to occur, with the resulting germinants being identified and quantified. Field observations on levels of disturbance and management practices at each were also considered.

When data for quadrats and transects were pooled, 263 species were found to occur across the eight sites, with 110 of these being common to all three vegetation categories. Only one of the eleven endemic taxa characteristic of KZNSS were found across all three vegetation categories, while none of the endemic taxa associated with IOCBG were found, suggesting

that identifying KZNSS or IOCBG based on endemic (i.e. diagnostic) species may be inappropriate at the sites investigated here. Further comparisons showed KZNSS and Ecotonal to contain more species than IOCBG, which were spread across more plant families (55 found in total), although IOCBG had one less site than KZNSS and Ecotonal. Diversity measures indicated that Ecotonal is more similar to KZNSS, with more species in common between KZNSS and Ecotonal than Ecotonal had with IOCBG. Additionally, diversity measures show very little differentiation between the dominant taxa of IOCBG from KZNSS. Cluster analyses and ordinations confirmed the current classification of Ecotonal sites as part of IOCBG, despite Ecotonal sharing more superficial similarities with KZNSS. Island biogeography theory's area and distance effects were not upheld – most likely due to the sites not being truly isolated from each other and a very localised spatial scale, the limited temporal scale (current status a result of the past 200 years), the lack of a true originating mainland and anthropogenic disturbance.

Interestingly, the below-ground flora represented only c. 10% of the species found above-ground for all three categories, with Sørensen similarity index ranging from c. 15 – 22% as opposed to the 50% expected for southern African grasslands. This suggests that seedbank health and hence, regenerative potential may be poor at many of these sites and this may necessitate species reintroduction and habitat restoration at a number of these sites. Additionally, the effects of disturbance were evident across sites in all three vegetation categories, with disturbed sites (Edgecliff Open Space, Inanda Mountain and Roosfontein Nature Reserve) containing fewer species of conservation concern, fewer indigenous taxa in general and more alien plant taxa. Diversity indices also suggest that disturbed sites were more heterogeneous. However, disturbance agents such as herbivory appear to have had an enriching effect in term of the abundance of graminoids within the germinable soil seedbank. Alien taxa also occurred frequently in the below-ground flora but were not noted in the above-ground flora which suggests that given further disturbance/transformation, some of these sites are prone to alien plant invasion. The study suggests that IBT is not applicable to vegetation islands (grasslands in this case) with varying levels of transformation in urban matrices. The results confirm the high levels of transformation reported for sub-tropical grasslands within South Africa, specifically KZNSS, and highlight the need for floristic surveys to delimit different grassland types and in turn ensure their appropriate conservation and/or rehabilitation.

## Acknowledgements

This project was funded by the eThekweni Municipality – University of KwaZulu-Natal Joint Research Partnership, KwaZulu-Natal Sandstone Sourveld Project as well as the Wildlife Conservation Trust. Thank you to those involved in the EM-UKZN joint partnership (especially Richard Boon, Jessica Cockburn, Dr. Sandy Williams-Munroe and Prof. Rouget) for academic advice and keeping me on my toes. Thanks Dr Sershen Naidoo and Dr Clinton Carbutt for your co-supervision on this project.

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# Contents

Preface .....	i
Plagiarism declaration.....	ii
Abstract.....	iii
Acknowledgements.....	v
Contents .....	vi
List of tables.....	viii
List of figures.....	ix
List of Abbreviations .....	xi
Chapter 1: Introduction.....	1
1.1 Background.....	1
1.2 KZNSS Vegetation .....	1
1.3 Research rationale and motivation.....	3
1.4 Aims, objectives and hypotheses .....	5
Chapter 2: Literature Review.....	7
2.1 History of vegetation classifications in South Africa .....	7
2.2 Grassland diversity and importance of classification.....	9
2.3 Durban grasslands and their classifications .....	11
2.4 Floristic methods and statistics, including reference to Island Biogeography Theory .....	17
2.5 Added benefits of soil sampling and comparing above-ground to below-ground flora.....	21
2.6 Gaps in the literature.....	23
Chapter 3: Methods and Materials.....	24
3.1 Site selection and typology .....	24
3.2 Vegetation type confirmatory analyses.....	25
3.2.1. Floristic studies .....	25
3.2.2 Seedbank studies.....	26
3.3 Data analysis.....	27
3.3.1 Species richness and background comparisons.....	27
3.3.2 Alpha diversity.....	28
3.3.3 Beta diversity .....	29
3.3.4 Community composition and structure .....	30
3.3.5 Island biogeography analyses .....	30
3.3.6 Soil seed bank comparisons .....	31
Chapter 4: Results.....	32
4.1 Overview and site characteristics.....	32

4.2 Sampling effort .....	34
4.3 Floristics.....	34
4.4 Alpha diversity analyses .....	41
4.5 Beta diversity analyses.....	42
4.6 Clustering and Ordination Analyses .....	43
4.7 Island biogeography analyses .....	46
4.8 Germinable soil seedbank analyses.....	47
Chapter 5: Discussion .....	53
5.1. Introduction.....	53
5.2 Overview of floristic diversity .....	53
5.2 Delimitation .....	55
5.3 Effects of disturbance on above-and below-ground flora .....	59
5.4 Island biogeography effects .....	62
6. Conclusion .....	65
6.1 Major findings.....	65
6.2 Challenges and short-comings .....	66
6.3 Recommendations for Future Research .....	67
References.....	68
Appendix A.....	74
Appendix B .....	87



## List of tables

<b>Table 2.1:</b> Vegetation classifications of the eight selected sites according to four different classification systems (1a = Typical Coastal-belt Forest, 5 = Ngoni Veld, 16 = Based on Silver Glen Nature Reserve, 17 = Based on Kenneth Steinbank Nature Reserve, 23 = Coastal Bushveld-Grassland, 24 = Coast-Hinterland Bushveld, SVs5 = KwaZulu-Natal Sandstone Sourveld and CB3 = Indian Ocean Coastal Belt Grassland)-----	12
<b>Table 2.2:</b> Endemic taxa to KwaZulu-Natal Sandstone Sourveld (KZNSS) and Indian Ocean Coastal Belt Grassland (IOCBG) including conservation status, life form and niche specialisation. -----	15
<b>Table 4.1:</b> Summary of site characteristics, management authority and practices at the eight sites investigated in this study. -----	33
<b>Table 4.2:</b> Summary of sampling effort, number of quadrats sampled, number of species found in quadrats, total number of species found (transect and quadrat data combined) as well as number of singletons, doubletons and unique species for each site. -----	35
<b>Table 4.3:</b> Overview of species of conservation concern (according to the South African Biodiversity Institute Redlist [SANBI, <a href="http://www.redlist.sanbi.org">http://www.redlist.sanbi.org</a> ]) found and their relative abundance <sup>b</sup> (based on quadrat and transect data). Hyphen denotes absence -----	39
<b>Table 4.4:</b> Alien taxa and their relative abundance <sup>b</sup> at each site, listed according to their invasive status: Category 1b (according to NEMBA, DEA, 2014), Undeclared (according to the Agricultural Research Council [ARC, <a href="http://www.agis.agric.za/wip/">http://www.agis.agric.za/wip/</a> ]), and unlisted by both NEMBA, DEA and the ARC but alien. (Based on quadrat and transect data). Hyphen denotes absence.-----	40
<b>Table 4.5:</b> Summary of the number of important, biogeographically important and endemic species found at sites in relation to the number of diagnostic species reported to be in IOCBG <sup>a</sup> and KZNSS <sup>b</sup> (based on quadrat and transect data). -----	41
<b>Table 4.6:</b> Beta diversity values for the eight sites investigated based on quadrat data. -----	42
<b>Table 4.7:</b> Abundance (number of germinants) which emerged from germinable soil seedbank samples collected at the eight sites investigated. -----	48
<b>Table 4.8:</b> Comparisons of species richness and composition between above- and below-ground for the three vegetation categories investigated. -----	49
<b>Table 4.9:</b> The three most abundant (in terms of number of individuals) species within the germinable soil seedbank and corresponding rank in terms of abundance in the above-ground flora for the eight sites studied. -----	51

## List of figures

- Figure 1.1:** Map of KwaZulu-Natal Sandstone Sourveld's estimated original extent shown in black (modified from Government Gazette 34809 released by the South African government, Department of Environmental Affairs, 2011). ----- 2
- Figure 1.2:** Current state of KZNSS and IOCBG (A: Spyhill being encroached by an ever expanding urban edge, B: Giba Gorge divided into unmaintained sections by roadways, C: Springside encroached by invasive plant species, D: Inanda being encroached by farming). ----- 4
- Figure 2.1:** The organisation of ecosystems within the eThekweni Municipal Area (allocated as ecosystem 9, KZN2) according to the Department of Environmental Affairs (2011) showing the placement of KZNSS and IOCBG.-----17
- Figure 3.1:** Sites chosen for investigation (edited from Google Earth 2015). Site codes are: KZNSS-1 = Giba Gorge Environmental Precinct, KZNSS-2 = Inanda Mountain, KZNSS-3 = Springside Nature Reserve, Eco-1 = Edgecliff Open Space, Eco-2 = Spyhill Open Space, Eco-3 = Tanglewood Nature Reserve, IOCBG-1 = New Germany Nature Reserve and IOCBG-2 = Roosfontein Nature Reserve. -----25
- Figure 4.1:** Distribution of common and unique species across the three vegetation categories: Indian Ocean Coastal Belt Grassland (IOCBG), KwaZulu-Natal Sandstone Sourveld (KZNSS) and Ecotonal. Species numbers are based on the combination of quadrat and transect data. -----36
- Figure 4.2:** Number of species found in each of the three vegetation categories and overall for the five most speciose families (n = 3 for KZNSS, n = 3 for Ecotonal, n = 2 for IOCBG, and n = 8 for Overall). Results based on quadrat and transect data.-----36
- Figure 4.3:** Values for Shannon's exponential and Simpson's inverse indices for each of the eight sites investigated: KZNSS-1 = Giba Gorge Environmental Precinct, KZNSS-2 = Inanda Mountain\* and KZNSS-3 = Springside Nature Reserve, Eco-1 = Edgecliff Nature Reserve\*, Eco-2 = Spyhill Open Space, Eco-3 = Tanglewood Nature Reserve, IOCBG-1 = New Germany Nature Reserve and IOCBG-2 = Roosfontein Nature Reserve\*). Asterisk denotes disturbed sites (based on quadrat data). -----41
- Figure 4.4:** Three beta diversity measures comparing sites within and across vegetation categories using total species found. Values represent mean  $\pm$  SD (within KZNSS n = 3; within Ecotonal n = 3; within IOCBG n = 1; KZNSS to Ecotonal n = 9; KZNSS to IOCBG n = 6; Ecotonal to IOCBG n = 6). ( $\beta_{gt}$  and  $\beta_t$  p>0.05, Kruskal-Wallis,  $\beta_3$  p>0.05, ANOVA).-----43
- Figure 4.5:** Unweighted Pair Group Means Analysis (UPGMA) phenogram (with Jaccard similarity) using the log transformed presence-absence values for the overall (quadrats and transect data) species found across all eight sites (Cophenetic correlation: Mantel statistic R = 0.9123, p = 0.009901 [n = 8]). Alphabets indicate clusters defined by the phenon line; colours represent vegetation category; site names are indicated in the key with disturbed sites denoted by an asterisk. The number of species found at each site and used in the analysis is given below the site codes.-----44
- Figure 4.6:** Results of a Non-parametric Multi-Dimensional Scaling (NMDS) analysis performed on the Bray-Curtis similarity matrix obtained using the square root transformed average abundance data of species found in the individual quadrats (n = 8 sites, stress = 0.004541). Site codes: KZNSS-1 = Giba Gorge Environmental Precinct, KZNSS-2 = Inanda Mountain\*, KZNSS-3 = Springside Nature Reserve, Eco-1 = Edgecliff Nature Reserve\*, Eco-2 = Spyhill Open Space, Eco-3 = Tanglewood Nature Reserve, IOCBG-1 = New Germany Nature Reserve and IOCBG-2 = Roosfontein Nature Reserve\*. Asterisk denotes disturbed sites. -----45
- Figure 4.7:** Results of a Non-parametric Multi-Dimensional Scaling (NMDS) plot based on the Bray-Curtis similarity matrix obtained using the square root transformed abundance data of species

within each quadrat across all eight sites (n = 140 for 8 sites combined, Stress = 17.398). Site names are indicated in the key with disturbed sites denoted by an asterisk. -----46

**Figure 4.8:** Scatter plot of the log transformed area and species richness for each site examined ( $r^2 = 0.512$ ,  $p > 0.05$ , for linear regression analysis,  $n = 8$ ). KZNSS-1 = Giba Gorge Environmental Precinct, KZNSS-2 = Inanda Mountain\*, KZNSS-3 = Springside Nature Reserve, Eco-1 = Edgecliff Open Space\*, Eco-2 = Spyhill Open Space, Eco-3 = Tanglewood Nature Reserve, IOCBG-1 = New Germany Nature Reserve and IOCBG-2 = Roosfontein Nature Reserve\*. An asterisk denotes disturbed sites (based on quadrat and transect data). -----47

**Figure 4.9:** Number of species within the five most speciose families in the germinable seed banks of the three vegetation categories. Values represent the sum of four trials (2 in spring-summer and 2 in autumn-winter) of  $n = 30$  per site, except for IOCBG-2 where  $n=35$  for each of the four trials. -----50

## **List of abbreviations**

### Commonly used abbreviations

DEA: Department of Environmental Affairs

Eco: Ecotonal

EM: eThekweni Municipality

EMA: eThekweni Municipal Area

IAS: Invasive Alien Species

IOCBG: Indian Ocean Coastal Belt Grassland

KZNSS: KwaZulu-Natal Sandstone Sourveld

NEMBA: National Environmental Management: Biodiversity Act

SANBI: South African National Biodiversity Institute

UKZN: University of KwaZulu-Natal

# **Chapter 1: Introduction**

## **1.1 Background**

Island biogeography studies traditionally focussed on oceanic islands and the nearest mainland continent, however, the theory can be applied to terrestrial situations where the distribution of vegetation is patchy, fragmented and island-like (Whittaker and Fernandez-Palacios, 2007). The two main factors examined within island biogeography studies are the size of 'islands' (larger 'islands' contain more species) and the distance between 'islands' ('islands' closer to the 'mainland' contain more species and 'islands' closer together have more species in common). These are known as the area effect and the distance effect, respectively (Gotelli, 2008 and MacArthur and Wilson, 1967).

Habitat loss and habitat fragmentation are two different processes which yield different patterns of patches within a landscape (Fahrig, 2003). Habitat loss refers to the loss of a habitat area by various processes (e.g. urbanisation) whilst habitat fragmentation does not necessarily result in the loss of total area of the habitat, but changes the distances between patches due to various processes (e.g. urbanisation and the development of nature reserves) (Fahrig, 2003). Incorporation of these two processes allows for a better understanding of the factors leading to area and size effects (Saunders *et al.*, 1991).

Habitat loss and habitat fragmentation are known to occur in urban environments (Fahrig, 2003). These processes lead to further isolation of an ecosystem and raise conservation concerns (Saunders *et al.*, 1991). Therefore, studying a system in an island biogeographical framework at a landscape level allows for conservation recommendations to be made (Gotelli, 2008). This study examines a system which currently exists in a series of patches which were historically larger and combined (see Figure 1.1) but have become smaller, further apart and fewer in number due to habitat loss and fragmentation (Department of Environmental Affairs [DEA], 2011).

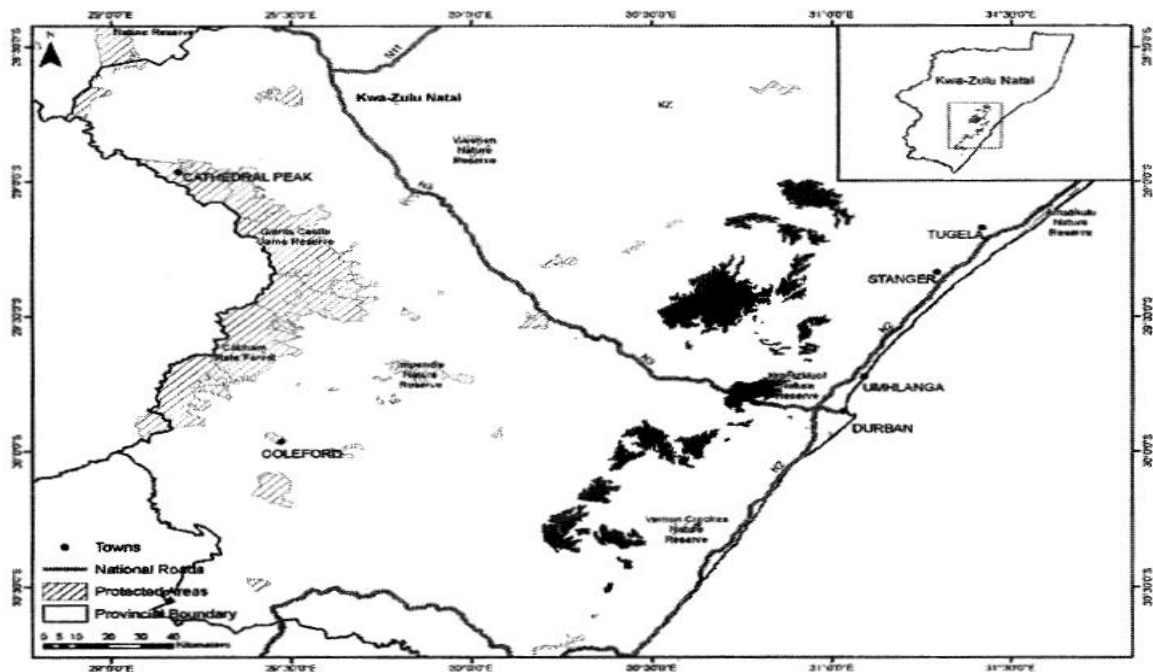
## **1.2 KZNSS Vegetation**

KwaZulu-Natal Sandstone Sourveld is characterised as a species-rich, short tufted grassland with scattered low shrubs and geoxylic suffrutices occurring on flat or rolling plateau outcrops (Rutherford

*et al.*, 2006b). Additionally, KZNSS thrives in nutrient-poor soil which is highly leached due to intense rainfall events during summer (Rutherford *et al.*, 2006b).

Nationally, critically endangered, endangered and vulnerable ecosystems occupy 9.5% of the country's terrestrial area, whilst within the province of KwaZulu-Natal this figure is 19.9% - the third highest in the country (DEA, 2011). KwaZulu-Natal Sandstone Sourveld (KZNSS) vegetation is listed as an endangered ecosystem within the savanna biome, found only in the province of KwaZulu-Natal and mainly within the eThekweni Municipal Area (EMA) in which significant irreversible loss of habitat has occurred (DEA, 2011; Rutherford *et al.*, 2006b).

Of the estimated original 135, 000 ha of KZNSS (shown in Figure 1.1), 28% remains, less than 1% of which is protected (DEA, 2011). Only 13% of the original distribution of KZNSS remains within the EMA (DEA, 2011), mostly as small, isolated patches indicative of both habitat loss and habitat fragmentation. With so little of the original habitat remaining it is of vital importance to understand what is left so that the correct actions can be taken to conserve the KZNSS remaining within the EMA.



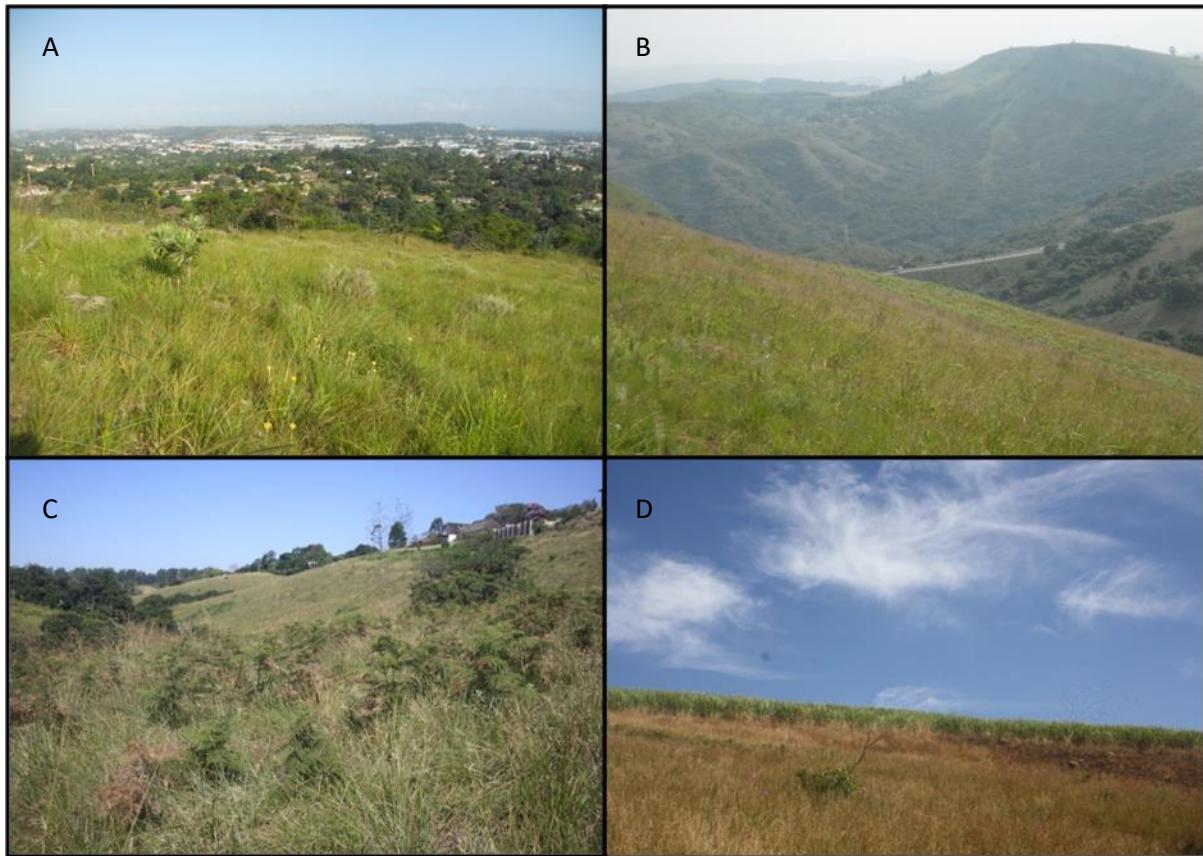
**Figure 1.1:** Map of KwaZulu-Natal Sandstone Sourveld's estimated original extent shown in black (modified from Government Gazette 34809 released by the South African Government, Department of Environmental Affairs, 2011).

In this study, several characteristic patches of KZNSS within the EMA were selected for detailed study. The entire KZNSS vegetation type could not be studied due to time and budget constraints. The selected sites are described in subsequent chapters.

### **1.3 Research rationale and motivation**

The KZNSS within the EMA is under threat, with less than 1% of KZNSS occurring within protected reserves – only one of which is within the EMA boundary (DEA, 2011). Additionally, KZNSS within the EMA is largely understudied in comparison to the other vegetation types found within the municipality (Rutherford *et al.*, 2006b). There is currently very little published data on the remnants of KZNSS within the EMA and throughout the province of KwaZulu-Natal. This makes it important to study and confirm a vegetation delineation of KZNSS so that patches can be better managed and protected. Also, with KZNSS being distributed in a patchy and fragmented nature makes it an ideal system to study in an island biogeography framework.

Since only patches of KZNSS remain within an urban landscape, the system is prone to various stressors which can decrease the biodiversity in the system (DEA, 2011). These include invasive aliens from nearby suburban areas, dispersal limitations to organisms (including plants) living within the system, and human disturbance from utilisation of the land (Fischer and Lindenmayer, 2007). Most of these disturbance are known to occur within the EMA and KZNSS specifically, and are shown occurring on various sites within the EMA in Figure 1.2 below. In Spyhill Open Space (classified as IOCBG), there is encroachment by neighbouring suburbs (Fig. 1.2A). In Giba Gorge Environmental Precinct (classified as KZNSS) the site is divided into relatively unmaintained sections by roadways (Fig.1.2B). In Springside Nature Reserve (classified as KZNSS) there is encroachment by invasive alien species (Fig. 1.2C). In Inanda Mountains (classified as KZNSS) there is encroachment of farming activities onto the site (Fig. 1.2D). Examining the flora of KZNSS was thus a vital first step in a process to better understand and conserve this endangered vegetation type (see Mace, 2004).



**Figure 1.2:** Current state of KwaZulu-Natal Sandstone Sourveld (B – C) and Indian Ocean Coastal Belt Grassland (A) within the eThekweni Municipal Area (A: Spyhill Open Space being encroached by an ever expanding urban edge, B: Giba Gorge Environmental Precinct divided into relatively unmaintained sections by roadways, C: Springside Nature Reserve encroached by invasive plant species, D: Inanda Mountains being encroached by farming).

Distributed through the EMA is a vegetation type similar to KZNSS, namely Indian Ocean Coastal Belt Grassland (IOCBG) (Mucina and Rutherford, 2006). The distributions of these two vegetation types overlap. The vegetation classification of sites as KZNSS or IOCBG varies depending on the criteria used for their delineation. Thus in order to accurately study the island biogeography of KZNSS, it was first necessary to clarify which patches were KZNSS and which were IOCBG, by seeking to identify a specific floristic signature for each of the two vegetation types that appear superficially very similar.

Floristic surveys were used to determine whether patches were KZNSS or IOCBG, since floristic surveys are an integral part of studying a plant based system in an island biogeography framework (Fahrig, 2003). However, floristic surveys focus on examining the above-ground flora, giving insights into the current distribution of plant species at the sites, whilst giving very little insights into the future of the sites. Knowing the presence and abundance of species above- and below-ground allows



for inferences on the future of the sites (Bakker and Berendse, 1999). This study additionally addressed the paucity of floristic and seed bank data in KZNSS for the examined sites. This is the first study of its kind in the eThekweni Municipal Area examining the germinable soil seed bank and making comparisons with the above-ground flora.

#### **1.4 Aims, objectives and hypotheses**

The broad aim of the study was to investigate the floristics of selected fragments of KZNSS within the EMA. This aim was then divided into the following specific objectives:

- (a) To delineate these two vegetation types of KZNSS and IOCBG from each other and determine which species, if any, were responsible for their delineation. Since KZNSS, which is endangered, and IOCBG, which is vulnerable, co-exist sharing similar environmental conditions it is important to determine how grassland sites can be identified within the EMA as KZNSS or IOCBG. These vegetation types thus require the use of floristics to delineate KZNSS and IOCBG (DEA, 2011). It is predicted that geology is the most important criterion in determining vegetation type (albeit at a larger scale) as determined by Ellery *et al.* (1995). Grassland patches with the Westville Member as their underlying geology are predicted to be KZNSS, whilst those growing on soils derived from dwyka and tillite formations are predicted to be IOCBG.
- (b) There is a variety of statistical analyses for floristic data and the various scales at which vegetation types are mapped results in many complications in delineating similar vegetation types and ecotonal vegetation types (Anderson and Clements, 2000). Selecting data collection and statistical methods for vegetation classification purposes is highly debated and various researchers apply different methodologies (e.g. Anderson and Clements, 2000; Brown *et al.*, 2013). Thus an objective of comparing the sites in terms of alpha and beta diversity as well as using a variety of other statistical methods was advocated in order to achieve objective (a). It is predicted that larger and better protected sites have higher alpha diversities (Rice and Toney, 1998; Olf and Ritchie, 1998).
- (c) The fragmented grasslands could experience some of the effects predicted by island biogeography theory which may further complicate the delineations of these vegetation types as these islands exist in a complex landscape matrix prone to dramatic and rapid changes– a phenomenon which has not been thoroughly examined (Whittaker and Fernández-Palacios,

2007). This reasoning lead to the objective of comparing the sites in an island biogeography framework to test the distance and area effects. It is predicted that the area effect will have an over-riding effect above the distance effect in determining the species richness of patches.

- (d) Germinable soil seedbank studies have not been performed within the EMA. A study was needed which examined both the above- and below-ground floristics of grasslands within the EMA for a better understanding of patch conservation and management. This lead to the final objective of comparing the flora found above- and below-ground by first characterising the germinable soil seed bank of each patch and thereby determine patch health. Since large mammal herbivory (such as grazing) increases the abundance of seeds in the soil (Olf and Ritchie, 1998), it is predicted that the patches where large mammal herbivory occurs have a more intact soil seed bank store which is closely related to the above-ground flora.

## Chapter 2: Literature Review

### 2.1 History of vegetation classifications in South Africa

Prior to 1953, vegetation classifications in South Africa centred on major vegetation associations aligned to rainfall regions (Cole, 1956). These earlier works included that of Pole-Evans (1936) and Adamson (1938) and were more descriptive than comparative (Cole, 1956).

In 1953, Acocks published one of the most important vegetation classifications in South Africa. Acocks recognised that vegetation undergoes succession towards a climax. He included this, along with the influence of climate change and anthropogenic factors which can influence vegetation, as part of his classification (Acocks, 1953). Acocks compiled historical data based on the descriptions found in the journals of early settlers and compared these to his current data obtained during a multitude of field investigations (Acocks, 1953). Acocks realised that there are major vegetation types, which had been previously described, but within them there were minor vegetation types (Acocks, 1953). He called these minor vegetation types ‘veld types’ and divided the country into 548 polygons classified into 70 different ‘veld types’ (Mucina and Rutherford, 2006). He defined veld types as “a unit of vegetation whose range of variation is small enough to permit the whole of it to have the same farming potentialities” (Acocks, 1988).

Cole (1956) recognised that Acocks’ work was not without its own shortcomings, mentioning that the publication did not describe all veld types in the same detail and length, neither did it include many details of work which had already been published at the time, rather focussed more on the work which was new. This was, however, not the only downfall with Acocks’ work. With the inclusion of succession and basing his separation of vegetation types on farming potentialities, some of the finer differences between similar vegetation types were lost as evidenced by later classifications using more polygons mapped at a finer scale, thereby generating more vegetation types. Despite these shortcomings, Acock’s seminal work has been used successfully as a reference for 50 years on national vegetation and is regarded by many (this author included) as being a great work of almost unparalleled proportions by a single individual.

Studies from the 1950s to the 1970s (excluding Acocks’ (1953)) focussed on smaller scales at a regional level and generally involved smaller nature reserves and private land (Brown *et al.*, 2013).

These studies were non-formal and descriptive in nature, forming mostly species lists more than detailed analyses (Brown *et al.*, 2013). During the 1980s there was methodological progress in vegetation classifications including the development of TWINSPLAN and TURBOVEG (Brown *et al.*, 2013).

Acocks revised his earlier 1953 work and a revision was released in 1988. Thereafter, Low and Rebelo (1998) produced *Vegetation of South Africa, Lesotho and Swaziland*. In this work, 68 veld types were identified using 3661 polygons (Mucina and Rutherford, 2006) as opposed to Acocks' 548 polygons.

Cowling and Hilton-Taylor (1997) produced *Vegetation of Southern Africa* which was more of a summation of current knowledge than new research. This led to the most recent account of *The Vegetation of South Africa, Lesotho and Swaziland* (Mucina and Rutherford, 2006). This work also included more analyses of environmental conditions, ecological evolution and paleontological data in order to determine man's impacts on vegetation types and assist in delineating them (Chytrý, 2008). Additionally, as reviewed by Chytrý (2008), Mucina and Rutherford's national vegetation delineation (2006) included over five times the number of polygons as Low and Rebelo (1998) as well as dramatically increasing the number of vegetation types from 68 (Low and Rebelo, 1996) to 435 (Mucina and Rutherford, 2006). This was six times the number of vegetation types identified by Acocks (1988) as well as Low and Rebelo (1998). This work incorporated the use of GIS and included a digitised map in the form of shape files for electronic use in order to produce more accurate maps than those previously released (Chytrý, 2008).

Most work on vegetation classifications post-2006 is still limited to local studies on private land and nature reserves, usually within municipal areas or larger national parks. Such studies are usually restricted in biome and incorporate only a few of the vegetation types found in national vegetation classifications. Studying vegetation at a finer scale and focussing on more in-depth comparisons of a few vegetation types in a smaller geographical region often leads to more vegetation types being found. For example, Mostert *et al.* (2008) examined the vegetation types of the Soutpansberg Conservancy and the Blouberg Nature Reserve complex, and found eight major vegetation types as opposed to the four identified by Acocks (1988).

## 2.2 Grassland diversity and importance of classification for conservation

Southern Africa hosts a large number of species of vascular plants with very high levels of endemism in all of its biomes (Cowling and Hilton-Taylor, 1997). These biomes often have non-distinct borders with fragments of one biome sometimes found within another (Cowling and Hilton-Taylor 1997, Rutherford *et al.*, 2006a). Of the biomes, savannas and grasslands occupy the highest percentages of land in southern Africa, 32.5% and 27.9%, respectively (Rutherford *et al.*, 2006a). The non-discrete borders of these two biomes sometimes makes the vegetation types within these biomes difficult to differentiate.

Grasslands are structurally simple, being dominated in abundance by members of the Poaceae family (Mucina *et al.*, 2006a). One of the main determining factors of grassland type is minimum annual temperature, distinguishing temperate grasslands from subtropical grasslands, with frosts a common feature of the former (Mucina *et al.*, 2006a). Tropical (and subtropical) grasslands occur globally and are often mistaken as the result of deforestation. However, these grasslands are ancient and contain high levels of endemism with many specialised plant taxa occurring in them (Bond, 2016).

The major subdivisions of the grassland biome in southern Africa, namely bioregions, are based on altitude and moisture, which are then further subdivided using floristic and environmental factors into vegetation types (Mucina *et al.*, 2006a). Mucina *et al.* (2006a) identified four bioregions and 72 grassland vegetation types in southern Africa. However, the term ‘grassland’ is often used loosely to describe any area dominated by grasses (Mucina *et al.*, 2006a). The term ‘grasslands’ is thus very broad and can refer to a number of vegetation types found beyond the grassland biome.

With grasslands covering such a large area within southern Africa, there are many variations in climatic, environmental and evolutionary conditions. Mucina and Rutherford (2006) removed subtropical grasslands from the grassland biome and placed them in the more subtropical Savanna (2 types) and the Indian Ocean Coastal Belt Biomes (5 types). Low and Rebelo (1998) included the eastern seaboard from the Albany Region through to Maputaland as part of the grassland biome in their national classification of vegetation types (Mucina *et al.*, 2006a). However, these eastern grasslands are classified as belonging to the Savanna or Indian Ocean Coastal Belt biomes by Mucina and Rutherford (2006).

The remaining grasslands in southern Africa were divided by Mucina and Rutherford (2006) into 72 vegetation types belonging to the following bioregions: Drakensberg Grassland, Dry Highveld Grassland, Mesic Highveld Grassland and Sub-Escarpment Grassland. These grasslands have all been almost exhaustively studied for their agricultural potential and management (e.g. O'Connor *et al.*, 2011). However, very little work has been published regarding the subtropical grasslands found along the eastern seaboard.

Subtropical grasslands in South Africa are found mostly along the eastern seaboard, in the Maputulan-Pondoland-Albany Biodiversity Hotspot where climate is favourable. However, this biodiversity hotspot is highly vulnerable (Jonas *et al.*, 2006). The largest contributions to this threat in decreasing order comes from alien plant species, population density increase, crop potential and habitat fragmentation (Jonas *et al.*, 2006). Rouget *et al.* (2006) found that many of the vegetation types (including grasslands) within this hotspot are difficult if not completely impossible to replace with very little protection and less than 60% of the natural habitat remaining. This is most prevalent around the urban areas, where the overall vulnerability is higher than the surrounding rural areas (Jonas *et al.*, 2006).

Recently, there has been a wave of agricultural expansion, especially in tropical savannas and grasslands with future threats predicted due to the growing human population (Dixon *et al.*, 2014). Grasslands in southern Africa, excluding the subtropical grasslands classified as savannas in the latest classification, cover c. 28% of South Africa's land surface, with very little protection (Carbutt *et al.*, 2011). Of the estimated original grassland biome 33% is irreversibly transformed and only 2% is conserved, much less than the 36.7% which has been identified as important for biodiversity conservation (Carbutt *et al.*, 2011). The grassland biome is threatened by agriculture as well as urban development and is highly fragmented. It has been recommended that in order for better grasslands conservation development agendas be balanced and the areas conserved be spread out over the biome in place of being clustered into centres (Carbutt *et al.*, 2011).

Logically, the threat of grassland transformation due to urbanisation is expected to be higher around expanding urban centres, particularly at the urban edge. Within the Maputulan-Pondoland-Albany biodiversity hotspot, a rapidly developing urban centre is the eThekweni Municipal Area. Thus threat levels are expected to be highest for vegetation types found within this municipality, particularly for

grasslands as they are highly amenable to transformation. For this reason, grasslands of the eThekweni Municipal Area are very important to conserve and restore.

Grassland conservation and restoration was thought to be straight-forward, but it has been shown to be more complex given the interaction of biotic and abiotic constraints (Bakker and Berendse, 1999). Grasslands contain high numbers of plant endemics (Mucina *et al.*, 2006a), making their conservation all the more important. However, in order for conservation efforts to be implemented and funding allocated to the conservation of a specific vegetation type. The vegetation type has to be clearly delineated and defined to know exactly how much is left and how close or far that it is from the conservation target in order to ensure persistence. Thus, in order to ensure that highly threatened subtropical grasslands are conserved, vegetation delineations of these grasslands need to be accurate and consistent to form a solid basis for monitoring and maintaining biodiversity (Brown *et al.*, 2013).

At smaller scales, when there are very little differences between environmental conditions it can be very difficult to differentiate between the structurally simple and similar grassland types (Mucina *et al.*, 2006a). This makes the subtropical grasslands of the Maputuland-Pondoland-Albany Biodiversity Hotspot very important to study and delineate, especially those where the threat level is especially great around the urban and suburban centre of the eThekweni Municipal Area.

### **2.3 Durban grasslands and their classifications**

Within the eThekweni Municipal Area (EMA), subtropical grasslands have been classified and reclassified as different vegetation types by different authors. Eight sites selected for this study were investigated in terms of their historical classification, using three of the most popular national vegetation classifications as well as one local vegetation classification (see Table 2.1).

**Table 2.1:** Vegetation classifications of the eight selected sites according to four different classification systems (1a = Typical Coastal-belt Forest, 5 = Ngoni Veld, 16 = Based on Silver Glen Nature Reserve, 17 = Based on Kenneth Steinbank Nature Reserve, 23 = Coastal Bushveld-Grassland, 24 = Coast-Hinterland Bushveld, SVs5 = KwaZulu-Natal Sandstone Sourveld and CB3 = Indian Ocean Coastal Belt Grassland)

Site	Acocks (1988) <sup>a</sup> Veld types	Roberts (1993) <sup>b</sup> Communities	Low and Rebelo (1998) <sup>a</sup> Vegetation Types	Mucina and Rutherford (2006) <sup>a</sup> Vegetation Types
Inanda Mountain	1a	16	23	SVs5
Giba Gorge Environmental Precinct	5	16	24	SVs5
Springside Nature Reserve	5	16	24	SVs5
New Germany Nature Reserve	1a	16	23	CB3
Roosfontein Nature Reserve	1a	17	23	CB3
Spyhill Open Space	1a	16	24	CB3
Edgecliff Open Space	1a	16	24	CB3
Tanglewood Nature Reserve	1a	16	24	CB3

<sup>a</sup> Classification at a national scale

<sup>b</sup> Classification at a local scale (eThekweni Municipal Area)

There is agreement that these eight sites belong to two different vegetation types, however, which sites belong to which vegetation type and the delineation of vegetation types are different for each of the above studies (Table 2.1). This lack of consistency in the allocation of the sites into similar vegetation units may be due to the criteria used to delineate and define vegetation types. The delimiting and defining factors are examined in chronological order below.

According to Acocks (1988), Veld Type 1a is ‘Typical Coastal-belt Forest’ and is in various stages of succession between grassland and forest, rarely existing as an open grassy savanna. Heavy grazing could cause *Aristida junciformis* Trinius to become dominant. This would make Veld Type 1a appear more like Veld Type 5, Ngoni Veld, which is also dominated by *A. junciformis* (Acocks, 1988). Additionally, Veld Type 5 is described as containing *Watsonia densiflora* Baker, *Commelina africana* L. and *Polygala* species whilst Veld Type 1a is described to contain *Tephrosia*, *Desmodium*, *Indigofera* and *Berkheya* species (Acocks, 1988).



Roberts' (1993) eThekweni Municipal Area study did not include any of the sites in this study, so this analysis is based on the species compositions given for Silver Glen and Kenneth Steinbank Nature Reserves under the descriptions of the community types. Community 16, based on Silver Glen Nature Reserve includes *Tephrosia macropoda* Harvey, *W. densiflora*, *Scabiosa columbaria* L. and *Aster bakerianus* Burt Davey as important herbs (Roberts, 1993). Whilst Community 17, based on Kenneth Steinbank Nature Reserve, includes *T. macropoda*, *Helichrysum* and *Selago* species as important herbs (Roberts, 1993). According to Roberts (1993), all of the sites except the most eastern site (Roosfontein Nature Reserve), belong to Community 16 (as shown in Table 2.1).

The vegetation classification of Low and Rebelo (1998) revealed that Inanda Mountains, New Germany Nature Reserve and Roosfontein Nature Reserves belonging to Vegetation Type 23 (Coastal Bushveld-Grassland) whilst the remaining five sites belong to Vegetation Type 24 (Coast-Hinterland Bushveld) (Table 2.1). Both of these vegetation types are described as belonging to the Savanna biome and receiving larger amounts of rainfall ( $\pm 1000$  mm pa) (Granger, 1998, Granger *et al.*, 1998). Vegetation Type 23 is described to contain *A. junciformis*, *Themeda triandra* Forsskal and *Eugenia albanensis* Sond. (Granger *et al.*, 1998). Whilst Vegetation Type 24 is described to contain the graminoids *A. junciformis*, *T. triandra* and *Monocymbium ceresiiforme* Stapf. as well as the herbs *T. macropoda*, *Thunbergia atripicifolia* E. Mey., *Berkheya setifera* DC and *Vernonia natalensis* Sch. Bip. ex. Walp. in abundance (Granger, 1998).

Vegetation Type 23, listed as Coastal Bushveld-Grassland, is described as a synonym to Acocks Coastal Forest and Thornveld (Acocks' Veld Type 1) and as occurring mostly on soils of marine origin (Granger *et al.*, 1998). As opposed to this, Granger (1998) described Vegetation Type 24, Coast-Hinterland Bushveld, as a synonym to Ngoni Veld (Acocks' Veld Type 5) occurring on higher altitudes than Vegetation Type 23 and "on exposed, upland hilltops and ridges".

Thus in all of these pre-2006 classifications not only the division of the sites (shown in Table 2.1) but also the species listed as being dominant or important are different for each vegetation type. The latest classification by Mucina and Rutherford (2006) also divides the sites into two vegetation types, both of which are subtropical grassland types KwaZulu-Natal Sandstone Sourveld (KZNSS; SVs5), and Indian Ocean Coastal Belt Grassland (IOCBG; CB3), each belonging to a different biome of Savanna and Indian Ocean Coastal Belt respectively.

KwaZulu-Natal Sandstone Sourveld is described by Rutherford *et al.* (2006b) to be a short, species-rich grassland containing scattered geolyxix suffrutices, low shrubs and proteas occurring on flat or rolling plateau tops and steep slopes. KwaZulu-Natal Sandstone Sourveld's distribution is described as being inland on elevated sandstone plateaus from Port Shepstone to Mapumulo with the underlying rock formation of Ordovician Natal Group sandstones (Rutherford *et al.*, 2006b). The vegetation type is described as having high levels of endemism with eleven endemic taxa, many of which are noted as being niche specialists or have life form specifications (Table 2.2). Additionally, KZNSS is described as having a very low to low risk of erosion with an altitude range of 500 – 1100 m a.s.l. in a summer rainfall region experiencing mist, which is important in providing additional moisture for the vegetation that very rarely experiences frost (Rutherford *et al.*, 2006b).

Indian Ocean Coastal Belt Grassland, on the other hand, is described by Mucina *et al.* (2006b) to be confined to highly dissected undulating coastal plains broken up by urban sprawl and farming activities. Indian Ocean Coastal Belt Grassland's distribution is described as being from Port Edward to Mtunzini along the coast across a variety of underlying rock formations (including Ordovician Natal Group sandstones, Dwyka tillite and Ecca shale) as well as across the remnants of old dunes with Berea Red Sand (Mucina *et al.*, 2006b). The vegetation type has only three endemic taxa, two of which are presumed extinct whilst the third is critically rare (Table 2.2). Additionally, IOCBG is described as having a low to moderate risk of erosion with an altitude range of 20 – 450 m a.s.l. in a summer rainfall region with high air humidity and no occurrence of frost (Mucina *et al.*, 2006b).

**Table 2.2:** Endemic taxa to KwaZulu-Natal Sandstone Sourveld (KZNSS) and Indian Ocean Coastal Belt Grassland (IOCBG) including conservation status, life form and niche specialisation.

Species	Endemic vegetation type	Conservation Status <sup>c</sup>	Life Form Specifications <sup>c</sup>	Niche Specialist Details <sup>c</sup>
<i>Phymaspermum pinnatifidum</i> (Oliv.) Källersjö <sup>d</sup>	KZNSS <sup>a</sup>	Least Concern	None available	None available
<i>Eriosema rossii</i> C.H. Stirt.	KZNSS <sup>a</sup>	Least Concern	None	None
<i>Crassula inandensis</i> Schönland & Baker	KZNSS <sup>a</sup>	Least Concern	None	Found in shaded areas along streams
<i>Brachystelma modestum</i> R.A.Dyer	KZNSS <sup>a</sup>	Near Threatened	None	Shallow soils, amongst rocks in drier grassland areas 900 – 1200 m a.s.l.
<i>Brachystelma pulchellum</i> (Harv.) Schltr.	KZNSS <sup>a</sup>	Near Threatened	None	Shallow soils near sandstone outcrops
<i>Cynorkis compacta</i> (Rchb.) Rolfe	KZNSS <sup>a</sup>	Vulnerable	None	Rocky outcrops in crevices
<i>Hesperantha gracilis</i> Baker	KZNSS <sup>a</sup>	Vulnerable	None	Hangs from moss cushions or patches of humus on dripping wet cliffs
<i>Tephrosia inandensis</i> H.M.L. Forbes	KZNSS <sup>a</sup>	Endangered	Long-lived resprouter, generations of 30-50 years	None
<i>Eriosema populifolium</i> subsp. <i>populifolium</i> Benth. ex Harv.	KZNSS <sup>a</sup>	Endangered	None	Moist grassland, restricted to deep black soils, 400-1 100 m a.s.l.
<i>Gladiolus cruentus</i> T. Moore	KZNSS <sup>a</sup>	Critically Endangered	None	South facing damp sandstone cliffs, 400- 900 m a.s.l.
<i>Brachystelma natalense</i> (Schltr.) N.E. Br.	KZNSS <sup>a</sup>	Critically Endangered	Complete lack of recruitment in both sites where it is found	None
<i>Kniphofia pauciflora</i> Baker	IOCBG <sup>b</sup>	Critically Endangered	One population, surviving by clonal reproduction	Marshy grassland, 10-200 m a.s.l.
<i>Vernonia africana</i> (Sond.) Druce	IOCBG <sup>b</sup>	Extinct	Noted as extinct since 1980	None
<i>Barleria natalensis</i> Lindau	IOCBG <sup>b</sup>	Extinct	Noted as extinct since 1996	None

<sup>a</sup> KZNSS = KwaZulu-Natal Sandstone Sourveld, species listed in Rutherford *et al.* (2006b)

<sup>b</sup> IOCBG = Indian Ocean Coastal Belt Grassland, species listed in Mucina *et al.* (2006b)

<sup>c</sup> as reported by the South African National Biodiversity Institute Redlist (2015)

<sup>d</sup> no details were available as the species has not yet been selected for investigations by SANBI and was automatically given least concern status

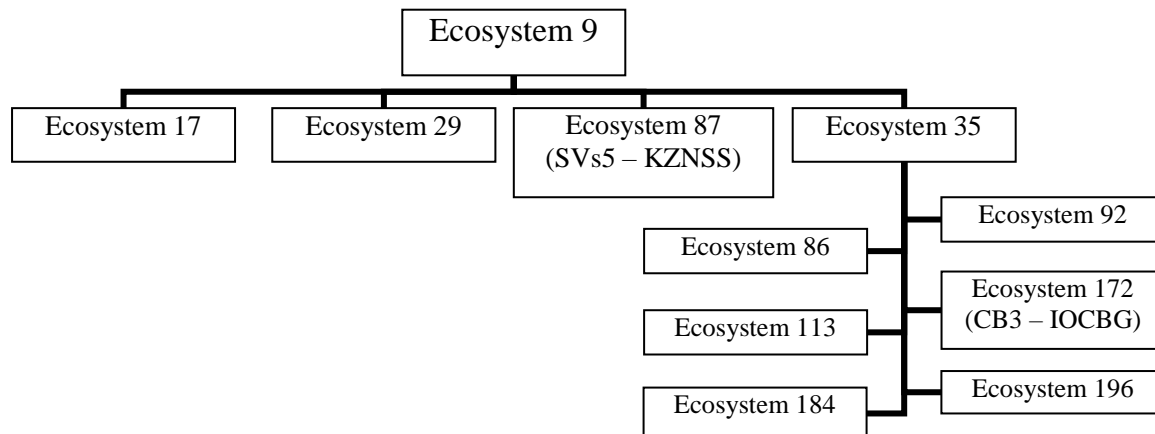
The species mentioned by the Mucina and Rutherford (2006) classification includes some of the species mentioned in earlier classifications. Thus based on the species mentioned in each of the classifications as well as some of the abiotic constraints (including altitude and geology) of the various classifications it appears that Mucina and Rutherford's (2006) CB3 (Indian Ocean Coastal Belt Grassland) is anomalous to Acocks' Veld Type 1a (Typical Coastal-belt Forest) and to Roberts' (1993) Community 17, as well as Vegetation Type 23 (Coastal Bushveld-Grassland) of Low and Rebelo (1998). Similarly, Mucina and Rutherford's (2006) SVs5 (KwaZulu-Natal Sandstone Sourveld) is considered synonymous to Acocks' Veld Type 5 (Ngoni Veld), Roberts' (1993) Community 16 and to Vegetation Type 24 (Coast-Hinterland Bushveld) of Low and Rebelo (1998).

The boundaries between these two vegetation types have not been fixed, resulting in some sites being grouped together as one vegetation type in one classification and then split apart in another vegetation classification (see Table 2.1). For the remainder of this study only the latest vegetation classification of Mucina and Rutherford (2006) is considered.

The two vegetation types of KZNSS and IOCBG are separated by an altitude difference of 50 m and the occurrence of mist and the rare occurrence of frost with KZNSS being higher in elevation and experiences mist and more rarely frost (Mucina *et al.*, 2006b; Rutherford *et al.*, 2006b). Additionally, IOCBG occurs on the underlying geology of several different rock formations, including Ordovician Natal Group sandstones which is the only underlying geology of KZNSS (Mucina *et al.*, 2006b; Rutherford *et al.*, 2006b). Finally, the ranges of IOCBG and KZNSS extend along the KwaZulu-Natal coast, with IOCBG occurring closer to the coast, whilst KZNSS is further inland within an elevational range of 450 – 500 m a.s.l.

In 2011 the Department of Environmental Affairs [DEA] (South African National Government) released a national list of ecosystems which are threatened and in need of protection (DEA, 2011). This gazette was based largely on Mucina and Rutherford's (2006) vegetation delineations of the country. According to the DEA (2011) the eThekweni Municipal Area is divided into several different ecosystems as shown visually below (Fig. 2.1).

According to the DEA (2011), the Durban Metropole North Coast Grassland (listed as ecosystem 9; Fig. 2.1), encompasses KZNSS and IOCBG amongst other ecosystems found in the eThekweni Municipal Area. It is critically endangered with very high irreplaceability and high threat, and is a priority area for meeting explicit biodiversity targets as defined in a systematic biodiversity plan. In the case of ecosystem 9, this plan is the KwaZulu-Natal Terrestrial Conservation Plan (C-Plan) V4 developed by Goodman (2007) for Ezemvelo KZN Wildlife.



**Figure 2.1:** The organisation of ecosystems within the eThekweni Municipal Area (allocated as ecosystem 9, KZN2) according to the Department of Environmental Affairs (2011) showing the placement of KZNSS and IOCBG.

KwaZulu-Natal Sandstone Sourveld (ecosystem 87 which is a category of ecosystem 9) is listed as being endangered with irreversible loss of natural habitat with the remaining natural habitat being less than the government set conservation goal of the biodiversity target plus 15% (DEA, 2011). Whilst IOCBG (ecosystem 172 falling under ecosystem 35 – which is a category of ecosystem 9) is listed as being vulnerable with irreversible loss of natural habitat and the remaining natural habitat being less than 60% of the original area of the ecosystem (DEA, 2011).

#### 2.4 Floristic methods and statistics, including reference to Island Biogeography Theory

Any spatial and temporal changes in habitats are first observed in vegetation (Brown *et al.*, 2013). For this reason, floristic analyses must be employed to determine vegetation delineations prior to any other vegetation classification techniques (such as spatial mapping using satellite imagery). There are a variety of methods used to gather floristic data, including nearest neighbour and point measure

techniques (Sorrels and Glenn, 1991). However, quadrats or plots are the most commonly used methods of gathering floristic data, being most valuable when a sufficient number of quadrats are sampled to adequately cover the site and the size of the quadrats is suitable to the type and character of the vegetation studied (Sorrels and Glenn, 1991). Quadrats include measurements of species abundance and thus can be used to measure spatial patterns and cover of vegetation, as well as perform quantitative analyses on plant populations (Sorrels and Glenn, 1991).

Transects are less time consuming than quadrats (Sorrels and Glenn, 1991) and are performed by determining a walked line where species touching or in a set distance from the line are either counted and identified or only identified. Where species are counted along a transect the accuracy with regards to vegetation cover is roughly equal to that of quadrats when vegetation is of a uniform size. However, when vegetation is of various sizes transects are more accurate than quadrats in determining vegetation cover (Sorrels and Glenn, 1991). Transects can also be performed to include significant environmental gradients and are selected to represent environmental gradients known as ‘gradsects’ (Sorrels and Glenn, 1991).

In this study species abundance is taken to be a measure of vegetation structure. Vegetation composition refers to the presence of species within a given area. Grasslands are often spatially heterogeneous and experience high levels of alpha and beta diversity with lower levels of gamma diversity (Mucina *et al.*, 2006a). Thus for grasslands it is best to examine both vegetation structure and composition.

Based on the above, quadrats are preferred for examining vegetation structure; despite being more time consuming they allow for comparisons between different areas within a site to determine the spatial heterogeneity within a single site as well as across sites. Also based on the above, transects are preferred in order to examine vegetation composition as they are less time consuming when only the presence of species is required, not abundances. The vegetation composition data can, however, be supplemented with data obtained by performing quadrats.

There are various statistical models used to aid vegetation classifications to examine vegetation composition and structure in terms of alpha and beta diversity as well as to compare sites via

clustering and ordination methods (e.g. Chiu *et al.*, 2014; Koleff *et al.*, 2003; Kindt and Coe, 2005). Alpha diversity is usually derived from measures of species abundances and is often calculated using Simpson's and Shannon's indices and their various derivatives where Simpson's Inverse and Shannon's Exponential indices are the most capable of yielding accurate comparisons of alpha diversity (Chiu *et al.*, 2014).

Beta diversity has been well described and used to measure species richness gradients as well as broad- and narrow-sense turnover and allows for measures of heterogeneity within an area to be expressed and compared, often using only species composition (species presence and absence) as the form of data input (Koleff *et al.*, 2003). Measures of heterogeneity such as beta diversity give an indication of the spatial turnover of species composition (Koleff *et al.*, 2003). These diversity indices aid in classification and delineation of vegetation categories by providing further insights into the vegetation of an area or site.

Furthermore, sites can be compared to each other by use of clustering and ordination analyses (based on species composition and vegetation structure, respectively) so as to determine how closely sites resemble each other (Kindt and Coe, 2005). Prior to clustering and ordination, distance matrices have to be calculated, for which various different indices are available – each of which emphasise different attributes of the data set (Kindt and Coe, 2005). The resulting distance matrices are sometimes further transformed to allow normalising, with the logarithmic transformation being the most useful in normalising the data (Kindt and Coe, 2005).

Cluster analyses can be used to identify groups of clusters within a set of observations and many different types of cluster analyses exist using different algorithms and rationales (Anderson and Clements, 2000). Many cluster analyses use distance matrices calculated on the presence-absence of species comparing sites in terms of species composition where species are variables (Anderson and Clements, 2000). After a cluster analysis is performed on a set distance matrix, a cophenetic correlation can then be used to determine how well the resulting dendrogram represents the distance matrix (Kindt and Coe, 2005). A variety of cluster analyses can be performed and cophenetic correlations calculated so that the cluster analysis which best represents the distance matrix can be selected (Kindt and Coe, 2005).

Ordination analyses use abundance values (vegetation structure) as data input for the distance matrices calculations. For vegetation structure analyses, these data are usually not normally distributed and thus Non-metric Multi-Dimensional Scaling (NMDS) analyses are commonly used in vegetation studies (Salako *et al.*, 2013). Salako *et al.* (2013) indicated that the most efficient similarity/dissimilarity indices are the Jaccard and Sørensen indices (based on presence-absence data) as well as the Bray-Curtis Index (based on abundance data). Stress values give an idea of how well the ordination represents the distance matrix (Kindt and Coe, 2005). Thus once the Bray-Curtis Index is applied to the abundance data and a NMDS ordination is run for a given number of permutations and the output with the lowest stress value can be selected.

All these different analyses result in allowing comparisons of biodiversity in its pristine state, however, biodiversity is further affected by a multitude of factors such as pollution, grazing and habitat fragmentation. The effects of habitat fragmentation on biodiversity is well studied (Fahrig, 2003). Habitat fragmentation and habitat loss are two different processes often driven by urbanisation and human needs which turn landscapes into smaller fragments (Fahrig, 2003). This results in the fragments becoming analogous to islands in an “ocean of urbanization”. To study these terrestrial patches, island biogeography theory can be applied to situations where vegetation is distributed in a patchy and fragmented manner (Whittaker and Fernandez-Palacios, 2007).

Island biogeography theory describes biodiversity patterns within and between islands (MacArthur and Wilson, 1967). The two main factors affecting biodiversity in islands are the sizes of the islands as well as the distance of islands to the mainland (and each other), where larger islands should contain more species, whilst islands which are closer to each other should display more similarity in species composition and structure (MacArthur and Wilson, 1967). These are known as the area and distance effects respectively (MacArthur and Wilson, 1967). The grassland patches within the eThekweni Municipal Area should thus show some of the area and distance effects of fragmentation described by island biogeography theory as the various sites have different sizes and exist in a patchy and fragmented way with different distances between each other. Thus sites are to be examined in terms of island biogeography theory to test the strength of the effects of area and distance on the system so as to inform the conservation effort required to safeguard KZNSS.



Any ecological study within an urban framework has a multitude of additional factors to consider as well as expected outcomes (Rebele, 1994). Rebele (1994) noted that there will be an increase in alien species and that connectivity between islands (patches of natural land) may vary not only with proximity, but with distance from the city centre as well as various other factors such as anthropogenic dispersals and substrates which are not part of the original soil state. These factors must be taken into account when examining the KZNSS system within an island biogeography framework in order to fully understand the results.

## **2.5 Added benefits of soil sampling and comparing above-ground to below-ground flora**

A variety of abiotic and biotic factors influence the above-ground flora in a grassland site, thereby influencing the vegetation structure and composition. Such factors can act at the landscape level (in a broader scale) and at a smaller, local, scale. Abiotic factors known to influence vegetation structure and composition in grasslands at the landscape level include temperature, the occurrence of frost, as well as the rainfall season and amount (Mucina *et al.*, 2006a). However, at the smaller scale, where these landscape factors are relatively similar, factors such as soil nutrients, fire frequency and intensity, soil pH, altitude and underlying geology from which the soil is derived can have a great impact in determining the vegetation structure and composition (Mucina *et al.*, 2006a). Biotic factors are also known to affect vegetation composition and structure.

The impact of grazing and herbivory has shown a mostly positive impact on species richness in grassland sites (Olf and Ritchie, 1998), whilst seed dispersal and dormancy will influence the germinable soil seedbank of sites (Bakker and Berendse, 1999), thereby influencing the vegetation composition and structure of a site. Recently, human activity has been shown to be the predominant determining factor of vegetation types and species richness in a suburban landscape (Čepelová and Münzbergová, 2012). Invasive alien species can impact the germinable soil seedbank and vegetation composition of a site (Garcia, 1995; Čepelová and Münzbergová, 2012). The abundance of species within the germinable soil seed bank can be calculated by using the equation described by Levésque *et al.* (1996) to determine the seed density.

Different species have various modes of seed dispersal. A fragmented landscape can often serve to hinder seed dispersal (Bakker and Berendse, 1999) resulting in species being lost from the germinable soil seedbank of a site and thus impacting the above-ground flora in terms of vegetation structure and

composition. Additionally, the abundance of a species in the germinable soil seedbank can impact the future abundance of that species in the above-ground flora (Bakker and Berendse, 1999).

These above-ground factors do not act in isolation on the germinable soil seedbank. The effects of herbivory on plant diversity differ across environmental gradients with soil fertility and precipitation playing the most important roles (Bakker and Berendse, 1999). Herbivory by large herbivores has been shown to have a positive effect on plant diversity where the soil is wet and fertile or infertile (Olf and Ritchie, 1998). Additionally, herbivory by large mammals acts to increase the seed production and survival for some species, whilst decreasing it for others (Paige and Whitham, 1987).

Comparing the below-ground flora to the above-ground flora can thus have multiple uses for conservation, for instance, determining the presence of invasive alien species and knowing the abundances of invasive alien species in the germinable soil seed bank can allow conservationists to deal with the invasion before it occurs (Garcia, 1995). The soil seed bank of some vegetation types can also be used to re-establish plant species lost from the original plant community (Kellerman and van Rooyen, 2007), which is an especially important conservation option in the cases of rare and endangered species.

In a suburban fragmented system where conservation is a key objective, it is thus important to not only examine the above-ground flora, but also the below-ground in terms of vegetation structure and composition. However, in South Africa – a country with high rates of endemism and plant species richness (Cowling and Hilton-Taylor, 1997), very little work is done to compare the above- and below-ground flora in a site specific manner. Many studies focus on factors affecting the germinable soil seed bank such as herbivory, but again focus on a few species (e.g. Paige and Whitham, 1987). Pierce and Cowling (1991) compared the above-ground vegetation structure and composition to that of the below-ground in grassland, thicket and fynbos vegetation types on the coastal dunes of Humansdorp, testing the effects of various disturbance regimes. Grasslands had a 50% similarity between the above- and below-ground vegetation composition and were more similar than the other two vegetation types investigated by Pierce and Cowling (1991).

Additionally, Kellerman and van Rooyen (2007) found that the grassland sections of the systems provided the highest seed densities (along with the forest/grassland ecotone) with great seasonal variation. This indicates that if seed banks are to be studied, seasonal variation of the germinable seed banks are needed to compare the above- and below-ground flora. In order to compare the above- and below-ground vegetation composition, only presence/ absence values are needed for a site. Thereafter various indices can be used to compare the similarity of above- and below-ground species composition e.g. the Sørensen co-efficient of community similarity as was used by Pierce and Cowling (1991).

## **2.6 Gaps in the literature**

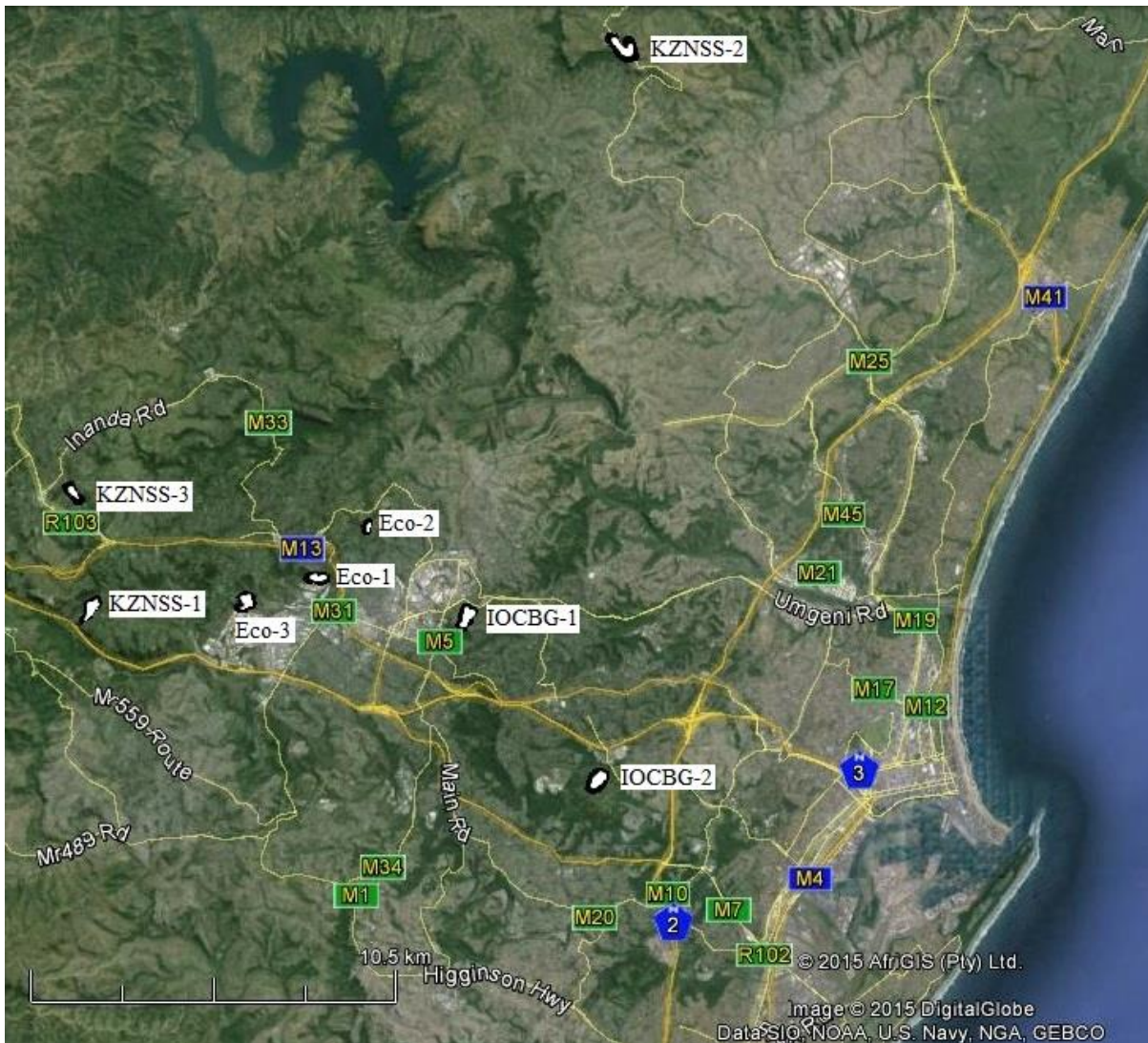
At present there are several gaps in the literature needing further examination and clarification. Firstly, classifications of the vegetation types at the national level are at present comprehensive, especially the most recent classification of vegetation types by Mucina and Rutherford (2006). However, not all work regarding classifications is complete. There are a high number of vegetation types occurring in small areas which often contain several biomes (Cowling and Hilton-Taylor 1997, Rutherford *et al.*, 2006a). This results in less distinct borders between vegetation types than those shown by Mucina and Rutherford (2006). Grasslands are extremely prone to this phenomenon where several grassland types are not currently classified as being in the grassland biome due to their subtropical distribution being better aligned to subtropical biomes such as the savanna biome (Mucina *et al.*, 2006a). Several of these subtropical grassland types fall within the Maputoland-Pondoland-Albany biodiversity hotspot which has a very high overall vulnerability (Jonas *et al.*, 2006). Within the Maputoland-Pondoland-Albany biodiversity hotspot, the largest urban area is the city of Durban with surrounding suburbs known as the eThekweni Municipal Area. The grasslands of the eThekweni Municipal Area are understudied and classification of these grasslands at a smaller scale is critically important given that various national and regional classifications having disagreeing results.

## Chapter 3: Methods and Materials

### 3.1 Site selection and typology

Rutherford *et al.* (2006b) delimited the KwaZulu-Natal Sandstone Sourveld (KZNSS) (coded SVs 5) as one of 440 new vegetation types in KwaZulu-Natal. The Department of Environmental Affairs (2011) listed KZNSS as a valid vegetation type using the Rutherford *et al.* (2006b) vegetation map and description. However, since 2006 no investigations using floristic data have been undertaken to determine the extent and ecological integrity of KZNSS. In consultation with the eThekweni Municipality (Environmental Planning and Climate Protection Division [EPCPD], 2012), eight sites were selected. These sites included protected nature reserves (New Germany, Springside, Tanglewood, Roosfontein), an environmental precinct (Giba Gorge), urban green spaces (Spyhill, Edgecliff) and open access communal land (Inanda Mountain).

However, since different habitat delineations differ on which sites are KZNSS (see Table 2.1 for details regarding sites in this study) it was necessary for the present study to also ascertain how floristically representative the sites were of KZNSS and determine the use of floristics in habitat delineation in KZNSS. The sites selected for investigation in this study were therefore subjected to a GIS-based overlay analysis. The GIS exercise involved plotting the central co-ordinates of each site (Table 4.1) on the vegetation layer of Mucina and Rutherford (2006) to determine the vegetation type of each study site. The sites were interrogated in terms of geology to determine if they contained sandstone as an underlying geology using the map of the Natal Group Sandstone (Westville Member) developed by Bell and Lindsay (1999). These analyses allowed the separation of the sites into three categories, firstly, true KZNSS. Secondly, potential KZNSS less than 350m from the nearest KZNSS patch and within Indian Ocean Coastal Grassland Belt (IOCGB) according to Mucina and Rutherford (2006) (shown in Fig. 3.1), called Ecotonal. Lastly, IOCGB greater than 350 m from the nearest KZNSS patch according to Mucina and Rutherford (2006) (shown in Fig. 3.1 and Table 4.1).



**Figure 3.1:** Sites chosen for investigation (edited from Google Earth 2015). Site codes are: KZNSS-1 = Giba Gorge Environmental Precinct, KZNSS-2 = Inanda Mountain, KZNSS-3 = Springside Nature Reserve, Eco-1 = Edgecliff Open Space, Eco-2 = Spyhill Open Space, Eco-3 = Tanglewood Nature Reserve, IOCBG-1 = New Germany Nature Reserve and IOCBG-2 = Roosfontein Nature Reserve.

### 3.2 Vegetation type confirmatory analyses

#### 3.2.1. Floristic studies

Most of the sites selected were mosaics of grasslands and forests, but for this study only the grassland portions were examined. At each of the eight sites a minimum of fifteen  $5 \times 5$  m quadrats were laid out as prescribed by Curtis and Cottom (1956), spaced somewhat evenly (between 5 and 30 m apart depending on the site's size) to allow adequate coverage of the entire site including aspect and slope. Abundance of all species found within each of the quadrats were determined (graminoids being

counted in clumps and herbs being counted as individuals) and voucher specimens of each species were collected for taxonomic identification to species and in some cases to sub-species level. Due to time constraints, c. 60% of the quadrats at each site were surveyed during winter (1 June to 31 August 2012 – 2014) and c. 30% surveyed during summer (1 December to 28 February 2013 – 2015). The remaining quadrats were performed during autumn (1 March to 31 May 2014) and spring (1 September to 30 November 2013 – 2014).

In order to ensure better species representation, walked diagonal transects were undertaken at each site once a month across all seasons. Species in flower which were previously unrecorded were collected and deposited at the Ward Herbarium, Westville Campus, University of KwaZulu-Natal (UKZN). This helped to more accurately inform the presence of species on each site so that objective comparisons could be made and provide a comprehensive checklist of flora for each site. The monthly transects were also used to gather data on the phenology of species.

### **3.2.2 Seedbank studies**

In addition to the floristic survey, the soil seed banks of all sites were examined for the spring-summer flowering season (collected during late November and early December 2013, and 2014) as well as for the autumn-winter flowering season (collected during late April and early May 2013, and 2014). In order to determine which species should be reintroduced to a patch, studies on the above-ground flora as well as the germinable soil seed bank needs to be conducted over several patches of a fragmented habitat system (Bakker and Berendse, 1999).

During each sampling period, thirty seed bank samples were collected at each site no sooner than 24 hours and no later than 48 hours after the last rainfall event. Samples were removed from walked transects at each site with soil being removed after roughly every five meters in order to obtain adequate coverage of sites. Each sample constituted the top 3 cm of soil within a 15 × 15 cm area, after the above-ground leaf litter and plant material were removed. The soil samples were then sieved with a 10 mm sieve to remove rocks and root material and weighed on an electronic balance (AE Adams, CBK32).

Once sieved and weighed, the soil samples were processed 24 hours after collection according to the method outlined by Levésque *et al.* (1996). Round plastic pots, 12 cm deep and 7 cm wide, with four 0.5 cm holes at the base (to allow for drainage) were filled with 100 g of pine bark-based potting soil (Grovida, South Africa). A sub-sample of 200 g of collected soil sample was then spread evenly on top of the potting soil, covering the entire surface. Two replica pots were prepared for each of the thirty seed bank samples across all sites ( $n = 60$  for each sampling period). Ten control pots containing 200 g of potting soil in each were also prepared. The soil in the pots was then watered to field capacity before the surface was covered with a thin layer of river sand to negate the potentially stressful effects of excessive light exposure.

The pots were then placed in a shade house (60% monofilament black shade cloth) where the amount of light received was reduced but natural precipitation could still penetrate. In addition to natural precipitation, the pots were watered to field capacity once a week (every Friday) provided it did not rain on that day. Germinants were removed once a week if overcrowding was occurring, or if they had died or flowered. After five months germination observations were terminated. Germinants within pots were allowed to grow to maturity for identification purposes.

### **3.3 Data analysis**

#### **3.3.1 Species richness and background comparisons**

For only the quadrat data, EstimateS 9.0 (Colwell, 2013) was used to construct species accumulation curves to determine if sufficient sampling had been performed. The non-parametric estimators, Chao2 and Jack1, were used to estimate total species richness. Non-parametric estimators have been shown to be closer to the true value of species richness than parametric or area based species richness estimators (Chiarucci, 2012). Additionally, for spatially non-heterogeneous habitats, such as grasslands, it has been shown that of the non-parametric estimators, Jack1 and Chao2, gave values closer to the actual number of species than Jack2 and Chao1 estimators (Xu *et al.*, 2012).

Due to time constraints quadrat sampling could not be carried out to the point where all rare species are found. Thus percentage sampling effort was calculated by dividing the number of species found by each estimator and multiplied by 100. This was repeated after every few quadrats at each site were

sampled. When the average of the percentage sampling effort according to Jack1 and Chao2 estimators became acceptable ( $\geq 80\%$ ) no further sampling was done.

Species found were investigated in terms of their conservation status (using the South African National Biodiversity Institute Redlist, 2015 website) and all non-indigenous taxa were investigated in terms of their invasive status (according to National Environmental Management: Biodiversity Act [NEMBA], DEA, 2014). Additionally, species not on the NEMBA, DEA list were investigated using the Agricultural Research Council [ARC, <http://www.agis.agric.za/wip/>]).

Species found in the three vegetation categories were compared to those listed by Rutherford *et al.* (2006b) for KZNSS and Mucina *et al.* (2006b) for IOCBG. All species listed as endemic, biogeographically important and important were compiled and compared to the lists of species found in each of the three vegetation categories to determine how many of the species listed were found and in which vegetation category they were found.

### **3.3.2 Alpha diversity**

Again using the statistical software EstimateS 9.0 (Colwell, 2013), Simpson's Inverse index and Shannon's Exponential index were calculated to compare alpha diversities of the sites. Simpson's Inverse and Shannon's Exponential indices contain Hill numbers and obey the Replication Principle making them more capable of yielding accurate comparisons of alpha diversity as opposed to the untransformed Simpson's and Shannon's indices (Chiu *et al.*, 2014). Additionally, the untransformed Simpson's index is more sensitive to changes in dominant land cover, whilst the untransformed Shannon's index is more sensitive to changes in rare species (Nagendra, 2002). These indices give set values and thus cannot be compared across site (since there is only one value per site) or vegetation category (since  $n = 2$  for IOCBG).



### 3.3.3 Beta diversity

Beta diversities were examined in terms of species richness (using the measurement of  $\beta_{gl}$ ) and species turnover (using  $\beta_{.3}$  as a narrow-sense measure of species turnover as well as  $\beta_t$  as a broad-sense measure of species turnover) equations in Koleff *et al.*, (2003).

$\beta_{gl}$  was used as it is the only richness gradient measure reviewed by Koleff *et al.* (2003) and known to be a true species richness gradient measure of beta diversity. Both narrow and broad sense measures were employed so as to better compare turnover within and between sites at a larger and finer scale. The narrow sense measure of  $\beta_{.3}$  was selected because unlike the similar  $\beta_{sim}$ ,  $\beta_{.3}$  has a maximum value (Koleff *et al.*, 2003).  $\beta_t$  was selected as a broad sense measure of species turnover as it has a maximum and is more robust than the popular  $\beta_w$  (Koleff *et al.*, 2003).

All beta measurements were run using all quadrats at each site comparing quadrats within sites. The resulting beta diversity measurements were then compared across vegetation category by use of a One-way Analysis of Variance (where the data was normally distributed -  $\beta_{.3}$ ) or an Independent Samples Kruskal Wallis test (where the data was not normally distributed -  $\beta_{gl}$  and  $\beta_t$ ) using SPSS 22. The measurements were also compared across sites by use of an independent samples t-test (where the data was normally distributed -  $\beta_{.3}$ ) or an Independent Samples Kruskal Wallis test (where the data was not normally distributed -  $\beta_{gl}$  and  $\beta_t$ ) using SPSS 22.

The same three beta diversity analyses were also run on the presence-absence data obtained by the combination of transect and quadrat data for each site and compared across sites within the same vegetation category and across vegetation categories. The within IOCBG comparison excluded as this had only one data point (two sites compared to each other). The values were then compared by means of a One-way Analysis of Variance (where the data was normally distributed -  $\beta_{.3}$ ) or an Independent Samples Kruskal Wallis test (where the data was not normally distributed -  $\beta_{gl}$  and  $\beta_t$ ) using SPSS 22.

### **3.3.4 Community composition and structure**

Community composition and structure of sites were compared by methods prescribed by Kindt and Coe (2005) using the statistical software package of R. For all analyses ecological and not Euclidean distances between sites were used as this allows a better representation of the data (Kindt and Coe, 2005). When performing clustering analyses, hierarchical clustering of an Unweighted Pair Group Mean (UPGMA) accompanied by a Cophenetic Correlation was performed on the Jaccard Index obtained using the square root presence-absence data in R. Clustering analyses performed herein (UPGMA's) are classified as hard clustering, and are thus better at clustering by the similarity of unit-specific means (Serban and Jiang, 2012) which allows a better base-line comparison of sites for this study. However, since clustering analyses such as the UPGMA performed, provide merely summaries of the data set they should not be used for interpretations on their own (Kindt and Coe, 2005). Thus the UPGMA was used in conjunction with many of the other forms of analyses to get a better understanding of the data.

Ordinations were performed using the square root of the average abundance data for quadrats in each site as well as using the square root of the abundance of species in each quadrat. These two data inputs were analysed using a Bray-Curtis Index and thereafter 100 permutations of Non-metric Multi-Dimensional Scaling (NMDS) were run on each using R, with the lowest stress value being selected.

### **3.3.5 Island biogeography analyses**

The shortest distance between sites (as the crow flies) as well as the area of investigated sections of the sites was calculated using Google Earth Pro. The area of sites was compared to the species richness of each site in logarithmic form as was shown by MacArthur and Wilson (1967) to determine if the size of a site has any impact on its species richness. The distance between sites was also compared to the number of species shared by sites in logarithmic form to determine if the distance effect was upheld, despite there being no true mainland.

### 3.3.6 Soil seed bank comparisons

To calculate the average germinable seed bank of an area in terms of germinable seeds of a species per m<sup>2</sup>, the following equation was applied:  $G = g_b \times [(Wt_b / Wt_a) / A]$  (Lévesque *et al.*, 1996); where  $g_b$  is the number of germinated seedlings in subsample b,  $Wt_b$  is the weight of subsample b after sieving and  $Wt_a$  is the total weight of the sample after sieving.  $A$  is a conversion factor for area defined as the surface area of the samples (the area soil removed:  $2.25 \times 10^{-2} \text{ m}^2$ ). Due to the large number of pots which contained no germinants and many species being found in only a few pots, these abundances were not statistically compared.

The abundance of germinants was thus compared across vegetation categories statistically by using the number of germinants (separated into herbs and graminoids as well as in total) occurring within a site (with seasons as technical replicates) by use of a One-way Analysis of Variance (where the data was normally distributed - herbs) or an Independent Samples Kruskal Wallis test (where the data was not normally distributed - graminoids and in total) using SPSS 22.

The below-ground flora was also compared to the above-ground flora in terms of floristic composition, using both the Jaccard and Sørensen indices, run using the presence-absence of species for each of the three vegetation categories. This method allows for additional comparisons of above- and below-ground flora as performed by other authors (e.g. Garcia, 1995; Pierce and Cowling, 1991). Additionally, the species from the below-ground (total number of germinants from a site of the same species) and above-ground (total number of individuals found in a site in the quadrats of the same species) flora were ranked in terms of abundance. The three most abundant species from the below-ground flora were then compared to the above-ground flora within each site so as to determine their rank in abundance within the above-ground flora. These data were to be used in determining if there is a relationship between the most abundant species in the below-ground flora to the most abundant species in the above-ground flora as very few species were found in the below ground flora.

## Chapter 4: Results

### 4.1 Overview and site characteristics

The eight sites investigated are categorised as follows for ease of comparison: (1) sites within KwaZulu-Natal Sandstone Sourveld (KZNSS) are labelled KZNSS; (2) sites within Indian Ocean Coastal Belt Grassland (IOCBG), which were located less than 350 m from KZNSS, are labelled Ecotonal; (3) sites within IOCBG that were more than 350 m from KZNSS are labelled IOCBG (Table 4.1). Furthermore, the codes KZNSS-1, -2 and -3 represent KZNSS sites of Giba Gorge Environmental Precinct, Inanda Mountain and Springside Nature Reserve, respectively. The codes Eco-1, -2 and -3 represent Ecotonal sites at Edgecliff Open Space, Spyhill Open Space and Tanglewood Nature Reserve, respectively. The codes IOCBG-1 and -2 represent the IOCBG sites at New Germany Nature Reserve and Roosfontein Nature Reserve, respectively.

The eight sites differed in altitude, ranging from 108 m a.s.l. (IOCBG-2) to 652 m.a.s.l. (KZNSS-3) (Table 4.1). In terms of geography, KZNSS-2 is the most northern-eastern site whilst IOCBG-2 is the most southern, and KZNSS-3 is the most western (Table 4.1). The underlying geology of all the sites is Natal Sandstone, with the exception of IOCBG-2, which lies on Dwyka Group Tillite (Table 4.1). Whilst KZNSS-2, experiences uncontrolled burning, all other sites experience controlled burning (Table 4.1). The KZNSS-3, Eco-3 and IOCBG-1 sites are fenced with controlled access, whilst Eco-3 is privately owned and managed and KZNSS-3 and IOCBG-1 are protected and managed by the eThekweni Municipality (EM) (Table 4.1). The KZNSS-1 site is unfenced but has controlled access and is protected and managed by the EM. The remaining sites (KZNSS-2, Eco-1, Eco-2 and IOCBG-2), with the exception of Eco-1 and Eco-2 which are maintained by Working on Fire, are unfenced with uncontrolled access and are maintained by the EM (Table 4.1). The KZNSS-2 site, which is communal land, is used for grazing and is therefore burnt annually in mid-April (Personal observations, 2012-2015). Additionally, KZNSS-2 experiences the highest volume of foot traffic followed by IOCBG-2 (Personal observations, 2012-2015). The Eco-1 site, which has a history of not being burnt regularly, is currently undergoing restoration efforts in some areas containing invasive *Eucalyptus* spp. (Personal observations, 2012-2015). Based on the above, KZNSS-2, Eco-1 and IOCBG-2 are regarded here as disturbed sites and KZNSS-3, Eco-3 and IOCBG-1 as pristine sites, with the remaining sites (KZNSS-1 and Eco-2) falling closer to near-pristine than disturbed in terms of overall condition, management and disturbance history.

**Table 4.1:** Summary of site characteristics, management authority and practices at the eight sites investigated in this study.

Site Name <sup>a</sup>	Current vegetation type classification <sup>b</sup>	Size <sup>c</sup> (ha)	Altitudinal range <sup>c</sup> (m above sea level)	Geology	Central GPS co-ordinates (degrees, minutes, seconds) <sup>c</sup>		Management authority	Protection level	Burning practices
					Latitude	Longitude			
<b>KZNSS-1</b>	KZNSS	5	564-611	Natal Sandstone <sup>d+e</sup>	29°48' 35.04"S	30°46' 35.40"E	eThekwini Municipality	Unfenced, controlled access	Controlled
<b>KZNSS-2</b>	KZNSS	27,3	428-476	Natal Sandstone <sup>d+e</sup>	29°39' 54.70"S	30°56' 22.02"E	Communal land	Unfenced, uncontrolled access	Uncontrolled
<b>KZNSS-3</b>	KZNSS	11,6	627-652	Natal Sandstone <sup>d+e</sup>	29°46' 51.79"S	30°46' 24.07"E	eThekwini Municipality	Fenced, controlled access	Controlled
<b>Eco-1</b>	IOCGB (<350 m from KZNSS)	10,2	386-456	Natal Sandstone <sup>d+e</sup>	29°48' 10.11"S	30°50' 34.62"E	Working on Fire	Unfenced, uncontrolled access	Controlled
<b>Eco-2</b>	IOCGB (<350 m from KZNSS)	3,2	418-476	Natal Sandstone <sup>d+e</sup>	29°47' 21.50"S	30°51' 34.89"E	Working on Fire	Unfenced, uncontrolled access	Controlled
<b>Eco-3</b>	IOCGB (<350 m from KZNSS)	14	407-503	Natal Sandstone <sup>d+e</sup>	29°48' 32.35"S	30°49' 21.27"E	Walker Family Trust	Fenced, controlled access	Controlled
<b>IOCBG-1</b>	IOCGB (>350 m from KZNSS)	15,5	341-376	Natal Sandstone <sup>d+e</sup>	29°48' 50.36"S	30°53' 19.51"E	eThekwini Municipality	Fenced, controlled access	Controlled
<b>IOCBG-2</b>	IOCGB (>350 m from KZNSS)	19,3	108-171	Dwyka Group Tillite <sup>e</sup>	29°51' 22.88"S	30°55' 44.91"E	eThekwini Municipality	Unfenced, uncontrolled access	Controlled

<sup>a</sup> Site names: KZNSS-1 = Giba Gorge Environmental Precinct, KZNSS-2 = Inanda Mountain, KZNSS-3 = Springside Nature Reserve, Eco-1 = Edgecliff Open Space, Eco-2 = Spyhill Open Space, Eco-3 = Tanglewood Nature Reserve, IOCBG-1 = New Germany Nature Reserve and IOCBG-2 = Roosfontein Nature Reserve

<sup>b</sup> Based on the delineation of vegetation types by Mucina and Rutherford (2006)

<sup>c</sup> Determined using Google Earth Pro (2014)

<sup>d</sup> Based on Bell and Lindsay (1999)

<sup>e</sup> Based on Geological Survey by eThekwini Municipality (1984)

## 4.2 Sampling effort

Prior to analysing data collected during the floristic surveys it was necessary to ascertain whether acceptable levels of sampling effort had been achieved. Sampling effort was based on Jack1 and Chao2 estimates of species richness for each site using quadrat data. A sampling effort of  $\geq 80\%$  was reached for each of the eight sites, with sites differing in terms of the number of quadrats required and the total number of species found (see Table 4.2). The number of quadrats required to reach this cut-off ranged from 15-21 quadrats per site, while the number of species found in total for the quadrats ranged from 45-124 per site. The number of species found increased by 10-35 species per site when the transect data were included. The number of singletons (species in one quadrat only) and doubletons (species in two quadrats only) per site ranged from 1-13 and 3-11 species, respectively. The number of unique species (with  $<10$  individuals across quadrats) ranged from 7-36 species per site.

## 4.3 Floristics

A total of 263 species (listed per site in Appendix A) were recorded across the eight sites: KZNSS and Ecotonal (with three sites each) contained 192 and 186 species, respectively, whilst IOCBG (with two sites) contained 169 species. All three vegetation categories had 110 of these 263 species in common (41.83%; Fig. 4.1). KwaZulu-Natal Sandstone Sourveld and Ecotonal had 28 species in common as well as 35 and 30 unique species, respectively. Indian Ocean Coastal Belt Grassland had 22 unique species with 19 in common with KZNSS and 18 in common with Ecotonal.

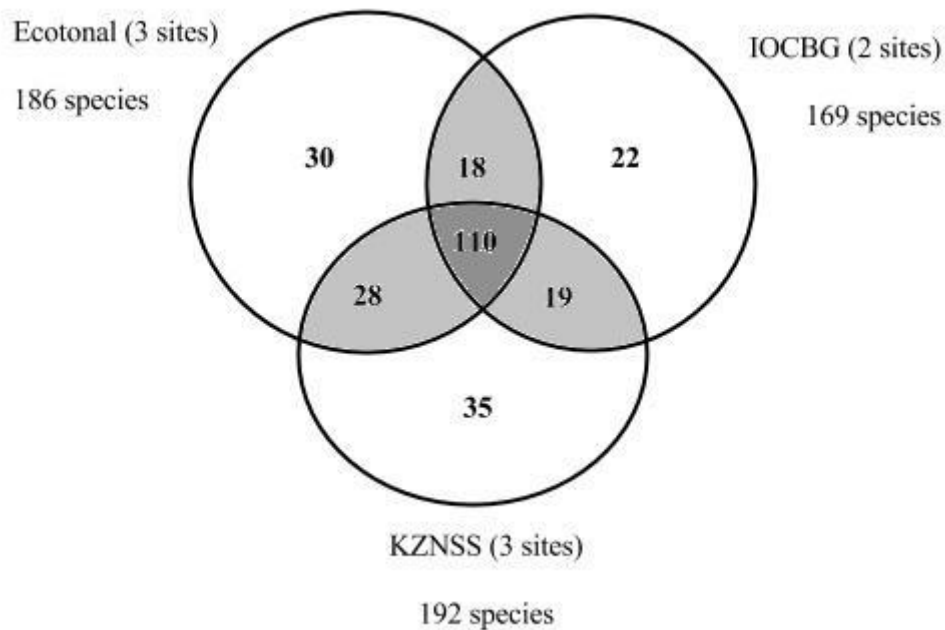
Overall, the 263 species represented 55 plant families. When the number of plant families represented at each site was determined (data not shown), the vegetation categories followed the same trend as that described for number of species. However, KZNSS had the most families, followed by Ecotonal and then IOCBG (45, 42 and 38, respectively). An assessment of the five most speciose families revealed Asteraceae to have the highest number of species (59), followed in decreasing order by Poaceae (32), Fabaceae (29), Rubiaceae (10) and Lamiaceae (9) (Fig. 4.2). When these five major families are considered, based on vegetation categories, KZNSS had the highest number of species for Asteraceae, Poaceae and Fabaceae (Fig. 4.2). However, the number of species for the Rubiaceae was the same (8) across categories, while KZNSS had one less species (6) than Ecotonal and IOCBG (7 each) for the Lamiaceae (Fig. 4.2).

**Table 4.2:** Summary of sampling effort, number of quadrats sampled, number of species found in quadrats, total number of species found (transect and quadrat data combined) as well as number of singletons, doubletons and unique species for each site.

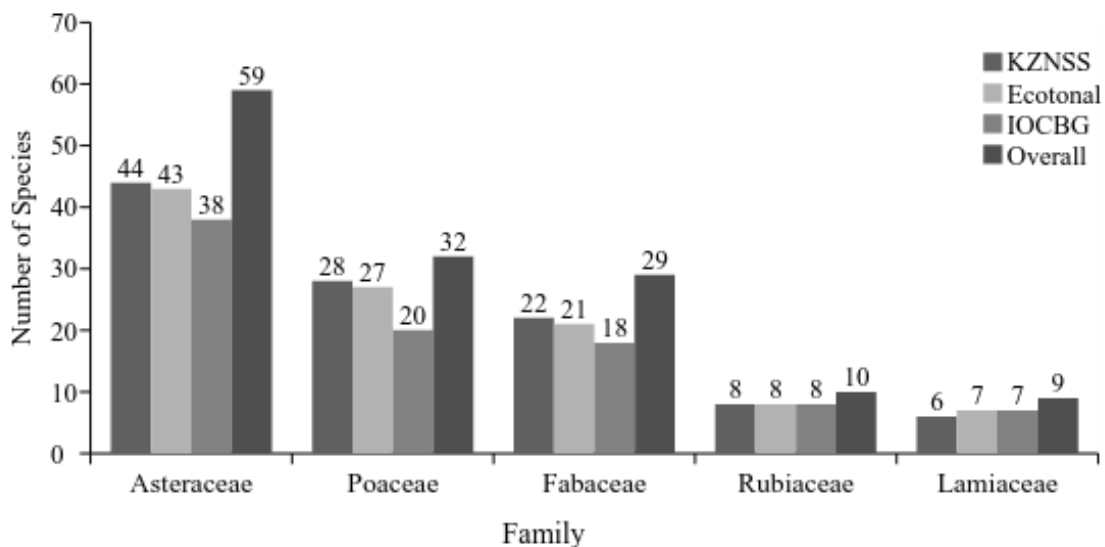
Site <sup>a</sup>	Sampling Effort (%)			Number of quadrats	Number of species found in quadrats	Total number of species found	Single-tons	Double-tons	Number of unique species (<10 individuals across quadrats)
	Jack1	Chao2	Mean						
<b>KZNSS-1</b>	83,12	87,79	85,46	20	98	132	6	6	22
<b>KZNSS-2<sup>b</sup></b>	84,09	83,09	83,59	18	74	97	8	3	18
<b>KZNSS-3</b>	77,05	83,70	80,38	18	111	122	6	11	35
<b>Eco-1<sup>b</sup></b>	90,33	97,58	93,96	15	61	98	1	6	7
<b>Eco-2</b>	80,30	81,63	81,11	18	117	139	12	6	33
<b>Eco-3</b>	77,24	83,67	80,46	15	99	128	13	4	32
<b>IOCBG-1</b>	80,05	80,44	80,25	21	124	144	12	8	36
<b>IOCBG-2<sup>b</sup></b>	84,27	93,05	88,66	15	45	65	13	4	32

<sup>a</sup> Site names: KZNSS-1 = Giba Gorge Environmental Precinct, KZNSS-2 = Inanda Mountain, KZNSS-3 = Springside Nature Reserve, Eco-1 = Edgecliff Open Space, Eco-2 = Spyhill Open Space, Eco-3 = Tanglewood Nature Reserve, IOCBG-1 = New Germany Nature Reserve and IOCBG-2 = Roosfontein Nature Reserve

<sup>b</sup> Denotes sites where disturbance was observed.



**Figure 4.1:** Distribution of common and unique species across the three vegetation categories: Indian Ocean Coastal Belt Grassland (IOCBG), KwaZulu-Natal Sandstone Sourveld (KZNSS) and Ecotonal. Species numbers are based on the combination of quadrat and transect data.



**Figure 4.2:** Number of species found in each of the three vegetation categories and overall for the five most speciose families (n = 3 for KZNSS, n = 3 for Ecotonal, n = 2 for IOCBG, and n = 8 for Overall). Results based on quadrat and transect data.

Nine taxa of the 263 taxa found overall are recognised to be of conservation concern by the South African National Biodiversity Institute (Redlist; South African National Biodiversity Institute [SANBI], 2015) (Table 4.3). The abundance of taxa of conservation concern was also examined. In



this context common was considered 10-50 individuals per 100m<sup>2</sup>, rare ≤5 individuals per 100m<sup>2</sup> and very rare 1 individual per 100m<sup>2</sup>. The Declining, Near Threatened and Vulnerable species were either rare or very rare in all sites where they were present (Table 4.3). More specifically, one species was listed as data deficient-taxonomically problematic (*Drimia elata* Jacq.), two species (*Hypoxis hemerocallidea* Fisch, C.A. Mey. & Avé-Lall and *Boophone disticha* Herb.) are in decline, two species (*Aloe linearifloia* A. Berger & Reynolds and *Crotalaria dura* J.M. Wood & M.S. Evans) are near threatened, two species (*Alepidea amatymbica* Eckl. & Zeyh. and *Eriosemopsis subanisophylla* Robyns) are vulnerable, while two species (*Eriosema populifolium* subsp. *populifolium* Benth. ex Harv. and *Lotononis filiformis* B. E. van Wyk) are endangered. The sites with the highest numbers of taxa of conservation concern were KZNSS-1 and Eco-3 (each with five species which included both of the endangered species). The site with the lowest number of taxa of conservation concern was KZNSS-3 (with only the endangered species, *E. populifolium* subsp. *populifolium*, which is found across all sites). At the disturbed sites (KZNSS-2, Eco-1 and IOCBG-2), there tended to be slightly lower numbers of taxa of conservation concern. In addition to the differences in number of taxa of conservation concern occurring between disturbed and undisturbed sites, the abundance of these taxa was typically lower at undisturbed sites. Two of the disturbed sites, Eco-1 and IOCBG-2, with two taxa of conservation concern each, each in relatively similar lower abundances for both sites. The third disturbed site, KZNSS-2, contained four taxa of conservation concern, with only one species being commonly found (roughly 10 individual per 100 m<sup>2</sup>) in the site (the endangered *E. populifolium* subsp. *populifolium*). The remaining three taxa of conservation concern were very rare to rarely (in relatively low abundances, with one to five individuals per 100 m<sup>2</sup>) found in the sites and included one declining (*H. hemerocallidea*), one vulnerable (*A. amatymbica*) and one additional endangered species (*L. filiformis*) (Table 4.3).

A total of 20 alien species were found across all sites, six of which are listed by the Department of Environmental Affairs in the ‘National Environmental Management: Biodiversity Act’ (NEMBA, DEA, 2014) as being Category 1b in KwaZulu-Natal and/ or nationwide. No invasive alien species of any other category were found in this study. Seven taxa found are listed as undeclared alien species by the Agricultural Research Council (<http://www.agis.agric.za/wip/>), whilst a further seven species were unlisted, but are alien to South Africa (Table 4.4). The highest number of alien taxa overall was found at KZNSS-3 (10 taxa), which is undisturbed, followed by KZNSS-2, Eco-1 and IOCBG-2 (with eight alien taxa each) which are all disturbed. However, many of the alien taxa found at KZNSS-3 were rarely found, whilst many found at the three disturbed sites (KZNSS-2, Eco-1 and IOCBG-2) were more common when compared to the other sites. The sites with the lowest number of alien taxa were

Eco-2, Eco-3 and IOCBG-1, each of which contained five alien taxa that were all very rare to rarely found (Table 4.4).

The species found in each of the three vegetation categories were compared to species recognised as important, biogeographically important and endemic to IOCBG and KZNSS by Mucina and Rutherford (2006) and are listed in Table 2.2. Many of these species were not found at any of the sites examined in this study and are denoted as not found in Table 4.5. Of the species mentioned in the IOCBG description given by Mucina *et al.* (2006b), twenty-six of the 42 important (including *W. densiflora*), three of the 20 biologically important (including *E. albanensis*) and none of the three endemic species were found across all three vegetation categories in total. When species found across all vegetation categories were compared to the KZNSS description given by Rutherford *et al.* (2006b), nineteen of the 36 important, five of the 22 biogeographically important (including *Aster bakerianus* Burt Davey, *Monocymbium cerasiiforme* Stapf. and *Tetraselago natalensis* Rolfe) and only one (*E. populifolium* subsp. *populifolium*) of the 11 endemic species were found (Table 4.5).

**Table 4.3:** Overview of species of conservation concern (according to the South African Biodiversity Institute Redlist [SANBI, <http://www.redlist.sanbi.org>]) found and their relative abundance<sup>b</sup> (based on quadrat and transect data). Hyphen denotes absence

Redlist status	Species name	KZNSS-1	KZNSS-2 <sup>a</sup>	KZNSS-3	Eco-1 <sup>a</sup>	Eco-2	Eco-3	IOCBG-1	IOCBG-2 <sup>a</sup>
<b>Data Deficient – Taxonomically Problematic</b>	<i>Drimia elata</i> Jacq.	-	-	-	Very rare	-	-	-	-
	<i>Boophone disticha</i> Herb.	-	-	-	-	-	Rare	-	-
<b>Declining</b>	<i>Hypoxis hemerocallidea</i> Fisch., C.A.Mey. & Avé-Lall.	Rare	Very rare	-	Very rare	-	-	-	Very rare
	<i>Aloe linearifolia</i> A.Berger & Reynolds	Rare	-	-	-	-	-	-	-
<b>Near Threatened</b>	<i>Crotalaria dura</i> J.M. Wood & M.S. Evans	-	-	-	Rare	-	-	Rare	Very rare
	<i>Alepidea amatymbica</i> Eckl. & Zeyh.	Very rare	Rare	-	-	Rare	Rare	-	-
<b>Vulnerable</b>	<i>Eriosemopsis subanisophylla</i> Robyns	-	-	-	-	Very rare	Rare	Rare	-
	<i>Eriosema populifolium</i> subsp. <i>populifolium</i> Benth. ex Harv.	Common	Common	Common	Rare	Common	Common	Common	Rare
<b>Endangered</b>	<i>Lotononis filiformis</i> B.E. van Wyk	Common	Rare	-	-	Rare	Common	Rare	-
	<b>Total number of species</b>	<b>5</b>	<b>4</b>	<b>1</b>	<b>4</b>	<b>4</b>	<b>5</b>	<b>4</b>	<b>3</b>

<sup>a</sup> Denotes sites considered to be disturbed

<sup>b</sup> Relative abundance: very rare = one individual per 100 m<sup>2</sup>, rare = ≤5 individuals per 100 m<sup>2</sup>, and common = 10 -50 individuals per 100 m<sup>2</sup>.

KZNSS-1 = Giba Gorge Environmental Precinct, KZNSS-2 = Inanda Mountain, KZNSS-3 = Springside Nature Reserve, Eco-1 = Edgecliff Open Space, Eco-2 = Spyhill Open Space, Eco-3 = Tanglewood Nature Reserve, IOCBG-1 = New Germany Nature Reserve, and IOCBG-2 = Roosfontein Nature Reserve).

**Table 4.4:** Alien taxa and their relative abundance<sup>b</sup> at each site, listed according to their invasive status: Category 1b (according to NEMBA, DEA, 2014), Undeclared (according to the Agricultural Research Council [ARC, <http://www.agis.agric.za/wip/>]), and unlisted by both NEMBA, DEA and the ARC but alien. (Based on quadrat and transect data). Hyphen denotes absence.

Invasive Status	Species name	KZNSS-1	KZNSS-2 <sup>a</sup>	KZNSS-3	Eco-1 <sup>a</sup>	Eco-2	Eco-3	IOCBG-1	IOCBG-2 <sup>a</sup>
<b>Invasive Aliens: Category 1b</b>	<i>Ageratum houstonium</i> Mei ex Krauss	-	Common	-	Common	Rare	Rare	-	Common
	<i>Chromolaena odorata</i> L.	Rare	Common	Rare	Common	Rare	-	Rare	Common
	<i>Lantana camara</i> L.	-	Rare	-	Rare	Rare	-	-	Rare
	<i>Ipomoea indica</i> (Burm.f.) Merr.	-	-	-	-	-	Rare	Rare	-
	<i>Pennisetum villosum</i> Hackel	-	-	-	-	-	Rare	Rare	-
	<i>Sphagneticola trilobata</i> DC	-	-	-	-	-	-	Rare	-
<b>Undeclared Alien Taxa</b>	<i>Bidens pilosa</i> L.	Rare	-	Rare	-	-	-	-	Rare
	<i>Hibiscus trionum</i> L.	-	-	Rare	-	-	-	Rare	-
	<i>Lactuca indica</i> L.	-	Rare	-	-	-	Rare	-	Rare
	<i>Paspalum notatum</i> Fluge	-	-	Very rare	Rare	-	-	-	-
	<i>Plantago major</i> L.	Very rare	-	-	-	-	-	-	-
	<i>Rubus rosifolius</i> Sm	-	-	Very rare	-	-	-	-	-
	<i>Taraxacum officinale</i> F.H. Wigg.	-	Rare	-	Common	Rare	-	-	-
<b>Unlisted Alien Taxa</b>	<i>Cymbopogon citratus</i> Stapf.	-	-	Very rare	-	-	-	-	-
	<i>Desmodium ciliare</i> DC	Rare	Common	Rare	-	-	Very rare	-	-
	<i>Hybanthus enneaspermus</i> (L.) F. Muell.	-	-	Rare	Very rare	-	-	-	-
	<i>Hypoxis decumbens</i> L.	Rare	Rare	Rare	-	-	-	-	-
	<i>Ornithogalum tenuifolium</i> F. Delaroche	-	-	-	-	-	-	-	Rare
	<i>Poa annua</i> Steud.	Rare	Common	Rare	Common	Rare	-	-	Common
	<i>Polystachya virgate</i> Steud.	-	-	-	Rare	-	-	-	Rare
<b>Total number of species</b>	<b>6</b>	<b>8</b>	<b>10</b>	<b>8</b>	<b>5</b>	<b>5</b>	<b>5</b>	<b>8</b>	

<sup>a</sup> Denotes sites considered to be disturbed

<sup>b</sup> Relative abundance: very rare = one individual per 100 m<sup>2</sup>, rare = ≤5 individuals per 100 m<sup>2</sup>, and common = 10 - 50 individuals per 100 m<sup>2</sup>.

KZNSS-1 = Giba Gorge Environmental Precinct, KZNSS-2 = Inanda Mountain, KZNSS-3 = Springside Nature Reserve, Eco-1 = Edgecliff Open Space, Eco-2 = Spyhill Open Space, Eco-3 = Tanglewood Nature Reserve, IOCBG-1 = New Germany Nature Reserve, and IOCBG-2 = Roosfontein Nature Reserve).

**Table 4.5:** Summary of the number of important, biogeographically important and endemic species found at sites in relation to the number of diagnostic species reported to be in IOCBG<sup>a</sup> and KZNSS<sup>b</sup> (based on quadrat and transect data).

No. of Species	IOCBG <sup>a</sup>			KZNSS <sup>b</sup>		
	Important	Biogeographically Important	Endemic	Important	Biogeographically Important	Endemic
<b>Reported<sup>c</sup></b>	<b>42</b>	<b>20</b>	<b>3</b>	<b>36</b>	<b>22</b>	<b>11</b>
No. found:						
KZNSS	24	2	0	19	1	1
Ecotonal	21	3	0	15	3	1
IOCBG	23	3	0	15	3	1
No. not found	16	17	3	17	17	10

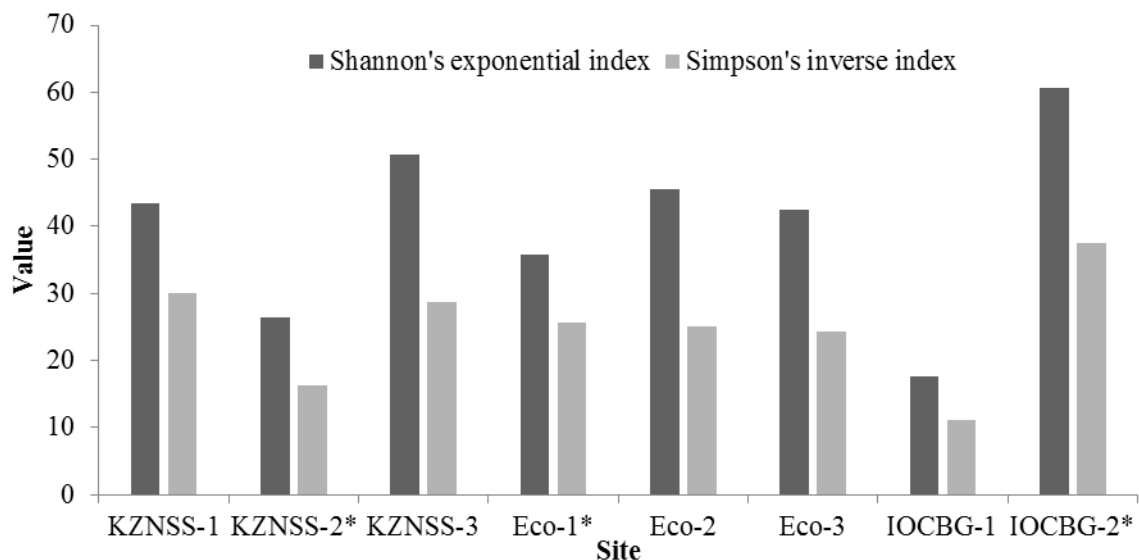
<sup>a</sup> Mucina *et al.* (2006b)

<sup>b</sup> Rutherford *et al.* (2006b)

<sup>c</sup> Total number of diagnostic species reported for the vegetation type. n = 2 for IOCBG, n = 3 for KZNSS and n = 3 for Ecotonal

#### 4.4 Alpha diversity analyses

Simpson's inverse and Shannon's exponential index values were calculated for each of the eight sites using the quadrat data. The highest value for both Shannon's exponential and Simpson's inverse indices were obtained for IOCBG-2 (Roosfontein Nature Reserve) whilst the lowest values for both indices were obtained for IOCBG-1 (New Germany Nature Reserve).



**Figure 4.3:** Values for Shannon's exponential and Simpson's inverse indices for each of the eight sites investigated: KZNSS-1 = Giba Gorge Environmental Precinct, KZNSS-2 = Inanda Mountain\* and KZNSS-3 = Springside Nature Reserve, Eco-1 = Edgecliff Nature Reserve\*, Eco-2 = Spyhill Open Space, Eco-3 = Tanglewood Nature Reserve, IOCBG-1 = New Germany Nature Reserve and IOCBG-2 = Roosfontein Nature Reserve\*). Asterisk denotes disturbed sites (based on quadrat data).

#### 4.5 Beta diversity analyses

Beta diversity measures ( $\beta_{gl}$ ,  $\beta_{.3}$  and  $\beta_t$ ) were determined using the quadrat data (as presence-absence) for each site (Table 4.6). Across vegetation categories (where values were tested irrespective of sites), the highest  $\beta_{gl}$  value was found for KZNSS ( $0.3350 \pm 0.2757$ ), whilst the lowest value was found for Ecotonal ( $0.2838 \pm 0.2014$ ). The highest  $\beta_{.3}$  and  $\beta_t$  highest values were found for Ecotonal ( $0.3178 \pm 0.09218$  and  $0.6924 \pm 0.1783$ , respectively), whilst the lowest value for  $\beta_{.3}$  was found for KZNSS ( $0.2884 \pm 0.09216$ ) and the lowest value for  $\beta_t$  was found for IOCBG ( $0.6637 \pm 0.1698$ ). Whilst  $\beta_{gl}$  values differed significantly across vegetation categories,  $\beta_{.3}$  and  $\beta_t$  did not. Within vegetation categories,  $\beta_t$  values were relatively lower for the disturbed sites (KZNSS-2, Eco-1 and IOCBG-2), with values in the midrange for  $\beta_{gl}$  and  $\beta_{.3}$  for these site. All beta diversity values were significantly different across sites when vegetation categories were not taken into consideration (Table 4.6).

**Table 4.6:** Beta diversity values for the eight sites investigated based on quadrat data.

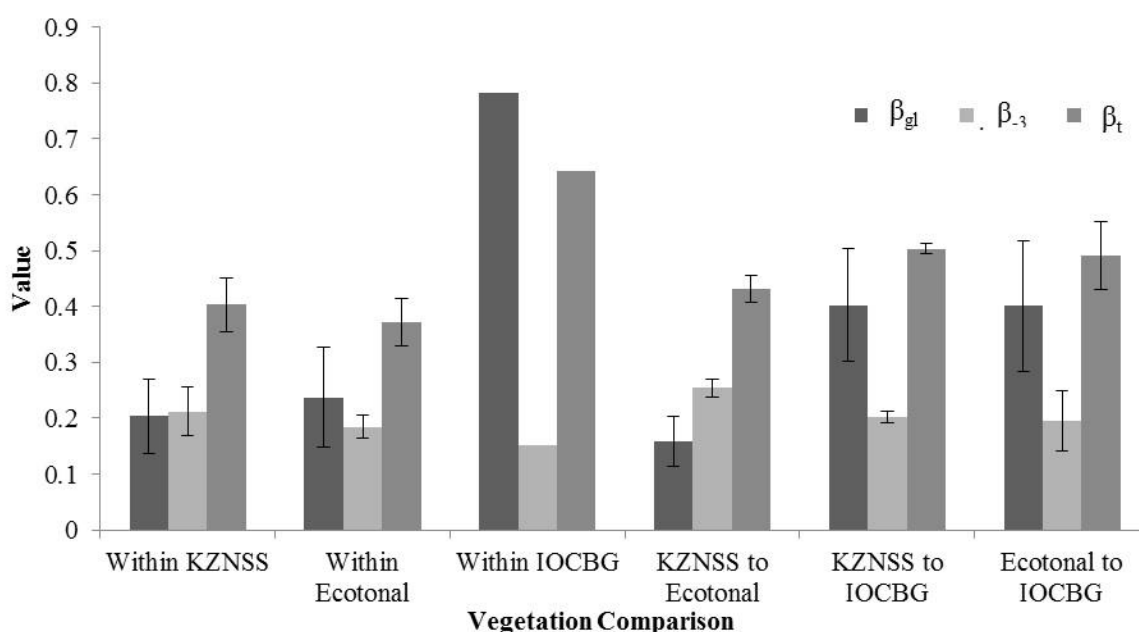
Site	$\beta_{gl}$	$\beta_{.3}$	$\beta_t$
<b>KZNSS-1</b>	$0.5026 \pm 0.3124$	$0.2261 \pm 0.06609$	$0.6183 \pm 0.1588$
<b>KZNSS-2<sup>a</sup></b>	$0.3255 \pm 0.2146$	$0.2884 \pm 0.07126$	$0.6463 \pm 0.1708$
<b>KZNSS-3</b>	$0.2098 \pm 0.1173$	$0.3450 \pm 0.07703$	$0.7036 \pm 0.1617$
<b>KZNSS Overall</b>	$0.3350 \pm 0.2757$	$0.2884 \pm 0.09216$	$0.6529 \pm 0.1694$
<b>Eco-1<sup>a</sup></b>	$0.2248 \pm 0.1500$	$0.3106 \pm 0.9698$	$0.6515 \pm 0.1588$
<b>Eco-2</b>	$0.3345 \pm 0.2242$	$0.3046 \pm 0.8531$	$0.6891 \pm 0.1347$
<b>Eco-3</b>	$0.2897 \pm 0.1795$	$0.3498 \pm 0.06602$	$0.7719 \pm 0.1582$
<b>Eco Overall</b>	$0.2838 \pm 0.2014$	$0.3178 \pm 0.09218$	$0.6924 \pm 0.1783$
<b>IOCBG-1</b>	$0.3000 \pm 0.1989$	$0.3260 \pm 0.07003$	$0.7138 \pm 0.1233$
<b>IOCBG-2<sup>a</sup></b>	$0.3200 \pm 0.1975$	$0.2550 \pm 0.08410$	$0.5746 \pm 0.1955$
<b>IOCBG Overall</b>	$0.2962 \pm 0.2024$	$0.3035 \pm 0.08497$	$0.6637 \pm 0.1698$

<sup>a</sup> Denotes sites considered to be disturbed.

Values represent mean  $\pm$  SD (n = 3 sites for KZNSS, n = 3 sites for Ecotonal and n = 2 sites for IOCBG). KZNSS-1 = Giba Gorge Environmental Precinct, KZNSS-2 = Inanda Mountain, KZNSS-3 = Springside Nature Reserve, Eco-1 = Edgecliff Open Space, Eco-2 = Spyhill Open Space, Eco-3 = Tanglewood Nature Reserve, IOCBG-1 = New Germany Nature Reserve and IOCBG-2 = Roosfontein Nature Reserve.

$p < 0.001$  for  $\beta_{gl}$  and  $\beta_t$  (Kruskal-Wallis test) and  $\beta_{.3}$  (ANOVA) when values were compared across sites and  $p < 0.001$  for  $\beta_{gl}$  (Kruskal-Wallis test) when values were compared across vegetation types

Beta diversity analyses were also run on the presence-absence data obtained by combining the transect and quadrat data for each site (Fig. 4.4). The category of ‘within IOCBG’ comparison was excluded as this had only one data point. For  $\beta_{gl}$  and  $\beta_t$  the highest values were found when comparing sites within IOCBG, followed by a comparison of KZNSS to IOCBG sites. The lowest value for  $\beta_{gl}$  was found when comparing KZNSS to Ecotonal sites, whilst the lowest value for  $\beta_t$  was found when comparing sites within Ecotonal. For  $\beta_{-3}$ , the highest value was found when comparing KZNSS to Ecotonal and the lowest value was found when comparing sites within IOCBG. However, beta diversity measures did not differ significantly when compared within and across vegetation categories.

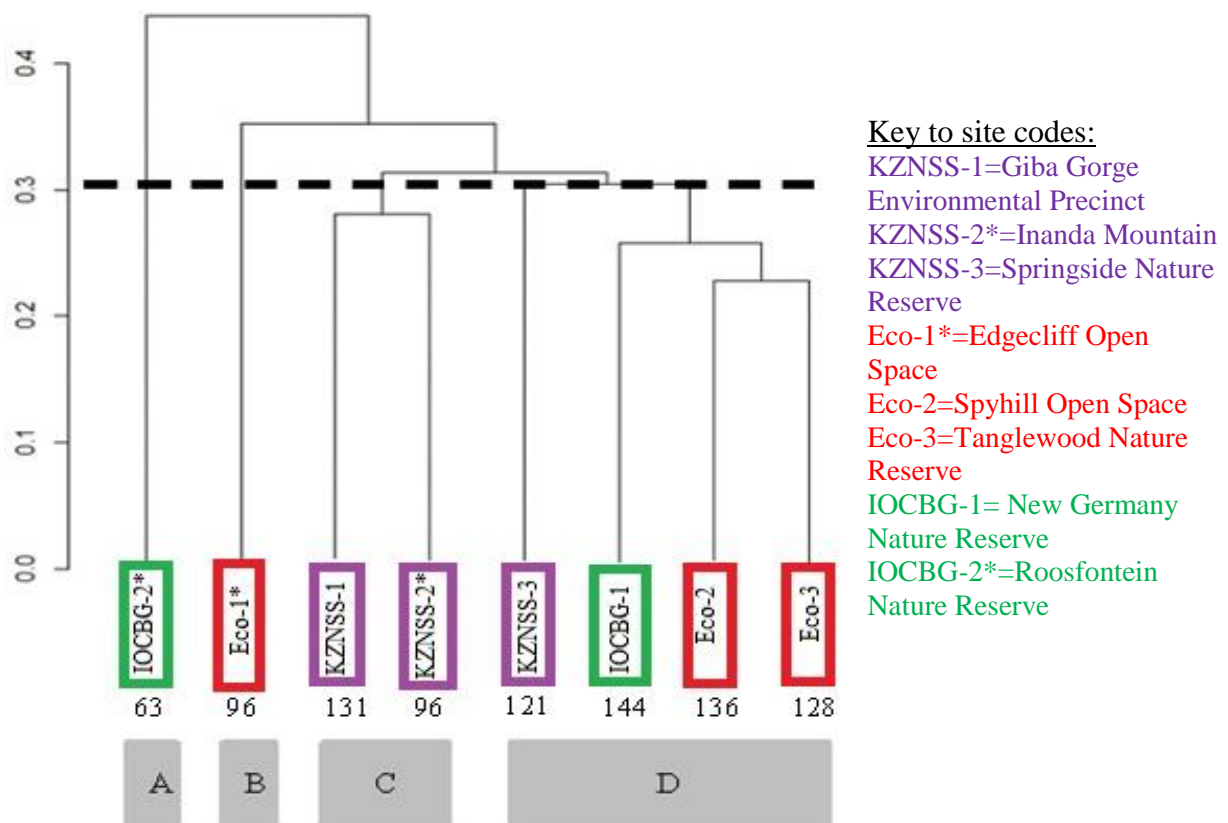


**Figure 4.4:** Three beta diversity measures comparing sites within and across vegetation categories using total species found. Values represent mean  $\pm$  SD (within KZNSS n = 3; within Ecotonal n = 3; within IOCBG n = 1; KZNSS to Ecotonal n = 9; KZNSS to IOCBG n = 6; Ecotonal to IOCBG n = 6). ( $\beta_{gl}$  and  $\beta_t$  p>0.05, Kruskal-Wallis,  $\beta_{-3}$  p>0.05, ANOVA).

#### 4.6 Clustering and Ordination Analyses

When total species numbers were analysed, with quadrat and transect data combined, Unweighted Pair Group Means Analysis (UPGMA) identified four clusters of sites shown in Fig. 4.5. Cluster A contained only the disturbed IOCBG-2, which had the lowest number of species overall (63 species);

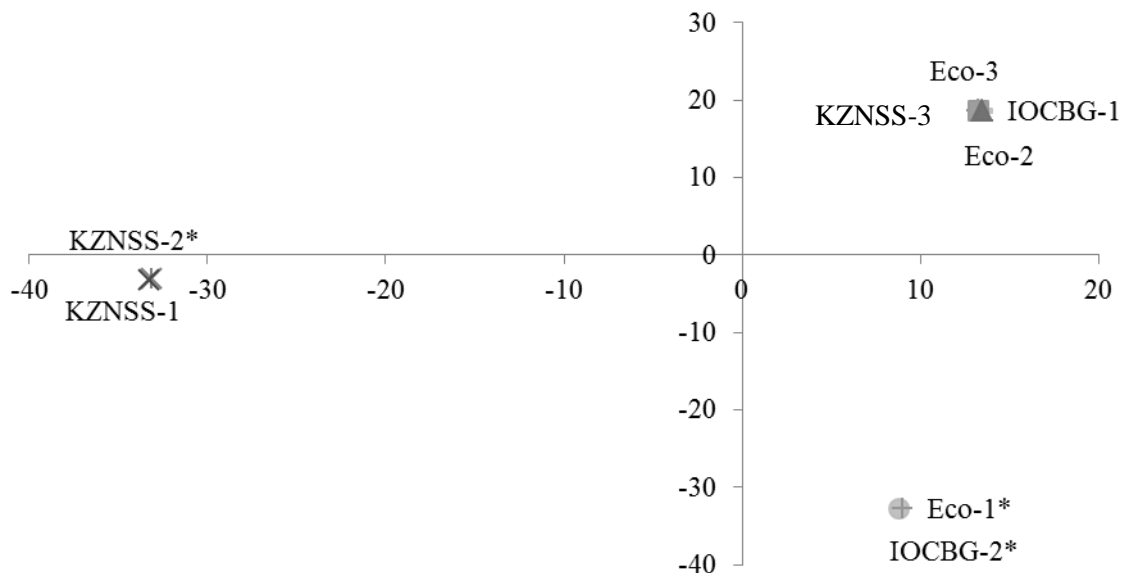
Cluster B contained only Eco-1 which had the second lowest number of species overall (96 species); and Cluster C contained two KZNSS sites, viz. KZNSS-1 which contained 131 species and KZNSS-2 (disturbed) which contained the same number of species as Eco-1 (96 species) and was also disturbed. The last cluster contained KZNSS-3, Eco-2 and Eco-3 as well as IOCBG-1 sites which range in species richness from 121 to 144 species, respectively and were all undisturbed. It should be noted that IOCBG-2 and Eco-1 (both disturbed) separate out first and second (clusters A and B), respectively in the phenogram and exhibited relatively lower species richness values. Clusters C was composed of both undisturbed and disturbed KZNSS sites, while Cluster D was composed of undisturbed sites from all three vegetation categories. The mantel statistic values indicate that the UPGMA is a significantly good representation of the distance matrix.



**Figure 4.5:** Unweighted Pair Group Means Analysis (UPGMA) phenogram (with Jaccard similarity) using the log transformed presence-absence values for the overall (quadrats and transect data) species found across all eight sites (Cophenetic correlation: Mantel statistic  $R = 0.9123$ ,  $p = 0.009901$  [ $n = 8$ ]). Alphabets indicate clusters defined by the phenon line; colours represent vegetation category; site names are indicated in the key with disturbed sites denoted by an asterisk. The number of species found at each site and used in the analysis is given below the site codes.

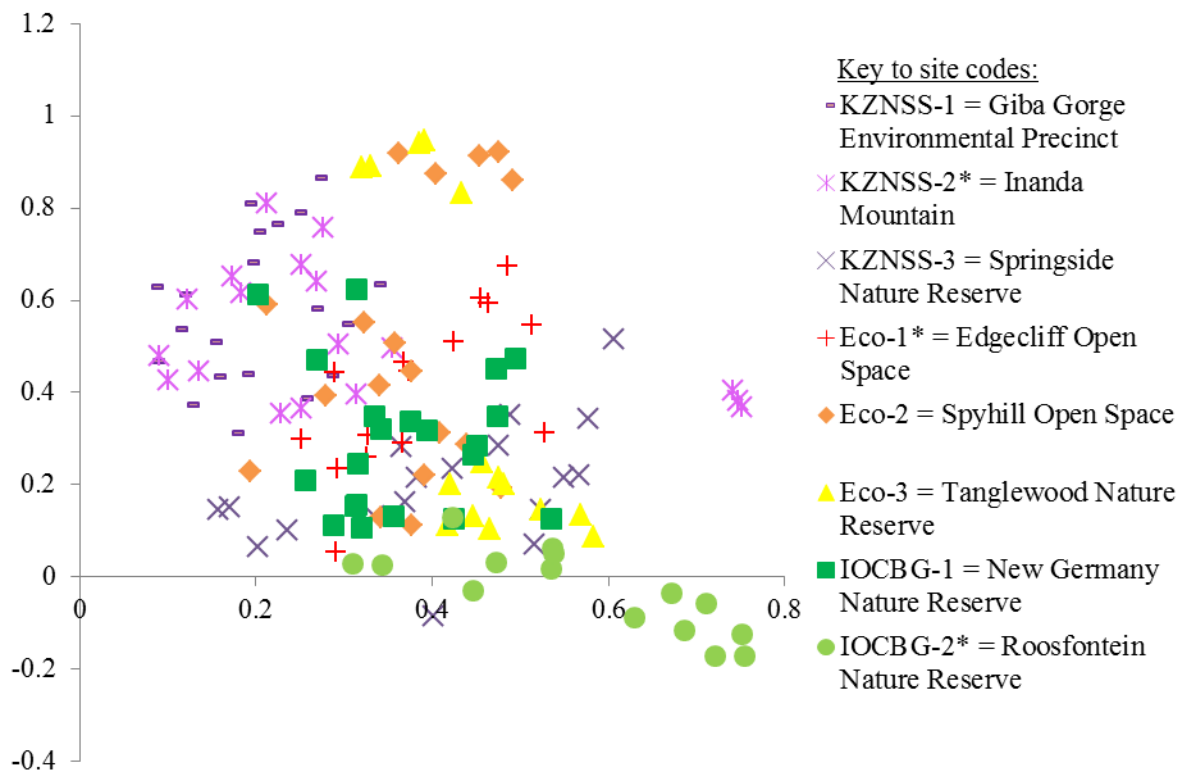


The Non-parametric Multi-Dimensional Scaling (NMDS) performed on the average abundances of species found within the quadrats showed a separation of the sites into three groups. These groupings are as follows: KZNSS-1 and -2; Eco-1 and IOCBG-2; KZNSS-3, Eco-2 and -3, and IOCBG-1. These groups are distinct from each other whilst individual sites within the groups almost overlap each other, indicating that there is little difference in the distance matrix between sites within a given group.



**Figure 4.6:** Results of a Non-parametric Multi-Dimensional Scaling (NMDS) analysis performed on the Bray-Curtis similarity matrix obtained using the square root transformed average abundance data of species found in the individual quadrats (n = 8 sites, stress = 0.004541). Site codes: KZNSS-1 = Giba Gorge Environmental Precinct, KZNSS-2 = Inanda Mountain\*, KZNSS-3 = Springside Nature Reserve, Eco-1 = Edgecliff Nature Reserve\*, Eco-2 = Spyhill Open Space, Eco-3 = Tanglewood Nature Reserve, IOCBG-1 = New Germany Nature Reserve and IOCBG-2 = Roosfontein Nature Reserve\*. Asterisk denotes disturbed sites.

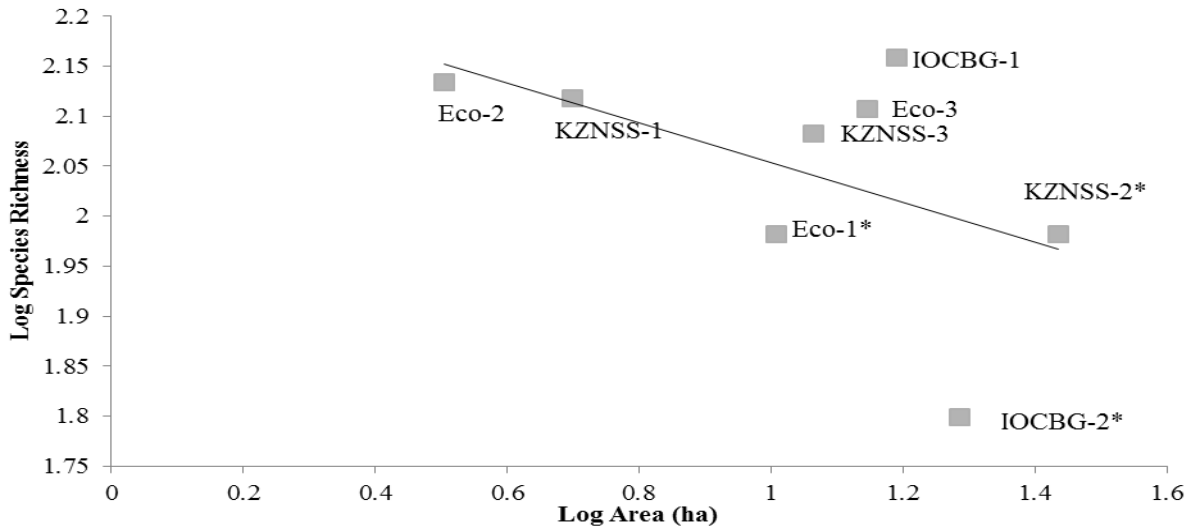
Non-parametric Multi-Dimension Scaling ordinations were also performed using the individual quadrat data for the sites (n = 140 for 8 sites combined) (Fig. 4.7). The output with the lowest stress (17.398) showed minimal separation of quadrats and different vegetation categories. Whilst some quadrats of IOCBG-2 separated from the main group, other IOCBG-2 quadrats remained part of the main group. The same can be seen for some quadrats of Eco-2 and Eco-3, where some quadrats separate from the main group, whilst the remaining quadrats remained within the main group.



**Figure 4.7:** Results of a Non-parametric Multi-Dimensional Scaling (NMDS) plot based on the Bray-Curtis similarity matrix obtained using the square root transformed abundance data of species within each quadrat across all eight sites ( $n = 140$  for 8 sites combined, Stress = 17.398). Site names are indicated in the key with disturbed sites denoted by an asterisk.

#### 4.7 Island biogeography analyses

The linear regression analysis of the area effect shows a relatively weak and insignificant negative correlation between area and species richness, even when the area was log transformed to account for the logarithmic nature of the area effect (Fig. 4.8). The disturbed sites represented outliers and when excluded the correlation was weaker and still not significant ( $r^2 = 0.502$ ,  $p > 0.05$ , linear regression analysis,  $n = 8$ ).



**Figure 4.8:** Scatter plot of the log transformed area and species richness for each site examined ( $r^2 = 0.512$ ,  $p > 0.05$ , for linear regression analysis,  $n = 8$ ). KZNSS-1 = Giba Gorge Environmental Precinct, KZNSS-2 = Inanda Mountain\*, KZNSS-3 = Springside Nature Reserve, Eco-1 = Edgecliff Open Space\*, Eco-2 = Spyhill Open Space, Eco-3 = Tanglewood Nature Reserve, IOCBG-1 = New Germany Nature Reserve and IOCBG-2 = Roosfontein Nature Reserve\*. An asterisk denotes disturbed sites (based on quadrat and transect data).

The distance effect was examined by comparing the log transformed distance between two sites to the log transformed number of species common to the two sites. Comparisons were made within vegetation (except for IOCBG) and between categories. The only two significant relationships for the five comparisons tested by linear regression analysis were found between Ecotonal and IOCBG sites ( $r^2 = 0.842$ ,  $p < 0.05$ , linear regression analysis,  $n = 5$ ) and between KZNSS and IOCBG sites ( $r^2 = 0.821$ ,  $p < 0.05$ , linear regression analysis,  $n = 5$ ). When comparisons of distance versus shared species for all sites to each other regardless of vegetation category were pooled and tested in totality, a weak but significant negative correlation between distance and number of shared species was revealed ( $r^2 = 0.402$ ,  $p < 0.05$ , linear regression analysis,  $n = 26$ ).

#### 4.8 Germinable soil seedbank analyses

Germinable soil seedbanks at all sites were sampled during two parts of the year, spring-summer (late November and early December 2013 and 2014) and autumn-winter (late April and early May 2013 and 2014) in order to accommodate for seasonal seeding and germination events. The data emanating from the spring-summer and autumn-winter samplings were therefore pooled for individual sites for all the analyses described in this section.

When all eight sites and both sampling seasons (spring-summer and autumn-winter) are considered, a total of 735 seedlings belonging to 25 different species emerged from the seedbank samples (Table 4.7). Across vegetation categories Ecotonal sites cumulatively gave rise to the highest total number of germinants (433 germinants), followed by KZNSS and IOCBG (237 and 121 germinants, respectively). When the abundance of germinants was compared in terms of life-form (graminoids and herbaceous) across vegetation categories, Ecotonal had the highest ( $p < 0.05$ ) number of graminoid germinants, while KZNSS had the highest ( $p > 0.05$ ) number of herbaceous germinants (281 and 156 germinants, respectively). When sites were compared within vegetation categories it was evident that across sites, Eco-3 had the highest number of germinants in total, while KZNSS-1 had the lowest number (207 and 51 germinants, respectively); Eco-3 had the highest number of graminoid germinants, whilst KZNSS-3 had the highest number of herbaceous germinants. The lowest abundances of graminoids and herbaceous seedlings were found in KZNSS-1 and IOCBG-2, respectively (Table 4.7).

**Table 4.7:** Abundance (number of germinants) which emerged from germinable soil seedbank samples collected at the eight sites investigated.

Site code	Abundance (number of germinants)		
	Graminoids	Herbaceous	Total
KZNSS-1	8	43	51
KZNSS-2 <sup>a</sup>	51	56	107
KZNSS-3	22	57	79
<b>KZNSS Total</b>	<b>81</b>	<b>156</b>	<b>237</b>
Eco-1 <sup>a</sup>	109	53	162
Eco-2	19	35	54
Eco-3	153	54	207
<b>Ecotonal Total</b>	<b>281</b>	<b>152</b>	<b>433</b>
IOCBG-1	17	52	69
IOCBG-2 <sup>a</sup>	31	21	52
<b>IOCBG Total</b>	<b>48</b>	<b>73</b>	<b>121</b>

Values represent the sum of four trials (2 in spring-summer and 2 in autumn-winter) of  $n = 30$  per site, except for IOCBG-2 where  $n=35$  for each of the four trials. When data was compared within life-forms across vegetation categories,  $p < 0.05$  for graminoids ( $n = 16$  [8 sites  $\times$  2 seasons], Kruskal-Wallis test),  $p > 0.05$  for herbaceous plants ( $n = 16$  [8 sites  $\times$  2 seasons], ANOVA) and  $p > 0.05$  for total ( $n = 16$  [8 sites  $\times$  2 seasons], Kruskal-Wallis test).

<sup>a</sup> Denotes sites considered disturbed

KZNSS-1 = Giba Gorge Environmental Precinct, KZNSS-2 = Inanda Mountain, KZNSS-3 = Springside Nature Reserve, Eco-1 = Edgecliff Nature Reserve, Eco-2 = Spyhill Open Space, Eco-3 = Tanglewood Nature Reserve, IOCBG-1 = New Germany Nature Reserve and IOCBG-2 = Roosfontein Nature Reserve.

The cumulative number of graminoid species found within each vegetation category ranged from 24 to 28 species above-ground, while this was equivalent to four below-ground (i.e. in the germinable soil seedbank) in all vegetation categories. Above-ground species richness for herbs ranged from 145

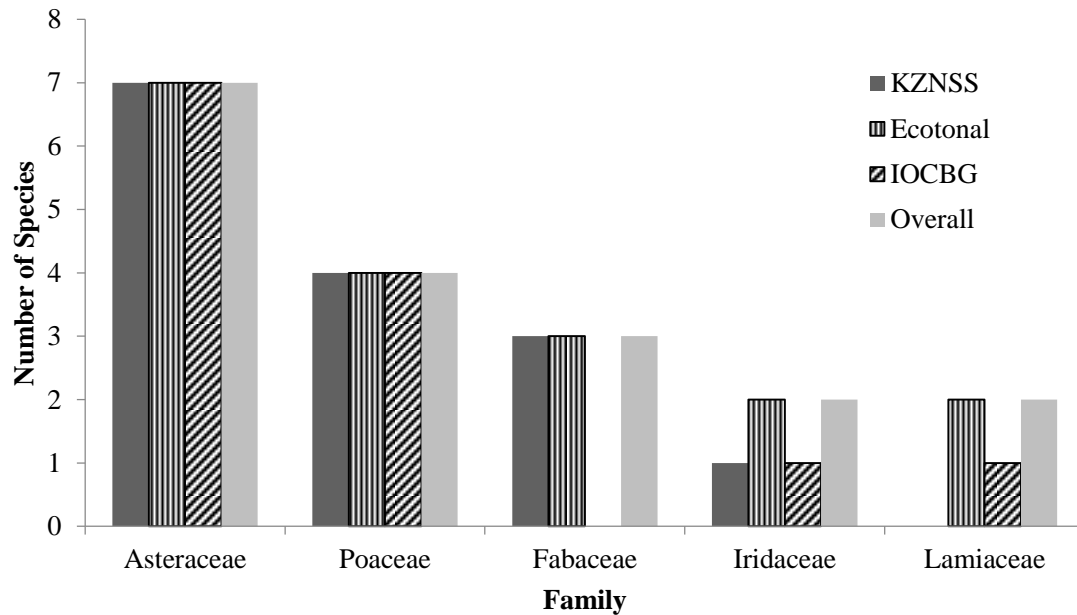
to 164 species, whilst the below-ground species richness ranged from 11 to 19. Herbaceous species richness was lowest in IOCBG both above- and below-ground and highest above ground for KZNSS and below-ground in Ecotonal. Comparison of Sørensen similarity (as a percentage) and Jaccard similarity values both showed above- and below-ground are most similar in terms of species composition in Ecotonal and least similar in IOCBG (Table 4.8).

**Table 4.8:** Comparisons of species richness and composition between above- and below-ground for the three vegetation categories investigated.

Vegetation Category <sup>a</sup>	Above/ Below Ground Samples	Number of Species			Sørensen similarity (%)	Jaccard similarity
		Total	Herbs	Graminoids		
KZNSS	Above	192	164	28	16.19	0.08808
	Below	17	13	4		
Ecotonal	Above	186	159	27	22.12	0.1243
	Below	23	19	4		
IOCBG	Above	169	145	24	15.22	0.08235
	Below	15	11	4		

<sup>a</sup> KZNSS = KwaZulu-Natal Sandstone Sourveld, Ecotonal and IOCBG = Indian Ocean Coastal Belt Grassland. The below-ground flora values represent the sum of four trials (2 in spring-summer and 2 in autumn-winter) of n = 30 per site, except for IOCBG-2 where n=35 for each of the four trials. The above-ground flora values represent the total number of species found in both quadrat and transect data.

The five most speciose families below-ground are shown in Fig. 4.9 (see Appendix B for species details) for each vegetation category and overall. Asteraceae was the most well represented family in all three vegetation categories, followed by Poaceae and Fabaceae (7, 4 and 3 species, respectively). All three vegetation categories contained all of the Asteraceae and Poaceae species found in total (7 and 4 species, respectively). Differences in species richness for these five families across vegetation categories were evident and included the following: IOCBG did not contain the three Fabaceae species found in the other categories; KZNSS and IOCBG contained one less member of the Iridaceae than Ecotonal (n = 2); the Lamiaceae were best represented in Ecotonal (n = 2) and not represented in KZNSS.



**Figure 4.9:** Number of species within the five most speciose families in the germinable seed banks of the three vegetation categories. Values represent the sum of four trials (2 in spring-summer and 2 in autumn-winter) of n = 30 per site, except for IOCBG-2 where n=35 for each of the four trials.

The three most abundant species in the seed bank per site was examined in greater detail (Table 4.9). This was done by comparing the top three most abundant species found in the below-ground flora to their rank position in abundance of the above-ground flora. There was little similarity to the positions held by the top three most abundant below-ground species to their respective positions in the above-ground flora, with top three most abundant below-ground species appearing in the top 5 most abundant above ground species only 20.83% of the time. In two cases a top three below-ground species was third in the above-ground flora (*Monocymbium cerasiiforme* Stapf. in KZNSS-1 and -3) and in three cases a species from the top three below-ground flora occupied a position of fourth in the above-ground flora (*Senecio madagascarensis* Poiret. in Eco-1, *Helichrysum adenocarpum* subsp. *adenocarpum* DC. in IOCBG-1 and *Digitaria eriantha* Steudel. in IOCBG-2) (Table 4.9). In fact, only one species, *M. cerasiiforme*, occupied the same position as the third most abundant species in both the below-and above-ground flora of KZNSS-1 and -3.

Furthermore, one species, *Ageratum houstonianum*, which was the 2<sup>nd</sup> most abundant in the germinable soil seedbank at KZNSS-1 was not present in the above-ground flora of this site. *Monocymbium cerasiiforme* and *Setaria lindenbergiana* were the graminoids that appeared most

frequently in the top three most abundant species below-ground (six and four times, respectively) across sites but were ranked 3<sup>rd</sup> to 66<sup>th</sup> in terms of density in the above-ground flora across sites.

**Table 4.9:** The three most abundant (in terms of number of individuals) species within the germinable soil seedbank and corresponding rank in terms of abundance in the above-ground flora for the eight sites studied.

Site code	Three most abundant species below-ground <sup>b</sup>	Abundance rank in above ground flora
<b>KZNSS-1</b>	1) <i>Helichrysum adenocarpum</i> subsp. <i>adenocarpum</i> DC	59 <sup>th</sup>
	2) <i>Ageratum houstonianum</i> Mill.	Not present
	3) <i>Monocymbium cerasiiforme</i> Stapf.	3 <sup>rd</sup>
<b>KZNSS-2<sup>a</sup></b>	1) <i>Monocymbium cerasiiforme</i> Stapf.	22 <sup>nd</sup>
	2) <i>Helichrysum adenocarpum</i> subsp. <i>adenocarpum</i> DC	11 <sup>th</sup>
	3) <i>Setaria lindenbergiana</i> Stapf.	13 <sup>th</sup>
<b>KZNSS-3</b>	1) <i>Helichrysum appendiculatum</i> Lessing.	11 <sup>th</sup>
	2) <i>Setaria lindenbergiana</i> Stapf.	66 <sup>th</sup>
	3) <i>Monocymbium cerasiiforme</i> Stapf.	3 <sup>rd</sup>
<b>Eco-1<sup>a</sup></b>	1) <i>Helichrysum aureonitens</i> Sch. Bip.	30 <sup>th</sup>
	2) <i>Monocymbium cerasiiforme</i> Stapf.	14 <sup>th</sup>
	3) <i>Senecio madagascarensis</i> Poiret.	4 <sup>th</sup>
<b>Eco-2</b>	1) <i>Monocymbium cerasiiforme</i> Stapf.	11 <sup>th</sup>
	2) <i>Helichrysum adenocarpum</i> subsp. <i>adenocarpum</i> DC	96 <sup>th</sup>
	3) <i>Senecio madagascarensis</i> Poiret.	40 <sup>th</sup>
<b>Eco-3</b>	1) <i>Setaria lindenbergiana</i> Stapf.	28 <sup>th</sup>
	2) <i>Ageratum houstonianum</i> Mill.	49 <sup>th</sup>
	3) <i>Monocymbium cerasiiforme</i> Stapf.	18 <sup>th</sup>
<b>IOCBG-1</b>	1) <i>Helichrysum adenocarpum</i> subsp. <i>adenocarpum</i> DC	4 <sup>th</sup>
	2) <i>Senecio madagascarensis</i> Poiret.	19 <sup>th</sup>
	3) <i>Helichrysum appendiculatum</i> Lessing.	9 <sup>th</sup>
<b>IOCBG-2<sup>a</sup></b>	1) <i>Digitaria eriantha</i> Steudel.	4 <sup>th</sup>
	2) <i>Setaria lindenbergiana</i> Stapf.	10 <sup>th</sup>
	3) <i>Cyperus obtusiflorus</i> var. <i>obtusiflorus</i> Vahl.	30 <sup>th</sup>

<sup>a</sup> Denotes sites considered to be disturbed

<sup>b</sup> Listed/ranked in decreasing order of abundance.

The below-ground flora values represent the sum of four trials (2 in spring-summer and 2 in autumn-winter) of n = 30 per site, except for IOCBG-2 where n = 35 for each of the four trials. The above-ground flora values represent the sum of all quadrats for each site as shown in Table 4.2.

KZNSS-1 = Giba Gorge Environmental Precinct, KZNSS-2 = Inanda Mountain, KZNSS-3 = Springside Nature Reserve, Eco-1 = Edgecliff Nature Reserve, Eco-2 = Spyhill Open Space, Eco-3 = Tanglewood Nature Reserve, IOCBG-1 = New Germany Nature Reserve and IOCBG-2 = Roosfontein Nature Reserve

*Helichrysum adenocarpum* subsp. *adenocarpum* (four times) and *S. madagascarensis* (three times) were the herbaceous species that appeared most frequently in the top three most abundant species below-ground across sites but were ranked 4<sup>th</sup> to 96<sup>th</sup> in terms of density in the above-ground flora across sites. The invasive alien *A. houstonianum* (Category 1b) was the second most abundant species below-ground in two sites, KZNSS-1 (where it was not found above-ground) and Eco-3 (where it was the 49<sup>th</sup> most abundant species in the above-ground flora).

Disturbance did not appear to influence the top three most abundant species below-ground, with only two species (both of which are graminoids) occurring in more than one disturbed site, viz. KZNSS-2 and IOCBG-2. Across vegetation categories (detailed data not shown), *M. ceresiiforme* was the most abundant species below-ground, occurring at the highest abundances in KZNSS and Ecotonal. However, this species did not occur in the top three most abundant species in IOCBG. Similarly, *H. appendiculatum* was the 2<sup>nd</sup> most abundant species below-ground in IOCBG but did not occur in the top three most abundant species KZNSS or Ecotonal. *S. madagascarensis* was the 2<sup>nd</sup> most abundant species below-ground in Ecotonal and the most abundant in IOCBG.

It should be noted that no diagnostic taxa or taxa of conservation concern were emerged from the germinable soil seedbanks across all sites. The only notable taxa found (at KZNSS-1, KZNSS-2, KZNSS-3, Eco-2, Eco-3, IOCBG-1) was *A. houstonianum*, which is classified as a Category 1b invasive alien.



## **Chapter 5: Discussion**

### **5.1. Introduction**

The grassland biome is known to contain high numbers of endemic plants (Mucina *et al.*, 2006a) and is the second largest biome in terms of land coverage in southern Africa (Rutherford *et al.*, 2006a). Tropical [and thus sub-tropical] grasslands have been previously thought to be a consequence of deforestation, however, these grasslands often predate deforestation and often contain many ancient endemic plant taxa (Bond, 2016). Subtropical grasslands in southern Africa do not exhibit typical grassland climatic characteristics (i.e. they are warmer and wetter) and are currently classified in subtropical biomes such as Savanna and Indian Ocean Coastal Belt (Mucina *et al.*, 2006a; Rutherford *et al.*, 2006b). The sites of this study are referred to as grasslands due to the dominance of grasses found within them as has been done in the latest vegetation classification (Mucina and Rutherford, 2006). Subtropical grasslands such as KZNSS and IOCBG are restricted to the eastern seaboard and occur within the Maputo-Pondoland-Albany biodiversity hotspot (Jonas *et al.*, 2006; Rutherford *et al.*, 2006b). These subtropical grasslands now exist as fragments of their former extent, often distributed within an urban-suburban matrix (Department of Environmental Affairs [DEA], 2011).

In light of the above, subtropical grasslands, especially those within close proximity to urban and suburban areas, are a conservation priority (DEA, 2011). Examining the flora within a particular floristic unit represents the first vital step in any conservation process within that unit, as it is important to first fully understand and describe what one is intending to conserve before designing and implementing any conservation strategies (Brown *et al.*, 2013). Floristic surveys, which are an integral part of studying a plant-based system within an island biogeography framework (Fahrig, 2003), were thus conducted within selected KwaZulu-Natal Sandstone Sourveld (KZNSS), Ecotonal and Indian Ocean Coastal Belt Grassland (IOCBG) patches in the EMA to ascertain whether the vegetation at each site was characteristic of KZNSS or IOCBG vegetation. Diversity was assessed for the above-and below-ground flora.

### **5.2 Overview of floristic diversity**

Sites ranged in species richness from 65 to 144 species, with KZNSS, Ecotonal and Indian Ocean Coastal Belt Grassland (IOCBG) having a total (quadrat and transect data combined) of 192, 186 and

169 species, respectively (Table 4.2; Figure 4.1). Asteraceae, Poaceae and Fabaceae were the most speciose families across sites (Figure 4.2). Together, these three families accounted for 45.6% of the 263 taxa found in this study. In a grassland study further inland in the Platberg region of the eastern Free State, the four most dominant families (in decreasing order) were Asteraceae, Poaceae, Cyperaceae and Fabaceae, and these four families accounted for only 40.4% of the 441 taxa found in the study region (Brand *et al.*, 2010). Whilst the present study was confined to only the grassland sections at each site, Brand *et al.* (2010) also included more riparian habitats which may explain why Cyperaceae was so well represented in their study. However, had sampling been conducted to 100% (which is implausible due to the logarithmic nature of the species accumulation curve) in the present study, it is estimated that only c. 328 species would have been found opposed to the 263 species which were found. This estimate is based on Jack1 and Chao2 estimators, which have been described as the two most reliable estimators of species richness for non-parametric area-based species richness in heterogeneous landscapes by Xu *et al.* (2012). These results therefore suggest that the species richness measured in this study is a true reflection of the flora at the sites surveyed.

Only nine taxa of conservation concern were found in the study (3.4% of the total taxa found). This is surprising since KZNSS is listed as an endangered vegetation type, whilst IOCBG is vulnerable (DEA, 2011), and both are known to contain endemic taxa which are of conservation concern (Mucina *et al.*, 2006b; Rutherford *et al.*, 2006b). The low number of taxa of conservation concern recorded was more likely due to the rarity of these taxa rather than a sub-optimal sampling effort. Additionally, niche specialists are known to occur in KZNSS and IOCBG, and could have been overlooked as a consequence of the fact that this study focused on the core grassland sections of each site, excluding forest patches, edges of the sites and cliff faces, where many of the niche specialists are known to occur within KZNSS (see Table 2.2). Flowering duration also influences species identification during floristic surveys: a short flowering duration for example can result in a species being overlooked during walked transects. Some of the species known to occur within KZNSS and IOCBG do not flower regularly, whilst others either have no sexual reproductive potential and/or are cryptic (see Table 2.2). These factors surely minimise the chances of these species being found in floristic surveys, however, the number of taxa found here are still higher than that reported in similar studies on grasslands (e.g. Brand *et al.*, 2010) and highlights the importance of these sites in terms of conserving red list taxa.

Twenty alien taxa were found across all sites, comprising of 7.6% of the total taxa found. Six of these alien taxa are classed as being Category 1b invasive alien plants (IAP's; Table 4.4). Based on the threats posed by IAP's (see Jones *et al.*, 2014) this is cause for concern. The high number of alien taxa is most likely due to the fact that all of the study sites are within an urban matrix and are thus prone to disturbance (Table 4.1) which is a key driver of IAP (Rebele, 1994). The percentage of alien taxa found in this study is higher than that found in similar studies, where more species were found in total and the study was conducted in a more isolated area (e.g. Brand *et al.*, 2010). Invasive alien taxa and alien taxa in general are usually more prolific where disturbance has occurred (Rebele, 1994). Subtropical grasslands, particularly those examined here, are vulnerable (DEA, 2011) making the presence of this many alien and invasive alien species, an indication of the effects of disturbance.

## **5.2 Delimitation**

In order for conservation efforts to be implemented and funding allocated for a specific vegetation type, the vegetation type has to be clearly delineated and defined in order to ascertain exactly how much is remaining intact and how close this is from the conservation target in order to ensure the persistence of the vegetation type. Thus, in order to ensure that highly threatened subtropical grasslands are conserved, vegetation delineations of these grassland types need to be accurate and consistent to form a solid basis for monitoring and maintaining biodiversity (Brown *et al.*, 2013).

In order for a developer to begin construction an Environmental Impact Assessment (EIA) is required for the area where the development is to occur, which would lead to the proposed area being listed as a vegetation type (Anderson and Clements, 2000). Developers would prefer sites to be listed as IOCBG than KZNSS, which is in less need of protection and thus would be easier to obtain permission to build especially in areas where sites could be IOCBG or KZNSS and little resolution is available. A variety of clustering methods could each yield a different result for classifying sites (Anderson and Clements, 2000) and thus dispute whether a site is KZNSS, IOCBG or ecotonal between the two. Therefore, floristic analyses and the use of correct multivariate cluster analyses are vital for the correct identification, delineation and ultimately the conservation of vegetation types (Anderson and Clements, 2000).

Floristic analyses can aid in the identification, delineation and ultimate conservation of vegetation types (Anderson and Clements, 2000). Floristic surveys can be particularly useful when environmental conditions overlap and vegetation units are spatially closer together (see Anderson and Clements, 2000; Brown *et al.*, 2013). The two vegetation types studied here, KZNSS and IOCBG, are spatially close and appear to be superficially similar in terms of their floristics (Figure 4.1), but are listed differently on the national list of ecosystems as endangered and threatened, respectively (DEA, 2011). Thus the floristic differences and similarities between KZNSS and IOCBG needed to be appraised in order for the two vegetation types to be better delineated and conserved.

Alpha diversity measures of Simpson's Inverse and Shannon's Exponential indices did not differ much between the IOCBG and KZNSS vegetation categories (Figure 4.4). The Shannon's Exponential index emphasises species richness whilst the Simpson's Inverse index is known to give an estimate that emphasises evenness (Luis, 1996; Nagendra, 2002), which suggests that species richness and evenness does not differ between KZNSS, Ecotonal and IOCBG sites studied here. To further analyse the differences in vegetation composition between vegetation categories, three beta diversity measures ( $\beta_{gl}$ ,  $\beta_{.3}$  and  $\beta_t$ ) were used to compare quadrats within each site using presence-absence of species in each quadrat. These measures differ in focus, whilst  $\beta_{.3}$  is a narrow-sense turnover measure indicating species loss and gain;  $\beta_t$  is a broad-sense turnover measure indicating a degree of overlap in species distributions;  $\beta_{gl}$  indicates less similarity in the numbers of species unique to each site at higher values of the index (Koleff *et al.*, 2004). When compared across vegetation categories, only  $\beta_{gl}$  was significantly different, with the highest value for KZNSS and the lowest value was found for Ecotonal. This indicates that across vegetation categories there are significant differences in the number of species unique to sites within a vegetation category, with KZNSS having more variation within the numbers of unique species per site than IOCBG and Ecotonal containing relatively even numbers of unique species in each site.

The beta diversity results, combined with those for alpha diversity suggest that there are differences in species composition between the vegetation categories, other than just species richness. However, when the same three beta diversity measures were run comparing the presence-absence data of sites from the same and different vegetation categories (Figure 4.4), these analyses found no significant difference in the comparison of species composition between different vegetation categories. However, KZNSS tends to display less variability between sites, whilst IOCBG and Ecotonal displayed far greater variability between sites in terms of composition (Figure 4.4).

In the most recent vegetation classification, three taxa are listed as endemic to IOCBG (Mucina *et al.*, 2006b), however, none of these were found in both vegetation categories (Table 4.5). This is largely because two of the endemic taxa are listed as being extinct while the third is critically endangered and presumably highly restricted (see Table 2.2 for details). Of the eleven taxa endemic to KZNSS (Rutherford *et al.*, 2006b) only one (*Eriosema populifolium* subsp. *populifolium*) was found (occurring across all three vegetation categories examined in this study) (Table 4.5). A possible reason why many of these endemic taxa were not found is that many of those endemic to KZNSS are niche specialists (e.g. *Brachystelma pulchellum* (Harv.) Schltr.), whilst some do not flower frequently, have low or no sexual reproductive potential and possibly reproduce purely asexually (e.g. *Tephrosia inandensis* H.M.L. Forbes) and/or are highly localised being restricted to just one or two locations (e.g. *Brachystelma natalense* (Schltr.) N.E. Br.) (see Table 2.2 for details). These endemic taxa are of diagnostic value as they can be used to delimit KZNSS from IOCBG and other similar vegetation types that are potentially compositionally different, but similar in terms of richness and structure. However, their limited occurrence at the sites surveyed suggested that other floristic features may also have to be used for more robust delimitation.

This then raised the question, if not by endemic taxa, how is it possible to delimit KZNSS from IOCBG? In order to answer this various analyses were conducted on floristic data for three vegetation categories, viz. KZNSS, IOCBG and Ecotonal. The most useful of these analyses was the cluster analyses (Figure 4.5) which clearly showed the separation of IOCBG from KZNSS, with Ecotonal being more similar to IOCBG. This confirms the current delimitation, which includes Ecotonal as IOCBG, despite Ecotonal being less than 350 m from KZNSS (Table 4.1) and appearing superficially floristically similar (as seen Figure 4.1). The ordination of sites, which took into account the average abundance of species based on quadrat data (thus not the full species list for each site as the cluster analysis did) showed that KZNSS and IOCBG are separate vegetation types, while Ecotonal was more similar to IOCBG (Figure 4.6), which suggests that IOCBG has a less consistent assemblage with more habitat heterogeneity, and thus more ecotones.

Historically KZNSS and parts of IOCBG were jointly classified as part of Ngongoni Veld (Acocks, 1988) and extended from the area behind coastal dune forests to the foot hills of the Drakensberg mountain range, broken only in ravines and cliffs by coastal scarp forest (Acocks, 1988; DEA, 2011).

More detailed and finer scale examinations have subsequently shown these two vegetation types to be separate entities (Mucina and Rutherford, 2006). Additionally, anthropogenic factors such as urbanisation have led to extensive transformation within both KZNSS and IOCBG further altering the diagnostic species richness and composition of these grasslands. These two vegetation types may well become completely distinct if enough time is allowed to pass. However, the ordination analyses on individual quadrat data collected in this study did not show significant separation of sites or vegetation categories (Figure 4.7). This suggests that the individual quadrats may be similar, but overall the sites and vegetation categories are different. Thus, to discriminate IOCBG from KZNSS accurately it is suggested that floristic data be collected for sites in question, but also to include pristine KZNSS sites (Giba Gorge Environmental Precinct (KZNSS-1) or Springside Nature Reserve (KZNSS-3)) and pristine IOCBG (New Germany Nature Reserve (IOCBG-1)) for comparisons. However, this was not always possible, given that most of the sites of this study are nested within the urban/ suburban matrix.

Across the vegetation categories, Ecotonal contained the highest number of germinants, followed by KZNSS and IOCBG (Table 4.7). It should be noted that whilst KZNSS and Ecotonal categories each had three sites to contribute the total number of germinants in these categories, IOCBG only had two sites and a lower number of germinants is thus expected. More species were found in KZNSS, followed by Ecotonal and IOCBG (32, 31 and 28 species, respectively; Table 4.8). This indicates that although KZNSS has a richer diversity of species within the germinable soil seedbank, Ecotonal sites are experiencing better management (particularly the undisturbed Eco-3), which contained the highest number of germinants found in any of the sites (207 germinants). Since the results of this study confirmed that Ecotonal is in fact IOCBG, the increased number of germinants in Ecotonal sites indicates that the IOCBG vegetation type as a whole is more adaptable to changes and is better equipped to deal with threats such as climate change and IAP's (see Bakker and Berendse, 1999).

Additionally, above-and below-ground flora were most similar within Ecotonal (Table 4.10). However, this may simply be an artefact of many species in higher abundances being found in Ecotonal (Table 4.7; Table 4.8). Grasslands are expected to have a 50% Sørensen similarity between the above-and below-ground vegetation composition but many graminoids reproduce via clonal propagation (Pierce and Cowling, 1991). The present study showed a much lower Sørensen similarity (15.22 – 22.12%) between above-and below-ground flora (Table 4.10). The Sørensen similarity was calculated by including all graminoid (which more often reproduce clonally and thus asexually)

species found in both the above-and below-ground flora, which could have contributed to this shortfall. Thus, although relatively low numbers of species were found in the germinable soil seedbank and the similarity between the above- and below-ground flora was also relatively low, this information is considered valuable as it allows for predictions of the restorative potential of vegetation types.

### **5.3 Effects of disturbance on above-and below-ground flora**

The vegetation types of KZNSS and IOCBG form part of the Maputo-Pondoland-Albany biodiversity hotspot, which is highly vulnerable (Jonas *et al.*, 2006). There are four major threats to biodiversity in this hotspot (listed in decreasing order of importance): IAP's, human population density increase, agriculture and habitat fragmentation (Jonas *et al.*, 2006). Invasive alien plant species have been linked to disturbance (Garcia, 1995) which can arise when an increase in population density brings about a demand for more land and hence, disturbance and habitat fragmentation. This is particularly true for the EMA (Rouget, *et al.*, 2006) which is the largest city within the Maputo-Pondoland-Albany biodiversity hotspot. With KZNSS and IOCBG both having substantial remaining ranges including the EMA, anthropogenic disturbances are bound to impact negatively on vegetation at sites without active protection.

One site from each of the three vegetation categories examined was considered 'disturbed' with anthropogenic disturbances ranging from unscheduled fire, to high levels of foot traffic and grazing. Mismanagement practices such as lack of burning were also observed. Inanda Mountain (KZNSS-2) is burnt too frequently - on an annual basis and earlier than the other sites, and had a high volume of foot traffic and grazing. Edgecliff Open Space (Eco-1) has a history of not being regularly burnt, whilst Roosfontein Nature Reserve (IOCBG-2) has a high volume of foot traffic (Table 4.1). The delimitation analyses showed minimal separation between KZNSS-2 and KZNSS-1, however, there was separation of IOCBG-2 and Eco-1 from the remaining sites (Figure 4.5). This separation is attributed to the relatively lower species richness in IOCBG-2 and Eco-1, which was not a prominent feature of KZNSS-2 site, despite this site being disturbed (Table 4.2). This indicates that this site may have had a very high species richness in the past, which is now lower due to disturbance, or that perhaps the site (and KZNSS in general) is more resilient than it was first thought to be.

Since the study sites lie within an urban matrix, it is expected that they would host alien species (Rebele, 1994). However, the abundance and diversity of aliens found differed across the sites. This is attributed to the inter-site difference in disturbance type and intensity (discussed above). In general, disturbed sites showed lower species richness (Table 4.2), with lower diversity and abundance of taxa of conservation concern (Table 4.3), and higher diversity and abundance of alien taxa (Table 4.4). This suggests that disturbance is having an impact within these grasslands, with the impact being less severe on KZNSS than IOCBG sites. The effects of stimulated grazing (including trampling and mowing) as well as improper burning have been shown to decrease species richness and have a profound effect on the floristic composition within grasslands elsewhere (Fynn *et al.*, 2004; Garcia, 1995; Čepelová and Münzbergová, 2012).

A further impact of disturbance can be seen when examining the diversity indices. Alpha diversity estimates differed more across sites, than vegetation types, indicating that something other than vegetation category was impacting on alpha diversity at the sites. The Shannon's Exponential index for example, was highest for IOCBG-2 (Figure 4.3), which also had the lowest species richness of 45 species based on quadrat sampling, that increased to 65 species with transect sampling (Table 4.2). A high value for Shannon's Exponential index is known to indicate a high level of entropy (Nagendra, 2002), indicating that at the disturbed site of IOCBG-2 there is more variability and less predictability of species occurrences across the site (i.e. less homogenous species composition across the site). The lowest Shannon's Exponential index value was found in the pristine IOCBG-1 (Figure 4.3), which had the highest species richness of 124 in quadrat sampling, that increased to 144 with transect sampling (Table 4.2). This indicates a level of homogeneity across the site, with species being spread more evenly across the site (Nagendra, 2002). The Simpson's Inverse index reflects higher evenness at lower values of this index (Luis, 1996) and shows a similar trend to that of Shannon's Exponential index, where sites with a lower species richness show higher values (Figure 4.3, Table 4.2). Evenness, in this case, refers to the level of homogeneity of species composition across a site. It seems plausible to conclude that disturbance lowers species richness and that a lowered species richness makes a site more heterogeneous (as shown above). Thus it can be said that for the EMA grasslands studied here, disturbance leads to heterogeneity in otherwise more homogenous vegetation.

Beta diversity measures also showed effects of disturbance. Beta diversity gives more information on the diversity and spread of a species than species richness (Koleff *et al.*, 2003). Low values of  $\beta_{gl}$ , which ranges from zero to two, were found (Table 4.6), indicating an even number of species unique



to each of the two quadrats being compared (Koleff *et al.*, 2003). Mid-range values of  $\beta_{.3}$ , which gives values ranging from zero to half, were found (Table 4.6), indicating a lower number of shared species and relatively equal numbers of species unique to each of the two quadrats being tested (Koleff *et al.*, 2003). Higher values of  $\beta_t$ , which ranges from zero to one, were found (Table 4.6), which indicates a higher degree of overlap of species found in the two quadrats being compared.

Despite only one beta diversity measure differing significantly across vegetation categories, all three beta measures were found to differ significantly across sites (Table 4.6). The disturbed sites (excepting KZNSS-1 which is not disturbed), which had lower species richness values, tending to have slightly higher values of  $\beta_{gl}$  (less similarity in the numbers of species unique to each quadrat) and lower values for  $\beta_{.3}$  and  $\beta_t$  (fewer species in common between quadrats being compared) (Table 4.2, Table 4.6). This supports the conclusions drawn from the alpha diversity analyses, and indicates that sites with lower species richness have a lower similarity – thus more variation between quadrats, whilst sites with higher species richness values have less variation between quadrats.

Disturbance has thus been shown to impact species richness and consequently the degree of variability of composition of a site. In the present study, disturbed sites were more heterogeneous in vegetation composition (having fewer species, spread more unevenly), whilst those which were undisturbed tended to be more homogenous in vegetation composition (having more species spread more evenly) across the site.

Disturbance to above-ground flora has also been reported to influence species richness and composition of the germinable soil seed bank (i.e. the below-ground flora); most often above-ground disturbance increases the germinable soil seed bank (e.g. Garcia, 1995; Čepelová and Münzbergová, 2012; Olf and Ritchie, 1998; Paige and Whitman, 1987). In the present study, with the exception of the pristine Eco-3, the germinable soil seed banks at the disturbed sites exhibited the highest number of germinants (Table 4.7). Most of these germinants were graminoids or indigenous herbaceous plants, with only one IAP being more abundant in the germinable soil seed bank of the disturbed sites. All of sites (except Eco-2 and IOCBG-1) contained the Category 1b invasive alien species *Ageratum houstonium* in their germinable soil seed bank. However, this species was only found in the above-ground flora of the three disturbed sites as well as Eco-3 (Table 4.6). This suggests that above-ground

disturbance seems to promote this species. The high prevalence of *A. houstonium* in seed banks suggest that this species will most likely become problematic in the future, allowing site managers to prepare for any invasions (Garcia, 1995). Other studies have also shown that the presence of IAP's can impact on the germinable soil seedbank and vegetation composition of a site (Garcia, 1995; Čepelová and Münzbergová, 2012).

The germinants emerging from the germinable soil seed bank at the Eco-3 site (Tanglewood Nature Reserve) were predominantly graminoids (Table 4.7). This site is subject to large mammal herbivory (viz. antelope) which is known to increase the abundance of graminoid seeds in the germinable soil seed bank (Olf and Ritchie, 1998; Paige and Whitman, 1987). According to Olf and Ritchie (1998), grazing actually stimulates graminoids to produce more seeds.

#### **5.4 Island biogeography effects**

The original extent of KZNSS (135,000 ha), has diminished to 28% of the original, with less than 1% being protected (DEA, 2011). Only 13% of the original extent of KZNSS remains within the EMA (DEA, 2011), mostly as small, historically isolated patches. Islands are predicted to have a species richness in proportion to their size (area effect), and islands closer to the mainland are predicted to have more species (distance effect) according to island biogeography theory (MacArthur and Wilson, 1967; Gotelli, 2008). Island biogeography theory is based on actual islands at sea, with a mainland being a continent or a larger island from which species spread to the surrounding islands. In this study, islands were the sites and there was no mainland available to test against. Thus the distance effect could not be tested as distance from the mainland, but was instead tested as distance between sites compared to the number of species shared between the two sites. The results suggested that fragmentation (islandisation) with subsequent transformation and possible connectivity (due to urbanisation) combined with the lack of a true mainland makes the island biogeography framework inappropriate for understanding floristic patterns and dynamics within subtropical grasslands types (e.g. KZNSS and IOCBG) in an urban framework.

Specifically, island biogeography theory predicts that smaller sites (i.e. area) will have a lower species richness, known as the area effect (MacArthur and Wilson, 1967; Gotelli, 2008). In this study, however, disturbance rather than area represented one of the major determinants of species richness at

a given site, irrespective of size (Figure 4.8). When the disturbed sites are removed from the analyses, the area effect still did not hold, indicating that within the urban matrix patch size of KZNSS and IOCBG is a poor predictor of species richness.

Additionally, island biogeography theory also predicts that sites which are closer to the mainland will have more species, whilst sites that are closer together will have more species in common, known as the distance effect (MacArthur and Wilson, 1967; Gotelli, 2008). The system of grassland patches within the EMA is without a true mainland, thus the only part of the distance effect was testable, i.e. the degree of similarity of species between sites compared to the distance between the sites. There was no observable trend with respect to the distance effect on the number of species in common between sites of different distances. It can thus be concluded that in an urban matrix the distance between patches of KZNSS and IOCBG does not contribute to the number of species two patches will have in common with one another. So, distance appears to be a poor predictor of shared species composition in the system studied.

In light of the high levels of habitat loss and unknown historic extent of existing patches (area and distance to each other), it is likely that disturbance is the major cause of the differences in species richness observed here, with the vegetation classification playing more of a role in determining similarity between sites than the number of species within a site. Island biogeography theory is thus inappropriate for understanding species richness and compositions of grassland patches examined within the EMA.

Island biogeography theory in its classical context predicts a state of equilibrium determined by four main factors; speciation, extinction, immigration and emigration. This equilibrium is achieved over large spatial and temporal scales (with exceptions, e.g. volcanic islands) (Gotelli, 2008). These factors are the basis of the area and distance effects. It should be noted that the temporal and spatial scale of the study was limited in the context of island biogeography theory. Spatially, the study was performed at a small scale, being localised to the EMA. Additionally, temporally the study was performed over a few years with the EMA being in existence for c. 200 years. So it seems reasonable to assume that the patterns observed are a consequence of the past 200 years.

Anthropogenic disturbance, unlike natural disturbances (e.g. volcanism), is relatively understudied and may negate the predictions of island biogeography theory (Fahrig, 2003; Rebele, 1994). Some sites examined in this study are disturbed by human activities and all are completely surrounded by urban development or human activities in one form or another. Some sites are linked by roads as well as having suburban backyards through which connectivity between patches can occur, so isolation or presumed isolation may not fully exist in an urban matrix, or may exist in varying degrees (Rebele, 1994). This indicates that sites may never become sufficiently isolated for the predictions of island biogeography theory to become effective.

Thus spatial and temporal scales of this study may thus be inappropriate to test the predictions of island biogeography theory given that extinctions, speciation, immigration and emigrations (all fundamental aspects of island biogeography theory) occur mostly in geological time frames in order to reach equilibrium (MacArthur and Wilson, 1967). Equilibrium has been known to be near impossible for natural ecosystems to achieve in an urban environment, especially since anthropogenic factors are more pronounced in these ecosystems (Rebele, 1994). The inclusion of the island biogeography aspect to this study has allowed the conclusion that differences noted are not as a result of the area or distance effect, but has not provided any further insights. It is suggested, that since the system may never achieve equilibrium because of human intervention and the constantly changing environment (Rebele, 1994). Instead, preserving what species remain should be aimed at as a conservation goal with the inclusion of possibly reintroducing species lost from KZNSS or IOCBG sites as a result of disturbance being reintroduced.

## **6. Conclusion**

### **6.1 Major findings**

The most important output of this study in terms of conservation and biodiversity science is the comprehensive, up to date, species lists provided by the study for each of the sites. These lists can act as checklists for site managers and can serve as species lists for KZNSS and IOCBG in general.

This study confirmed that KZNSS and IOCBG are two distinct vegetation types and supports the latest national vegetation classification (for South Africa) carried out by Mucina and Rutherford (2006). However, the results suggest that these two vegetation units are not easily identifiable and may superficially resemble each other in many respects (e.g. had many species in common). As a consequence of high levels of disturbance/transformation across many sites and/or the paucity of highly restricted endemic taxa, diagnostic taxa mentioned in previous classifications (Mucina and Rutherford, 2006) classifying either vegetation type is difficult. The study shows that detailed floristic surveys, with pristine sites as the benchmark, together with other edaphic and geological characteristics, may be needed in order to determine whether a particular patch is IOCBG or KZNSS.

Disturbance was shown to have a greater impact on IOCBG than KZNSS in terms of delimiting potentialities, with the former displaying looser species assemblage and a more ecotonal nature. This suggests that IOCBG patches may require more intensive/ careful protection as IOCBG patches are more prone to losing their floristic signature i.e. becoming less reminiscent of IOCBG if they are disturbed. However, this in no way suggests that KZNSS patches will remain intact without controlled protection. In fact, the KZNSS sites investigated here exhibited more taxa of conservation concern and alien taxa than IOCBG, as well as more endemic taxa.

The germinable soil seedbank provided useful insights into the disturbance history, alien plant threats and regenerative potential of the KZNSS and IOCBG sites investigated. However, the levels of similarity between the above- and below-ground flora for both vegetation was far below that expected for grasslands (Pierce and Cowling, 1991). Ecotonal (which has been confirmed as belonging to IOCBG) was shown to be more resilient to changes in the above-ground flora since it had a relatively

high abundance of individuals and species in the below-ground flora (see Bakker and Barendse, 1999). Given this fact, it is suggested that IOCBG may be superior to KZNSS in terms of regenerative potential. It is important to note that the seed banks of both vegetation types were not as rich (possibly as a result of degradation, isolation and disturbance in an urban setting) as other grasslands and both exhibited low levels of indigenous species and alien plant species, which suggests that species reintroduction and (particularly for the non-graminoid representatives) habitat restoration/rehabilitation may be necessary for both vegetation types if they continue to be disturbed/transformed.

This study identified several issues which were not specifically investigated but are important aspects for grassland classification and conservation. The first of these issues was the effects of fire as a disturbance on sub-tropical grassland types within an urban matrix (specifically KZNSS and IOCBG). Secondly, it was shown that both anthropogenic disturbance and herbivory can have effects on the germinable soil seedbank in KZNSS and IOCBG, but the exact mechanisms by which this occurs require further investigation.

## **6.2 Challenges and short-comings**

The first challenge facing this study was that a low number of sites were investigated due to the time and funding constraints. Whilst there are very few KZNSS and IOCBG sites remaining, it would have been more optimal to have included a few more sites so that more statistical comparisons could be made and used to better understand the variability of and relationship between KZNSS and IOCBG.

This study did not aim to investigate the effects of disturbance, but rather noted them. For this reason disturbance was not properly quantified and the study lacked a disturbance gradient by which the fundamental effects of disturbance could have been studied. Similarly, this study did not aim to investigate the effects of fire on KZNSS and IOCBG and thus fire history was not factored in and interpreted at each of the sites.

### **6.3 Recommendations for Future Research**

Future research on KZNSS and IOCBG (and subtropical grasslands in the broader sense) should include an investigation of the effects of fire as a disturbance in grassland patches within an urban matrix. The mechanisms by which herbivory influences the germinable soil seedbank and the implications/ impacts of above- and below-ground floristic dissimilarity also require further investigation.

Island biogeography theory may be unsuitable for studying grassland patches within an urban matrix since vegetation islands within urban settings may be highly similar and are impacted upon by anthropogenic disturbances that can lead to changing levels of isolation and connectivity over relatively short periods of space and time. Future research should also be conducted on other components of these grasslands (e.g. invertebrates) to determine whether or not an urban matrix negates island biogeography theory's predictions using lineages other than the flora. Future work should therefore take into account far greater spatial and temporal scales and use more non-equilibrium models to examine island biogeography theory within urban settings (see Rebele, 1994).

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## Appendix A

Species found by this study, invasive and redlist status (NE = not evaluated, LC = least concern, DDT = data deficient – taxonomically problematic, NT = near threatened, VU = vulnerable, EN = endangered) details as well as herbarium (Ward Herbarium, CCD = C.C. Drury for all numbers) for specimens collected during the study (X denotes a species was found in a particular site, but no herbarium specimen could be collected, hyphen denotes absence).

Family	Species name	Invasive Status	Redlist status	KZNSS-1	KZNSS-2	KZNSS-3	Eco-1	Eco-2	Eco-3	IOCBG-1	IOCBG-2
Acanthaceae	<i>Barleria obtusa</i> Nees	Indigenous	LC	X	X	X	-	CCD301	-	CCD267	-
	<i>Dyschoriste costata</i> (Nees) Kuntze	Indigenous	LC	-	-	-	CCD387	CCD356	CCD357	X	-
	<i>Dicliptera clinopodia</i> Nees.	Indigenous	LC	-	-	X	-	X	-	X	-
	<i>Isoglossa cilliata</i> Oerst.	Indigenous	LC	-	-	-	X	-	-	-	-
	<i>Ruellia cordata</i> Thunb.	Indigenous	LC	X	X	-	-	X	X	X	-
	<i>Rutty ovata</i> Harv.	Indigenous	LC	X	X	-	-	X	X	X	-
	<i>Thunbergia atriplicifolia</i> E.Mey.	Indigenous	LC	X	CCD217	CCD329	CCD392	CCD295	CCD359	CCD122	-
	<i>Thunbergia natalensis</i> Curtis, William	Indigenous	LC	-	X	X	-	X	X	X	-
Acanthaceae 2	N/A	N/A	-	-	-	-	-	-	-	X	-
Aizoaceae	<i>Zaleya pentandra</i> (L.) C.Jeffrey	Indigenous	LC	-	-	X	-	-	-	-	-
Alliaceae	<i>Tulbaghia acutiloba</i> Harv.	Indigenous	LC	CCD270	CCD222	-	-	-	-	X	CCD320
Amaranthaceae	<i>Amaranthus</i> sp. (hybrid)	N/A	N/A	-	-	-	-	-	X	-	-
Amaryllidaceae	<i>Boophone disticha</i> Herb.	Indigenous	Declining	-	-	-	-	-	X	-	-
	<i>Cyrtanthus breviflorus</i> Harv.	Indigenous	LC	-	-	-	-	-	-	CCD258	-
Anacardiaceae	<i>Searsia dentata</i> (Thunb.) F.A.Barkley	Indigenous	LC	-	-	X	-	-	-	-	-
Anthericaceae	<i>Chlorophytum cooperi</i> (Baker) Nordal	Indigenous	LC	-	-	-	-	-	-	CCD265	-

<b>Apiaceae</b>	<i>Alepidea amatymbica</i> Eckl. & Zeyh.	Indigenous	VU	X	X	-	-	X	X	-	-
	<i>Centella eriantha</i> Rich.	Indigenous	LC	X	-	X	-	-	-	X	-
<b>Apocynaceae</b>	<i>Asclepias albens</i> Schltr.	Indigenous	LC	X	X	X	-	CCD31	-	CCD129	-
	<i>Cynanchum ellipticum</i> (Harv.) Dyer, R.A.	Indigenous	LC	-	-	-	-	X	-	-	-
	<i>Schizoglossum atropurpureum</i> E.Mey	Indigenous	LC	-	X	-	-	-	-	-	-
<b>Asclepiadaceae</b>	<i>Cryptolepis oblongifolia</i> Schltr.	Indigenous	LC	CCD175	X	-	-	X	X	CCD417	-
<b>Asphodelaceae</b>	<i>Aloe linearifolia</i> A.Berger & Reynolds	Indigenous	NT	CCD173	-	-	-	-	-	-	-
	<i>Kniphofia linearifolia</i> Baker	Indigenous	LC	-	-	X	-	-	-	-	-
<b>Asteraceae</b>	<i>Ageratum houstonianum</i> Mill.	Invasive Alien Category 1b	NE	-	X	-	X	X	X	-	X
	<i>Aster bakerianus</i> Burt Davy	Indigenous	LC	CCD176	X	CCD336	CCD406	CCD342	CCD362	X	CCD384
	<i>Athrixia phyllicoides</i> DC	Indigenous	LC	X	-	X	CCD247	CCD10	CCD232	CCD160	CCD140
	<i>Baccharoides adoensis</i> H.Rob.	Indigenous	LC	X	-	-	-	-	X	-	-
	<i>Berkheya echinaceae</i> Burt Davy	Indigenous	LC	X	-	X	CCD85	CCD5	X	CCD128	-
	<i>Berkheya erysithales</i> Roessler	Indigenous	LC	X	-	-	-	X	-	X	-
	<i>Berkheya insignis</i> Thellung	Indigenous	LC	X	-	X	-	X	-	-	-
	<i>Berkheya multijuga</i> Roessler	Indigenous	LC	X	-	-	-	X	-	X	-
	<i>Berkheya rhapontica</i> Burt Davy	Indigenous	LC	X	-	X	X	X	-	X	-
	<i>Berkheya setifera</i> DC	Indigenous	LC	X	-	-	CCD403	CCD36	X	CCD130	-
	<i>Berkheya speciosa</i> O. Hoffm	Indigenous	LC	X	-	X	-	-	-	X	-
	<i>Berkheya umbellata</i> DC	Indigenous	LC	X	-	X	-	-	-	-	-
<i>Bidens pilosa</i> L.	Undeclared	NE	X	-	X	-	-	-	-	X	

	Alien Taxa										
<i>Callilepis laureola</i> DC.	Indigenous	LC	-	-	-	CCD398	-	CCD360	-	-	-
	Invasive										
<i>Chromolena odorata</i> L.	Alien Category 1b	NE	X	X	X	X	X	-	X	X	X
<i>Chrysanthemoides monolifera</i> (L.) Norl.	Indigenous	LC	X	-	-	-	-	-	X	-	-
<i>Dicoma zeyheri</i> Sond.	Indigenous	LC	-	-	-	-	CCD7	X	-	-	-
<i>Dimorphotheca jucunda</i> Phillips	Indigenous	LC	-	-	-	-	X	-	-	-	-
<i>Euryops laxus</i> (Harv.) Burt Davy	Indigenous	LC	X	CCD213	X	CCD253	CCD293	X	X	-	-
<i>Garuleum latifolium</i> Harv.	Indigenous	LC	-	X	-	-	-	CCD368	-	X	-
<i>Gazania krebsiana</i> Less.	Indigenous	LC	CCD271	-	-	-	CCD289	-	X	-	-
<i>Gerbera ambigua</i> Sch. Bip	Indigenous	LC	X	X	X	CCD409	CCD353	-	CCD425	CCD378	-
<i>Gerbera kraussi</i> (Cass.) Sch.Bip.	Indigenous	LC	X	-	-	-	-	-	-	-	-
<i>Gerbera piloselloides</i> (L.) Cass.	Indigenous	LC	-	-	-	-	CCD349	-	-	-	-
<i>Helichrysum adenocarpum</i> subsp. <i>adenocarpum</i> DC	Indigenous	LC	X	X	CCD240	CCD245	CCD6	CCD29	CCD141	CCD201	-
<i>Helichrysum allioides</i> Less.	Indigenous	LC	CCD443	-	-	-	-	-	-	CCD211	-
<i>Helichrysum appendiculatum</i> Lessing	Indigenous	LC	-	-	CCD112	CCD244	CCD74	CCD51	CCD145	CCD204	-
<i>Helichrysum argyrolepis</i> MacOwen	Indigenous	LC	-	-	-	-	X	-	-	-	-
<i>Helichrysum asplenifolius</i> Less.	Indigenous	LC	-	-	X	-	-	X	-	-	-
<i>Helichrysum aureonitens</i> Sch. Bip	Indigenous	LC	CCD174	CCD197	CCD118	CCD81	CCD2	CCD227	CCD243	CCD205	-
<i>Helichrysum aureum</i> Merrill	Indigenous	LC	X	X	X	CCD93	CCD297	CCD235	CCD149	CCD315	-
<i>Helichrysum auriceps</i> Hilliard	Indigenous	LC	CCD167	X	X	-	CCD72	CCD52	CCD132	-	-



<i>Helichrysum cymosum</i> D.Don	Indigenous	LC	-	-	CCD332	-	-	-	CCD143	-
<i>Helichrysum herbaceum</i> (Andrews) Sweet	Indigenous	LC	CCD171	-	X	-	CCD76	X	X	-
<i>Helichrysum inornatum</i> Hilliard & B.L.Burt	Indigenous	LC	X	-	-	-	-	-	-	-
<i>Helichrysum mundtii</i> Harv.	Indigenous	LC	-	-	-	-	CCD35	-	-	-
<i>Helichrysum nudifolium</i> (L.) Less.	Indigenous	LC	CCD278	-	CCD111	CCD94	CCD64	CCD233	CCD148	CCD318
<i>Helichrysum oreophillum</i> Klatt	Indigenous	LC	X	CCD220	CCD119	CCD83	CCD63	-	CCD139	-
<i>Helichrysum pallidum</i> DC	Indigenous	LC	-	-	X	CCD255	CCD62	X	X	-
<i>Helichrysum pillosellum</i> DC	Indigenous	LC	CCD276	-	-	CCD402	CCD296	X	-	-
<i>Hilliardiella pinifolia</i> (Less.) H.Rob.	Indigenous	LC	-	-	-	-	-	X	X	CCD321
<i>Lactuca indica</i> L.	Undeclared Alien Taxa		-	X	-	-	-	-	-	-
<i>Lactuca tysonii</i> Phillips	Indigenous	LC	X	-	X	X	X	-	X	-
<i>Lopholaena segmentata</i> S. Moore	Indigenous	LC	-	-	-	-	X	-	-	-
<i>Nidorella undulata</i> (Thunb.) Sond. ex Harv.	Indigenous	LC	-	-	-	X	-	-	-	-
<i>Phymaspermum acerosum</i> (DC.) Källersjö	Indigenous	LC	-	-	-	X	-	-	-	-
<i>Senecio brachypoda</i> DC	Indigenous	LC	-	-	X	-	-	-	-	-
<i>Senecio coronatus</i> (Thunb.) Harv.	Indigenous	LC	-	-	-	-	-	-	-	X
<i>Senecio glaberrimus</i> E. Walker	Indigenous	LC	CCD438	X	-	CCD407	CCD298	CCD363	CCD266	-
<i>Senecio madagascariensis</i> Poiret	Indigenous	LC	CCD441	-	X	-	-	X	CCD144	-
<i>Senecio natalicola</i> Hilliard	Indigenous	LC	-	-	-	-	-	X	-	-
<i>Senecio rhyncholaenus</i> DC	Indigenous	LC	-	-	-	CCD397	CCD354	X	X	X
<i>Sphagneticola trilobata</i> (L.)	Invasive	NE	-	-	-	-	-	-	X	-

	Pruski	Alien Category 1b										
	<i>Taraxacum officinale</i> F.H.Wigg.	Undeclared Alien Taxa	NE	-	X	-	X	X	-	-	-	-
	<i>Vernonia hirsuta</i> (DC.) Sch.Bip.	Indigenous	LC	-	-	X	-	-	-	-	-	-
	<i>Vernonia natalensis</i> Sch. Bp. ex. Walp	Indigenous	LC	CCD281	-	-	CCD411	CCD303	CCD361	X	-	-
	<i>Vernonia oligocephalus</i> Klatt	Indigenous	LC	CCD433	X	-	CCD401	CCD345	X	X	X	X
	<i>Vernonia sutherlandii</i> Harv.	Indigenous	LC	X	-	X	-	X	X	X	X	-
<b>Brassicaceae</b>	<i>Heliophila elongata</i> (Thun.) DC.	Indigenous	LC	-	X	-	-	-	-	-	-	-
<b>Campanulaceae</b>	<i>Lobelia flaccida</i> DC	Indigenous	LC	-	-	X	CCD95	CCD71	CCD237	CCD157	CCD207	
	<i>Monopsis decipiens</i> (Sond.) Thulin	Indigenous	LC	-	-	CCD388	-	-	-	X	CCD379	
	<i>Wahlenbergia huttonii</i> (Sond.) Thulin	Indigenous	LC	-	-	CCD73	CCD100	X	X	-	-	
<b>Capparaceae</b>	<i>Cleome bororensis</i> (Klotzsch) Oliv.	Indigenous	LC	X	X	-	-	-	-	-	-	
<b>Caryophyllaceae</b>	<i>Dianthus zeyheri</i> Sond.	Indigenous	LC	X	-	-	CCD313	CCD34	CCD236	-	-	
<b>Colchicaceae</b>	<i>Colchicum striatum</i> (Hochst. ex A.Rich.) J.C.Manning & Vinn.	Indigenous	LC	-	-	-	-	X	-	-	-	
<b>Commelinaceae</b>	<i>Commelina africana</i> L.	Indigenous	LC	CCD437	CCD192	CCD110	CCD416	-	CCD366	CCD133	CCD375	
	<i>Commelina benghalensis</i> L.	Indigenous	LC	X	X	CCD121	CCD88	CCD351	CCD60	X	CCD373	
	<i>Cynotis speciosa</i> Hasskarl	Indigenous	LC	CCD436	X	CCD334	CCD394	CCD33	CCD365	CCD423	-	
<b>Convolvulaceae</b>	<i>Ipomoea albivenia</i> Sweet	Indigenous	LC	X	CCD327	-	-	X	-	X	-	
	<i>Ipomoea indica</i> (Burm.f.) Merr.	Invasive Alien Category 1b	NE	-	-	-	-	-	X	X	-	
<b>Crassulaceae</b>	<i>Crassula alba</i> Forsskal	Indigenous	LC	X	X	X	-	X	CCD231	CCD156	-	

	<i>Crassula vaginata</i> Eckl. & Zeyh.	Indigenous	LC	-	-	-	CCD84	CCD65	-	CCD159	-
	<i>Kalanchoe rotundifolia</i> Haworth	Indigenous	LC	-	-	-	-	-	X	-	-
<b>Cucurbitaceae</b>	<i>Cucumis zeyheri</i> Sond.	Indigenous	LC	-	-	-	-	-	-	-	CCD381
	<i>Bulbostylis hispidula</i> Haines	Indigenous	LC	X	-	X	-	X	-	X	-
	<i>Carex zuluensis</i> C.B.Clarke	Indigenous	LC	-	-	-	-	-	-	-	X
	<i>Cyperus compressus</i> L.	Indigenous	LC	-	X	X	-	-	X	-	X
	<i>Cyperus congestus</i> Vahl.	Indigenous	LC	-	-	X	-	-	-	-	X
<b>Cyperaceae</b>	<i>Cyperus obtusiflorus</i> var. <i>obtusiflorus</i> Vahl	Indigenous	LC	CCD168	CCD190	CCD115	CCD87	CCD1	CCD58	CCD127	CCD372
	<i>Cyperus rotundus</i> L.	Indigenous	LC	-	-	-	-	-	-	-	CCD377
	<i>Cyperus sphaerocephalus</i> Vahl	Indigenous	LC	X	X	CCD333	CCD415	X	CCD27	CCD426	-
	<i>Kyllinga alba</i> Nees	Indigenous	LC	-	CCD196	-	-	-	-	-	-
<b>Dennstaedtiaceae</b>	<i>Pteridium aquilinum</i> Decken	Indigenous	LC	X	CCD282	X	-	-	X	-	-
<b>Dipsaceae</b>	<i>Scabiosa columbaria</i> L.	Indigenous	LC	X	X	-	CCD391	CCD69	CCD367	CCD420	-
<b>Ebenaceae</b>	<i>Diospyros galpinii</i> Winter	Indigenous	LC	-	-	-	-	-	X	X	-
	<i>Eriospermum cooperi</i> Baker	Indigenous	LC	-	-	X	-	-	-	-	CCD324
<b>Eriospermaceae</b>	<i>Eriospermum mackenii</i> (Hook.f.) Baker	Indigenous	LC	CCD280	X	CCD340	X	CCD352	X	X	CCD385
	<i>Eriospermum ornithogaloides</i> Baker	Indigenous	LC	CCD439	-	-	-	-	-	-	-
	<i>Acalypha punctata</i> Mei. ex Krauss	Indigenous	LC	-	-	CCD338	CCD254	CCD291	-	CCD257	-
<b>Euphorbiaceae</b>	<i>Clutia affinis</i> Sond.	Indigenous	LC	X	-	X	-	-	X	X	-
	<i>Clutia pulchella</i> L.	Indigenous	LC	X	X	-	-	-	X	X	-
	<i>Euphorbia ericoides</i> Lam.	Indigenous	LC	-	-	-	-	-	-	CCD264	-
	<i>Euphorbia natalensis</i> Bernh.	Indigenous	LC	-	-	-	-	-	-	CCD429	-
	<i>Acacia xanthophloea</i> Benth.	Indigenous	LC	-	-	-	-	-	-	X	-
<b>Fabaceae</b>	<i>Argyrolobium pauciflorum</i>	Indigenous	LC	-	-	-	-	CCD305	CCD364	X	-

Eckl. & Zeyh.											
<i>Aspalathus altissima</i> Dahlgren	Indigenous	LC	X	-	-	-	-	X	-	-	
<i>Chamaecrista plumosa</i> E. Mey (Meyer)	Indigenous	LC	X	X	X	X	CCD30	CCD56	CCD123	CCD374	
<i>Crotalaria lanceolata</i> E.Mey.	Indigenous	LC	-	X	-	-	-	X	X	-	
<i>Crotalaria pallida</i> Aiton	Indigenous	LC	-	X	-	-	X	X	CCD259	-	
<i>Crotalaria dura</i> J.M.Wood & M.S.Evans	Indigenous	NT	-	-	-	CCD410	-	-	CCD428	CCD383	
<i>Desmodium ciliare</i> DC	Unlisted Alien Taxa	NE	X	X	X	-	-	X	-	-	
<i>Desmodium setigerum</i> Harv.	Indigenous	LC	-	-	X	X	-	-	-	-	
<i>Eriosema cordatum</i> Sond.	Indigenous	LC	CCD182	CCD194	X	-	CCD292	X	X	-	
<i>Eriosema populifolium</i> subsp. <i>populifolium</i> Benth. ex Harv.	Indigenous	EN	CCD273	CCD283	X	CCD249	CCD66	X	CCD261	CCD323	
<i>Eriosema preptum</i> C.H.Stirt.	Indigenous	LC	-	-	-	-	-	-	-	CCD369	
<i>Eriosema salignum</i> E. Mey	Indigenous	LC	-	-	-	-	X	X	-	-	
<i>Indigofera dimiata</i> Vog. ex Walp.	Indigenous	LC	X	X	-	-	X	X	X	-	
<i>Indigofera eriocarpa</i> E.Mey	Indigenous	LC	-	-	-	-	-	-	X	-	
<i>Indigofera hedyantha</i> Eckl. & Zeyh.	Indigenous	LC	-	-	X	-	-	-	-	-	
<i>Indigofera hilaris</i> Eckl. & Zeyh.	Indigenous	LC	CCD177	X	CCD328	CCD390	CCD350	CCD313	X	-	
<i>Indigofera obscura</i> N.E.Br.	Indigenous	LC	X	X	X	-	-	-	-	-	
<i>Indigofera velutina</i> E. Mey	Indigenous	LC	X	X	-	-	X	X	-	-	
<i>Lotononis filiformis</i> B.-E.van Wyk	Indigenous	EN	X	-	-	-	CCD67	X	X	-	
<i>Lotononis galpinii</i> Dummer	Indigenous	LC	-	-	-	-	X	-	-	-	
<i>Ophrestia oblongifolia</i> (E.Mey.) H.M.L.Forbes	Indigenous	LC	-	-	CCD326	-	-	-	-	X	
<i>Pseudarthria hookeri</i> Wight	Indigenous	LC	-	-	X	-	-	-	-	-	

	& Arn.										
	<i>Sphenostylis angustifolia</i> Sond.	Indigenous	LC	X	CCD285	X	-	CCD294	CCD309	CCD262	-
	<i>Tephrosia elongata</i> E.Mey.	Indigenous	LC	X	-	X	-	-	X	-	-
	<i>Tephrosia macropoda</i> Harv.	Indigenous	LC	CCD169	CCD198	X	CCD102	CCD75	CCD54	CCD152	X
	<i>Tephrosia marginella</i> Forbes	Indigenous	LC	X	-	X	-	X	X	X	-
	<i>Tephrosia polystachya</i> E. Mey	Indigenous	LC	X	X	X	X	-	X	-	CCD212
	<i>Vigna unguiculata</i> (L.) Walp.	Indigenous	LC	-	X	-	-	-	-	X	X
	<i>Vigna vexillata</i> (L.) A.Rich.	Indigenous	LC	-	-	-	CCD412	-	-	CCD418	-
	<i>Zornia capensis</i> Persoon, L	Indigenous	LC	CCD183	-	CCD335	CCD400	X	X	CCD137	CCD370
	<i>Albizia</i> sp.	N/A	N/A	X	-	-	-	-	-	-	X
<b>Gentianaceae</b>	<i>Sebaea natalensis</i> Schinz	Indigenous	LC	-	-	-	X	X	-	-	X
	<i>Sebaea sedoides</i> Gilg	Indigenous	LC	-	-	-	X	-	-	-	-
	<i>Pelargonium pulchellum</i> Hoffmans	Indigenous	LC	-	-	X	-	-	-	-	-
<b>Hyacinthaceae</b>	<i>Albuca setosa</i> Jacq.	Indigenous	LC	-	X	-	-	CCD38	X	-	-
	<i>Drimia elata</i> Jacq.	Indigenous	DDT	-	-	-	X	-	-	-	-
	<i>Ledobouria revoluta</i> (L.f.) Jessop	Indigenous	LC	-	CCD223	CCD337	CCD405	-	-	-	-
	<i>Ornithogalum tenuifolium</i> F.Delaroche	Unlisted Alien Taxa	NE	-	-	-	-	-	-	-	CCD382
<b>Hypericaceae</b>	<i>Hypericum aethiopicum</i> Thunb.	Indigenous	LC	-	-	-	CCD396	CCD346	-	-	CCD322
<b>Hypoxidaceae</b>	<i>Hypoxis argentea</i> Harv. ex Baker	Indigenous	LC	CCD277	CCD221	-	-	CCD302	CCD312	CCD263	CCD319
	<i>Hypoxis decumbens</i> L.	Unlisted Alien Taxa	NE	X	X	X	-	-	-	-	-
	<i>Hypoxis filiformis</i> Baker	Indigenous	LC	CCD434	-	-	CCD77	CCD344	CCD311	CCD421	CCD317
	<i>Hypoxis hemerocallidea</i> Fisch., C.A.Mey. & Avé-Lall.	Indigenous	Declining	CCD442	X	-	CCD414	-	-	-	CCD316

	<i>Hypoxis rigidula</i> Baker	Indigenous	LC	X	-	CCD330	-	-	-	-	CCD371
<b>Iridaceae</b>	<i>Aristea abyssinica</i> Engler	Indigenous	LC	CCD162	X	-	-	CCD68	X	CCD151	-
	<i>Aristea torulosa</i> Klatt	Indigenous	LC	-	-	-	CCD413	-	-	CCD125	-
	<i>Dierama argyreum</i> L.Bolus	Indigenous	LC	-	-	-	CCD399	CCD300	-	-	-
	<i>Gladiolus dalenii</i> Van Geel	Indigenous	LC	-	-	-	-	-	-	X	-
	<i>Gladiolus inandensis</i> Baker	Indigenous	LC	CCD275	X	-	-	CCD290	-	CCD422	-
	<i>Gladiolus longicollis</i> Baker	Indigenous	LC	-	-	-	-	CCD347	X	-	-
	<i>Hesperantha baurii</i> Baker	Indigenous	LC	-	-	CCD339	CCD389	X	-	CCD430	-
	<i>Watsonia densiflora</i> Baker	Indigenous	LC	CCD164	CCD199	CCD109	CCD79	CCD3	CCD61	CCD136	-
<b>Lamiaceae</b>	<i>Leonotis leonurus</i> (L.) R.Br.	Indigenous	LC	-	X	X	X	X	X	X	-
	<i>Leucas martinicensis</i> Brown	Indigenous	LC	-	-	X	-	-	X	X	-
	<i>Ocimum filamentosum</i> Forssk.	Indigenous	LC	-	-	-	CCD408	X	CCD358	CCD268	-
	<i>Plectranthus rehmannii</i> Gurke	Indigenous	LC	X	-	-	-	CCD17	-	-	-
	<i>Pycnostachys fructosus</i> Hook	Indigenous	LC	-	-	-	-	-	X	-	-
	<i>Pycnostachys reticulata</i> Benth.	Indigenous	LC	X	-	-	-	-	CCD228	X	-
	<i>Rabdosiella calycina</i> (Benth.) Codd	Indigenous	LC	X	-	-	-	-	X	X	CCD209
	<i>Syncolostemon parviflorus</i> E. Mey. ex Benth.	Indigenous	LC	-	-	-	X	X	CCD55	CCD135	-
<i>Teucrium kraussii</i> Codd	Indigenous	LC	-	-	X	-	-	-	X	-	
<b>Malvaceae</b>	<i>Corchorus asplenifolius</i> Burch.	Indigenous	LC	-	-	-	-	-	-	X	-
	<i>Hibiscus trionum</i> L.	Undeclared Alien Taxa	NE	-	-	X	-	-	-	X	-
	<i>Melhania didyma</i> Eckl. & Zeyh.	Indigenous	LC	X	X	X	-	X	-	X	-
	<i>Triumfetta pilosa</i> Roth	Indigenous	LC	X	X	X	-	X	-	-	X
<b>Melastomataceae</b>	<i>Dissotis princeps</i> Triana	Indigenous	LC	-	-	X	CCD86	-	CCD53	-	CCD203

<b>Orchidaceae</b>	<i>Eulophia hians</i> Spreng.	Indigenous	LC	-	-	X	-	-	-	-	-
	<i>Eulophia parviflora</i> (Lindl.) A.V.Hall	Indigenous	LC	X	X	-	CCD250	-	-	-	-
	<i>Polystachya virgata</i> Schltr.	Unlisted Alien Taxa	NE	-	-	-	X	-	-	-	CCD208
	<i>Satyrium longicauda</i> Lindl.	Indigenous	LC	-	-	-	-	CCD42	-	-	-
<b>Orobanchaceae</b>	<i>Alectra sessiliflora</i> (Vahl) Kuntze	Indigenous	LC	-	-	CCD106	CCD103	X	-	CCD155	-
	<i>Buchnera simplex</i> Druce	Indigenous	LC	CCD178	-	X	CCD82	CCD8	X	CCD419	CCD202
	<i>Graderia scabra</i> (L.f.) Benth.	Indigenous	LC	-	-	-	-	CCD348	-	X	-
<b>Oxalidaceae</b>	<i>Oxalis semiloba</i> R. Monteiro	Indigenous	LC	-	X	-	CCD91	X	-	-	-
<b>Plantaginaceae</b>	<i>Plantago major</i> L.	Undeclared Alien Taxa	NE	X	-	-	-	-	-	-	-
<b>Poaceae</b>	<i>Alloteropsis semialata</i> Hitchc.	Indigenous	LC	CCD274	CCD216	-	CCD251	CCD343	-	-	-
	<i>Andropogon appendiculatus</i> Nees	Indigenous	LC	CCD180	CCD200	CCD242	-	X	X	CCD431	-
	<i>Andropogon gayanus</i> Kunth	Indigenous	LC	X	-	X	-	X	X	CCD260	-
	<i>Aristida junciformis</i> Trinius	Indigenous	LC	CCD184	CCD187	CCD120	CCD90	CCD16	CCD24	CCD154	CCD188
	<i>Ctenium connicum</i> Nees	Indigenous	LC	CCD226	CCD219	X	-	CCD11	CCD19	CCD158	-
	<i>Cymbopogon citratus</i> Stapf.	Unlisted Alien Taxa	NE	-	-	X	-	-	-	-	-
	<i>Cymbopogon nardus</i> (L.) Rendle	Indigenous	LC	-	-	X	-	-	CCD20	X	-
	<i>Cynodon dactylon</i> (L.) Pers.	Indigenous	LC	-	-	-	-	-	CCD25	-	-
	<i>Digitaria eriantha</i> Steudel	Indigenous	LC	X	CCD189	CCD117	CCD96	CCD9	CCD21	CCD153	X
	<i>Elionurus muticus</i> (Spreng.) Kunth	Indigenous	LC	X	-	-	-	-	-	-	-
	<i>Eragrostis racemosa</i> Steudel	Indigenous	LC	CCD179	X	X	-	X	-	CCD147	-
	<i>Eragrostis superba</i> Peyritsch	Indigenous	LC	-	CCD214	-	CCD92	-	CCD22	-	-
<i>Hemarthria altissima</i> (Poir.) Stapf. & C.E. Hubb.	Indigenous	LC	-	-	X	-	X	X	X	-	

<i>Heteropogon contortus</i> (L.) Roem. & Schult.	Indigenous	LC	X	X	-	-	-	-	-	-	-
<i>Imperata cylindrica</i> Raeusch	Indigenous	LC	-	X	X	-	X	X	-	-	CCD314
<i>Loudetia simplex</i> Vog. ex Walp.	Indigenous	LC	CCD165	-	CCD107	CCD246	CCD12	X	X	-	-
<i>Melinis nerviglumis</i> (Franch.) Zizka	Indigenous	LC	-	-	-	-	-	-	-	CCD427	-
<i>Melinis repens</i> (Willd.) Zizka	Indigenous	LC	CCD279	CCD218	CCD341	-	CCD307	CCD230	CCD269	-	-
<i>Monocymbium cerasiiforme</i> Stapf.	Indigenous	LC	CCD163	CCD186	CCD116	CCD99	CCD13	CCD238	CCD138	X	-
<i>Oropetium capense</i> Stapf.	Indigenous	LC	CCD172	-	CCD113	-	X	X	-	-	-
<i>Panicum natalense</i> Steudel	Indigenous	LC	CCD185	CCD225	CCD108	CCD97	CCD14	CCD23	CCD131	CCD368	-
<i>Panicum schinzii</i> Hackel	Indigenous	LC	CCD181	X	CCD241	CCD98	X	CCD26	CCD150	CCD206	-
<i>Paspalum notatum</i> Fluge	Undeclared Alien Taxa	NE	-	-	X	X	-	-	-	-	-
<i>Pennisetum villosum</i> R.Br.	Invasive Alien Category 1b	NE	-	-	-	-	-	CCD229	CCD142	-	-
<i>Poa annua</i> Steud.	Unlisted Alien Taxa	NE	X	X	X	X	CCD37	-	-	-	X
<i>Rendlia altera</i> (Rendle) Chiov.	Indigenous	LC	X	X	-	CCD404	CCD39	X	-	-	-
<i>Setaria lindenbergiana</i> Stapf.	Indigenous	LC	-	CCD191	-	CCD101	CCD40	X	CCD146	-	-
<i>Setaria sphacelata</i> var <i>sericea</i> Stapf. & C.E.Hubb.	Indigenous	LC	-	-	CCD114	CCD78	CCD41	CCD234	-	-	-
<i>Setaria verticillata</i> (L.) P.Beauv.	Indigenous	LC	X	X	-	-	-	-	-	-	-
<i>Sporobolus africanus</i> (Poir.) Robyns & Tournay	Indigenous	LC	-	-	-	-	CCD15	-	CCD432	-	-
<i>Sporobolus fimbriatus</i> Nees	Indigenous	LC	X	CCD224	X	-	-	CCD18	X	-	-
<i>Themeda triandra</i> Forsskal	Indigenous	LC	X	X	X	X	CCD306	X	X	-	-
<i>Tristachya leucothrix</i> Trin. ex Nees	Indigenous	LC	X	-	X	X	X	-	-	-	-



<b>Polygalaceae</b>	<i>Polygala amatymbica</i> Burch. ex DC.	Indigenous	LC	X	-	-	-	CCD50	X	-	-
	<i>Polygala hottentotta</i> C.Presl	Indigenous	LC	-	-	-	X	-	-	-	-
	<i>Polygala refracta</i> Burch. ex DC.	Indigenous	LC	X	-	-	-	-	-	-	-
<b>Proteaceae</b>	<i>Protea roupelliae</i> Meier	Indigenous	LC	X	X	-	-	X	X	X	-
	<i>Protea welwitschii</i> subsp. <i>welwitschii</i> Engler	Indigenous	LC	X	X	-	-	X	X	X	-
<b>Roseaceae</b>	<i>Rubus rosifolius</i> Sm.	Undeclared Alien Taxa	NE	-	-	X	-	-	-	-	-
<b>Rubiaceae</b>	<i>Burchellia bubalina</i> (L.f.) Sims	Indigenous	LC	X	-	-	-	X	-	X	-
	<i>Conostomium natalense</i> (Hochst.) Bremek.	Indigenous	LC	X	-	-	X	X	X	-	-
	<i>Eriosemopsis subanisophylla</i> Robyns	Indigenous	VU	-	-	-	-	X	X	X	-
	<i>Kohautia amatymbica</i> Eckl. & Zeyh.	Indigenous	LC	CCD440	-	-	X	CCD76	X	CCD134	CCD380
	<i>Oldenlandia herbacea</i> (Willd.) Roxb.	Indigenous	LC	-	-	-	-	-	-	X	-
	<i>Pachystigma venosum</i> Hochst.	Indigenous	LC	X	-	X	-	X	X	CCD424	-
	<i>Pavetta graciliflora</i> Wall	Indigenous	LC	-	-	X	-	-	X	X	-
	<i>Pentanisia angustifolia</i> Hochst.	Indigenous	LC	CCD166	CCD193	CCD105	CCD80	CCD32	CCD57	CCD123	-
	<i>Rothmannia globosa</i> (Hochst.) Keay	Indigenous	LC	X	-	-	-	-	X	-	-
	<i>Oldenlandia rosulata</i> K.Schum.	Indigenous	LC	-	-	X	-	-	-	-	-
<i>Anthospermum</i> spp	N/A	N/A	-	-	X	-	-	-	-	-	
<b>Rununculaceae</b>	<i>Clematis brachiata</i> Thunb.	Indigenous	LC	-	-	X	-	-	-	-	-
<b>Santalaceae</b>	<i>Thesium natalense</i> Sond.	Indigenous	LC	X	CCD286	CCD331	CCD248	X	-	-	CCD376
<b>Scrophulariaceae</b>	<i>Hebenstretia comosa</i> Hochst.	Indigenous	LC	X	CCD288	-	-	-	-	X	-
	<i>Selago monticola</i> J.M.Wood	Indigenous	LC	-	-	-	-	-	-	X	-

	& M.S.Evans										
	<i>Selago trausaldii</i> Killick	Indigenous	LC	X	CCD287	X	-	-	X	X	-
	<i>Sutera floribunda</i> Kuntze	Indigenous	LC	-	-	-	X	X	-	-	-
	<i>Tetraselago natelensis</i> Rolfe	Indigenous	LC	CCD170	CCD195	CCD239	CCD104	X	CCD28	CCD161	-
	<i>Zaluzianskya elongata</i> Hilliard & B.L.Burt	Indigenous	LC	X	-	X	-	-	X	-	-
<b>Sinopteridaceae</b>	<i>Cheilanthes viridis</i> Sw.	Indigenous	LC	-	-	CCD325	X	-	-	X	-
<b>Smilacaceae</b>	<i>Smilax anceps</i> Willdenow	Indigenous	LC	-	-	X	X	X	-	X	-
<b>Strelitziaceae</b>	<i>Strelitzia</i> sp.	N/A	N/A	-	-	-	-	-	X	-	X
<b>Thymelaeaceae</b>	<i>Gnidia burchellii</i> Gilg	Indigenous	LC	-	-	X	-	CCD4	CCD59	CCD124	-
	<i>Gnidia kruassiana</i> Meisn..	Indigenous	LC	CCD272	CCD215	-	CCD252	X	CCD308	CCD256	-
	<i>Gnidia splendens</i> Meisn..	Indigenous	LC	X	-	-	-	-	-	-	-
	<i>Lasiosiphon capitatus</i> (L.f.) Burt Davy	Indigenous	LC	X	CCD284	X	X	CCD304	CCD310	X	CCD210
<b>Verbenaceae</b>	<i>Lantana camera</i> L.	Invasive Alien Category 1b	NE	-	X	-	X	X	-	-	X
<b>Violaceae</b>	<i>Hybanthus enneaspermus</i> (L.) F.Muell.	Unlisted Alien Taxa	NE	-	-	-	CCD395	CCD355	-	-	-
<b>Unknown</b>	Type 1	N/A	N/A	-	X	-	-	-	-	X	-
	Type 2	N/A	N/A	-	-	-	-	-	-	X	-

## Appendix B

Species found in the germinable soil seedbank, their conservation/ alien status as well as the mean (and standard deviation) density of seeds per square metre for the different vegetation categories used in this study.

Family	Species	Conservation/Alien Status	Vegetation category (number of sites)		
			Mean $\pm$ Standard deviation germinable seeds per m <sup>2</sup>		
			KZNSS (3)	Eco (3)	IOCBG (2)
<b>Asteraceae</b>	<i>Ageratum houstonianum</i> Mill.	Invasive Alien: Category 1b	0.7038 $\pm$ 3.305	1.467 $\pm$ 7.741	0.08060 $\pm$ 0.9291
	<i>Aster bakerianus</i> Burt Davey	Indigenous, Least Concern	0.1401 $\pm$ 1.579	0.02720 $\pm$ 0.5165	0.2079 $\pm$ 1.807
	<i>Helichrysum adenocarpum</i> subsp. <i>adenocarpum</i> DC	Indigenous, Least Concern	1.642 $\pm$ 4.792	0.502 $\pm$ 2.780	0.9081 $\pm$ 3.492
	<i>Helichrysum appendiculatum</i> Lessing	Indigenous, Least Concern	0.6360 $\pm$ 3.031	0.2781 $\pm$ 2.035	0.3876 $\pm$ 2.014
	<i>Helichrysum aureonitens</i> Sch. Bip	Indigenous, Least Concern	0.2443 $\pm$ 1.850	0.3824 $\pm$ 2.269	0.2559 $\pm$ 1.614
	<i>Senecio glabberimus</i> E. Walker	Indigenous, Least Concern	0.04450 $\pm$ 0.8441	0.09970 $\pm$ 1.369	0.1245 $\pm$ 1.159
	<i>Senecio madagascarensis</i> Poiret	Indigenous, Least Concern	0.7028 $\pm$ 3.014	0.8490 $\pm$ 4.058	0.6681 $\pm$ 3.124
<b>Poaceae</b>	<i>Digitaria eriantha</i> Steudel	Indigenous, Least Concern	0.2068 $\pm$ 1.620	0.5524 $\pm$ 4.003	0.9778 $\pm$ 8.110
	<i>Monocymbium ceresiiforme</i> Stapf.	Indigenous, Least Concern	1.647 $\pm$ 5.538	4.110 $\pm$ 32.74	0.3825 $\pm$ 2.210
	<i>Setaria lindenbergiana</i> Stapf.	Indigenous, Least Concern	0.9551 $\pm$ 3.672	5.527 $\pm$ 18.38	0.5018 $\pm$ 3.010

	<i>Themeda triandra</i> Forsskal	Indigenous, Least Concern	0.000 ± 0.000	0.03970 ± 0.7532	0.1525 ± 1.424
<b>Fabaceae</b>	<i>Chamaechrista plumosa</i> E. Mey (Meyer)	Indigenous, Least Concern	0.1187 ± 1.300	0.1219 ± 2.314	0.000 ± 0.000
	<i>Indigofera hilaris</i> Eckl. & Zeyh.	Indigenous, Least Concern	0.05170 ± 0.9801	0.1149 ± 1.284	0.000 ± 0.000
	<i>Tephrosia macropoda</i> Harv.	Indigenous, Least Concern	0.1148 ± 1.312	0.05830 ± 0.7815	0.000 ± 0.000
<b>Iridaceae</b>	<i>Aristea abyssinica</i> Engler	Indigenous, Least Concern	0.000 ± 0.000	0.08740 ± 1.658	0.05080 ± 0.8212
	<i>Watsonia densiflora</i> Baker	Indigenous, Least Concern	0.06630 ± 0.9224	0.2782 ± 2.0765	0.000 ± 0.000
<b>Rubiaceae</b>	<i>Kohautia amatymbica</i> Eckl. & Zeyh.	Indigenous, Least Concern	0.000 ± 0.000	0.1309 ± 1.391	0.000 ± 0.000
	<i>Pachystigma venosum</i> Hochst.	Indigenous, Least Concern	0.000 ± 0.000	0.01690 ± 0.3204	0.1025 ± 0.9955
<b>Lamiaceae</b>	<i>Ocimum filamentosum</i> Forsskal	Indigenous, Least Concern	0.000 ± 0.000	0.02290 ± 0.4346	0.000 ± 0.000
<b>Campanulaceae</b>	<i>Lobellia flaccida</i> DC	Indigenous, Least Concern	0.000 ± 0.000	0.02820 ± 0.5342	0.05180 ± 0.5913
<b>Cyperaceae</b>	<i>Cyperus obtusiflorus</i> var. <i>obtusiflorus</i> Vahl	Indigenous, Least Concern	0.02600 ± 0.4942	0.1578 ± 2.145	0.2918 ± 2.552
<b>Eriospermaceae</b>	<i>Eriospermum mackeenii</i> (Hook.f.) Baker	Indigenous, Least Concern	0.03460 ± 0.6571	0.000 ± 0.000	0.04800 ± 0.7749
<b>Myrtaceae</b>	<i>Eugenia albanensis</i> Sond.	Indigenous, Least Concern	0.2625 ± 1.768	0.2378 ± 1.907	0.07890 ± 0.8994
<b>Santalaceae</b>	<i>Thesium natalense</i> Sond.	Indigenous, Least Concern	0.000 ± 0.000	0.01770 ± 0.3354	0.000 ± 0.000
<b>Scrophulariaceae</b>	<i>Tetraselago natalense</i> Rolfe	Indigenous, Least Concern	0.1669 ± 1.429	0.1226 ± 1.184	0.2831 ± 2.551

Categories are KZNSS = KwaZulu-Natal Sandstone Sourveld, Eco = Ecotonal and IOCBG = Indian Ocean Coastal Belt Grassland