


# A lot gone but still hanging on: Floristics of remnant patches of endangered KwaZulu-Natal Sandstone Sourveld



## Authors:

Charmaine C. Drury<sup>1</sup>  
Syd Ramdhani<sup>1</sup>  
Sershen Naidoo<sup>1</sup>   
Clinton Carbutt<sup>2</sup>  
Renira Boodhraj<sup>1</sup>  
Philani Mbatha<sup>1</sup>

## Affiliations:

<sup>1</sup>School of Life Sciences,  
Westville Campus, University  
of KwaZulu-Natal,  
South Africa

<sup>2</sup>School of Life Sciences,  
Pietermaritzburg Campus,  
University of KwaZulu-Natal,  
South Africa

## Corresponding author:

Syd Ramdhani,  
ramdhani@ukzn.ac.za

## Dates:

Received: 18 June 2016  
Accepted: 10 Aug. 2016  
Published: 03 Dec. 2016

## How to cite this article:

Drury, C.C., Ramdhani, S.,  
Naidoo, S., Carbutt, C.,  
Boodhraj, R. & Mbatha, P.,  
2016, 'A lot gone but still  
hanging on: Floristics of  
remnant patches of  
endangered KwaZulu-Natal  
Sandstone Sourveld', *Bothalia*  
46(2), a2110. <http://dx.doi.org/10.4102/abc.v46i2.2110>

## Copyright:

© 2016. The Authors.  
Licensee: AOSIS. This work  
is licensed under the  
Creative Commons  
Attribution License.

## Read online:



Scan this QR  
code with your  
smart phone or  
mobile device  
to read online.

**Background:** KwaZulu-Natal Sandstone Sourveld (KZNSS) is an endangered subtropical grassland type, of which a large proportion occurs within the eThekweni Municipal Area (EMA).

**Objectives:** Examining the flora of KZNSS will allow a more fundamental understanding of the potential variability across remnant patches of this vegetation type, increasing the ability to accurately delimit KZNSS from adjacent similar vegetation types.

**Method:** Floristic data were collected using quadrats and transects for three recognised KZNSS sites (Giba Gorge Environmental Precinct (GGEP), Inanda Mountain (IM) and Springside Nature Reserve (SSNR)), all within the EMA. Alpha diversity (Shannon's exponential and Simpson's inverse indices) and beta diversity measures were calculated and compared across all sites. An unweighted pair group method with arithmetic mean (UPGMA) analysis using the Jaccard index and a non-parametric multidimensional scaling (NMDS) ordination were used to assess similarity amongst quadrats across the three sites.

**Results:** One hundred and thirty-one plant species were found to occur in GGEP, 95 in IM and 121 in SSNR. However, of the total 193 species found to occur collectively (i.e. quadrat and transect data combined) across the three sites, only 50 species were common to all these sites. The results of the alpha and beta diversity analyses revealed significant floristic variability both within and across the KZNSS sites sampled, with Shannon's exponential index being highest in SSNR, followed by GGEP and lowest in IM. The lack of controlled access and unregulated burning regimes appear to have clearly affected the flora at the IM site in terms of species richness and increased evenness, as well as the relatively greater presence of introduced alien species and lower abundances of taxa of conservation concern. The pristine GGEP site had the highest number of species in total, with species being less evenly spread across the site, as well as the highest number of taxa conservation and low abundances of alien species. The main separations in the ordination results can be attributed to quadrat sampling performed pre- and post-burn.

**Conclusion:** The floristic distinction of IM from GGEP and SSNR is attributed here to the intermediate disturbance effect of fire in grasslands which can lead to species loss if burning is too frequent. The implications of these findings are discussed in the context of the delimitation, classification and management of KZNSS.

## Introduction

Subtropical grasslands in South Africa are found mostly along the eastern seaboard, in the Maputaland-Pondoland-Albany biodiversity hotspot, where suitable climate prevails. However, this biodiversity hotspot has a very high overall vulnerability, being threatened by invasive alien plant species (IAPS), urbanisation and agricultural activities (Jonas *et al.* 2006). Rouget *et al.* (2006) found that many of the vegetation types (including grasslands) within this hotspot are unique in terms of floristic composition, yet are subject to very little protection, with less than 60% of their natural habitat remaining. Protection levels are poorest around urban areas, where the overall vulnerability is higher than the surrounding rural areas (Jonas *et al.* 2006).

One of the most severely transformed vegetation types in the region is KwaZulu-Natal Sandstone Sourveld (KZNSS). A significant part of the range of KZNSS is found within the eThekweni Municipal Area (EMA) within KwaZulu-Natal Province. This vegetation type, located within an urban matrix, is listed by the Department of Environmental Affairs (2011) as endangered owing

to the irreversible loss of natural habitat. KZNSS falls within the Savanna biome and was coded as SVs5 by Rutherford *et al.* (2006). New patches of KZNSS are being identified and, with the present study, further increases in the size of KZNSS are likely. It is a species-rich grassland type with high levels of endemism, characterised by scattered geoxylic suffrutices, low shrubs and proteas occurring on flat or rolling plateau tops and steep slopes. According to Rutherford *et al.* (2006), KZNSS contains 12 endemic taxa (i.e. diagnostic taxa), namely *Brachystelma modestum* R.A.Dyer, *B. natalense* (Schltr.) N.E.Br., *B. pulchellum* (Harv.) Schltr., *Crassula inandensis* Schönland & Baker f., *Cynorkis compacta* (Rchb.f.) Rolfe, *Eriosema populifolium* subsp. *populifolium* Benth. ex Harv., *E. rossii* (Oliv.) Källersjö, *Gladiolus cruentus* T.Moore, *Helichrysum woodii* N.E.Br., *Hesperantha gracilis* Baker, *Phymaspermum pinnatifidum* (Oliv.) Källersjö and *Tephrosia inandensis* H.M.L.Forbes. However, some of these endemics are confined to sandstone cliffs rather than the flatter grassland portion of KZNSS (e.g. *Crassula inandensis*, *Cynorkis compacta*, *Gladiolus cruentus*, *Hesperantha gracilis*). This list of endemic taxa is based on expert opinion which may not be all inclusive, given that approximations were necessary. Data generated by studies such as the present one should be used to update existing lists.

KZNSS occurs along an altitudinal range of 500 – 1100 metres above sea level (m.a.s.l.) in the summer rainfall region that experiences mist, which is important in providing additional moisture (Table 1). Frost is a very rare occurrence within the region (Rutherford *et al.* 2006). Similar vegetation types occurring within the EMA include Ngongoni Veld (SVs4) and KwaZulu-Natal Coastal Belt Grassland (CB3), both of which experience similar environmental conditions and contain many of the same plant species as KZNSS (Rutherford *et al.* 2006). Again these overlaps, particularly in terms of species, are based on expert opinion. However, CB3 is more similar to KZNSS than SVs4 in terms of environmental parameters (Table 1; Mucina & Rutherford 2006). Although these other vegetation types were not directly examined in the present study, they may offer insights into KZNSS owing to their geographic proximity and similarity to KZNSS (Table 1).

KZNSS grasslands within the EMA have experienced extensive transformation primarily through urbanisation, resulting in small isolated fragments that are often further compromised by IAPS and unmanaged fire regimes (Department of Environmental Affairs 2011). The floristic

variability and degree of transformation across patches is, however, heterogeneous and needs to be examined more closely to determine the effects that various anthropogenic activities, associated abiotic and biotic changes and management practices might have had on the floristic integrity of KZNSS. Parr *et al.* (2014) noted that ‘... underpinning all of the threats facing tropical grassland biomes is the misclassification of vegetation that results in inappropriate management techniques’. Given the geographical and environmental proximity between KZNSS and similar vegetation types (Table 1), remnant patches of KZNSS must be carefully floristically profiled for proper classification. On this note, KZNSS has a history of being grouped with other similar vegetation types in the area, for which it is easily mistaken, and has only recently being separated from some of them by Mucina and Rutherford (2006). Vegetation delimitation is scale dependent, and vegetation units are not expected to have exactly the same floristic composition or signature. Additionally, within vegetation types are nested plant communities that have a similar floristic composition and structure (e.g. rocky outcrops) that are often grouped into the broader and/or different vegetation types. Delimiting KZNSS is a problem experienced by land owners, the local/municipal conservation bodies and other stake holders that are tasked with KZNSS conservation. Given the vague delimitation of KZNSS, its high conservation priority and the close similarity to other grasslands types (in terms of distribution, floristics and environmental variables) (Table 1), remnant patches of KZNSS must be examined more carefully to identify conservation priorities.

The present study therefore aimed to understand the floristic variability within and across three KZNSS grassland fragments with a view to developing a floristic signature and characterisation that can help delimit KZNSS, and distinguish it floristically from similar subtropical grassland types.

## Methods and materials

### Study sites

Three KZNSS sites were selected for investigation after consultation with local botanists and confirmatory field visits. These included Inanda Mountain (IM), Giba Gorge Environmental Precinct (GGEP) and Springside Nature Reserve (SSNR). Some environmental characteristics associated with each of the sites, extracted from the broader literature on KZNSS, are shown in Table 2.

**TABLE 1:** Environmental characteristics of KwaZulu-Natal Sandstone Sourveld (KZNSS) and two other grassland vegetation types (Ngoni Veld and KwaZulu-Natal Coastal Belt Grassland) found in the eThekweni Municipal Area.

Environmental parameter	SVs5 (KZNSS)	SVs4 (Ngoni Veld)	CB3 (KwaZulu-Natal Coastal Belt Grassland)
Altitude range (m above sea level)	500–1100†	400–900†	20–450‡
Precipitation season and mean annual amount (mm)	Summer 934†	Summer 888†	Summer 989‡
Underlying geology	Ordovician Natal Group sandstones†	Karoo Supergroup, Dwyka tillite†	Ordovician Natal Group sandstones, Dwyka tillite, Ecca shale and Mapumulo gneiss‡
Temperature ranges (min. – max. °C)	0.9–35.8†	-0.2–38†	5.8–32.6‡

†, Obtained from Rutherford *et al.* (2006).

‡, Obtained from Mucina *et al.* (2006).

**TABLE 2:** Location, size, altitude and management authorities of the three selected KZNSS sites.

Site name	Size† (m <sup>2</sup> )	Altitudinal range (m above sea level)	General location	Central GPS co-ordinates (degrees, minutes, seconds)†		Management authority	Protection	Burning practices
				Latitude	Longitude			
Giba Gorge Environmental Precinct	50054	564–611	Winston Park	29°48'40.46"S	30°46'35.40"E	eThekweni Municipality	Unfenced, controlled access	Controlled
Inanda Mountain	272795	428–476	Inanda	29°39'54.70"S	30°56'22.02"E	Communal land	Unfenced, uncontrolled access	Uncontrolled
Springside Nature Reserve	94761	627–652	Hillcrest	29°46'47.79"S	30°46'19.88"E	eThekweni Municipality	Fenced, controlled access	Controlled

†, Determined using approximate estimates of the reserve boundaries on Google Earth Pro.

## Data collection

At each of the three sites, a minimum of fifteen 5 × 5 m quadrats were laid out as prescribed by Curtis and Cottom (1956) and spaced between 5 m and 30 m apart, depending on the site, to accommodate potential variation across the site, including aspect and slope, but steep cliffs were excluded. Sampling only included the grassland portions of each site. Species abundance was determined within each quadrat and voucher specimens of each species were collected for taxonomic identification to species, and in some cases to subspecies level. For logistic reasons and to accommodate for seasonality, c. 60% of the quadrats at all sites were surveyed during winter (1 June – 31 August, 2012–2014), an additional c. 30% during summer (1 December – 28 February, 2012–2014). The remaining c. 10% of quadrats were performed during autumn (1 March – 31 May, 2013–2014) and spring (1 September – 30 November, 2012–2014).

Walked diagonal transects were also undertaken at each site, once a month, across all seasons to collect species in flower that were previously unrecorded in the quadrats. This helped to more accurately inform the presence of species at each site so that objective comparisons could be made and comprehensive floristic profiles could be generated for each site. All specimens in flower were collected and deposited at the Ward Herbarium (UDW), Westville Campus, University of KwaZulu-Natal, Durban, South Africa.

## Data analysis

EstimateS 9.0 (Colwell 2013) was used to construct species accumulation curves for the quadrat data only, to determine if sufficient sampling had been performed. The non-parametric estimators, Chao2 and Jack1, were used to estimate total species richness. Owing to time constraints, it was not possible to conduct quadrat sampling to the point where all species, especially rare species, were encountered. Percentage sampling effort was therefore calculated by dividing the number of species found by the projected number of species using the Jack1 and Chao2 estimators. This process was repeated after every five quadrats at each site were sampled. Sampling effort ceased when the average percentage sampling effort (using Jack1 and Chao2 estimators) reached an acceptable value ( $\geq 80\%$ ).

EstimateS 9.0 (Colwell 2013) was also used to calculate the Simpson's inverse and Shannon's exponential indices to compare alpha diversities of the sites based on quadrat data.

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  $\beta_1$  as a broad-sense measure of species turnover) (see Koleff, Gaston & Lennon 2003). All beta diversity measurements ( $\beta_{gl}$ ,  $\beta_{3}$  and  $\beta_1$ ) were performed using all quadrats at each site and quadrats were also compared within sites. The resulting beta diversity measurements for the average values within each site were then compared by using analysis of variance (ANOVA) in SPSS version 22. Only  $\beta_{gl}$  was found to be parametric (by a Shapiro-Wilks test;  $p > 0.05$ ) with the assumption of homogeneity of variance supported (by Levene's test;  $p > 0.05$ ) and significantly different ( $p < 0.05$ ). Cluster analyses were performed using the presence/absence data of species in quadrats across the three sites. The add-on package of BiodiversityR (Kindt & Coe 2005) was used in conjunction with R (R Core Team 2016) to generate a similarity matrix using the Jaccard index, and clustering was achieved using the unweighted pair group method with arithmetic mean (UPGMA). Thereafter BiodiversityR was used to generate a Bray-Curtis similarity matrix and a non-parametric multidimensional scaling analysis (100 runs) was performed. The groups identified by the UPGMA were combined with the ordination plot to gain a better understanding of the data and the influences of vegetation structure as well as composition on the grouping of quadrats (after Pinto *et al.* 2013).

## Results

The three sites range in altitude with IM (lowest point 428 m.a.s.l.) being the lowest and SSNR (highest point 652 m.a.s.l.) being the highest above sea level (Table 2). Additionally, IM is the most northern and eastern site whilst GGEP is the most southern site, and SSNR is the most western site; SSNR and GGEP are closer to each other than either of them are to IM in terms of size, altitude and geographic location (Table 2). Whilst GGEP and SSNR experience controlled burning and are subject to controlled access, as both sites are under eThekweni Municipality management, IM is on communal land that experiences uncontrolled burning and is not protected in terms of controlled access (Table 2). The socio-economic status and land-use patterns of the areas in which the sites are situated differ as well; whilst GGEP and SSNR are located in suburban areas (Winston Park and Hillcrest, respectively), IM is situated in a rural part of the Inanda-Ntuzuma-KwaMashu area (Table 2).

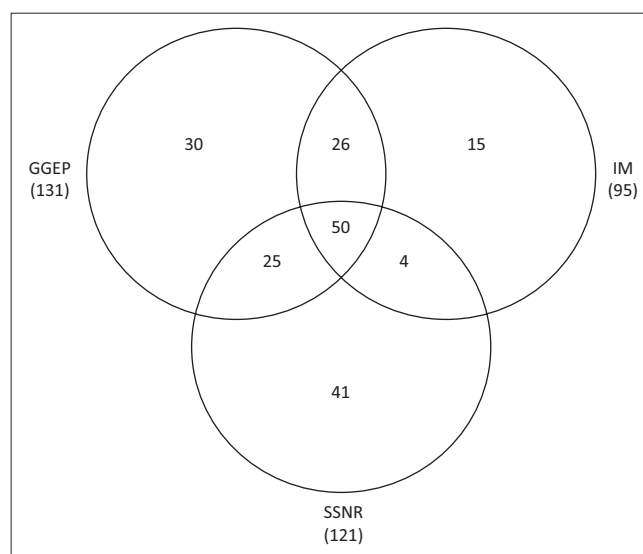
Cumulatively, a total of 193 plant species were found at the three sites; however, only 50 of these were common to all three sites (for details, see Appendix 1). Figure 1 shows that GGEP had the highest number of total and unique species,

followed by SSNR and then IM. At both IM and SSNR, 18 quadrats were required to reach an 80% sampling effort, whilst at GGEP 20 quadrats achieved an 80% sampling effort. Eighteen quadrats accounted for 74 and 111 species at IM and SSNR, respectively, while 20 quadrats accounted for 98 species at GGEP. Transect sampling increased the total number of species from 74 to 95, 111 to 121, and 98 to 131 for IM, SSNR and GGEP, respectively. Plant families most well represented at the three sites (i.e. quadrat and transect data combined) were Asteraceae, Poaceae and Fabaceae, with 44, 28 and 24 species, respectively (Appendix 1). These three families contributed to 50% of the total species found across the three sites.

Several taxa identified to be of conservation concern on the Red List of South African Plants (South African National Biodiversity Institute (SANBI) 2015) were found at study sites. These included, *Hypoxis hemerocallidea* Fisch, C.A. Mey. & Avé-Lall which is declining, *Aloe linearifolia* A.Berger & Reynolds which is near-threatened, *Alepidea amatymbica* Ecklon & Zeyher which is vulnerable, and *Eriosema populifolium* subsp. *populifolium* Benth. ex Harv. which is endangered. Of the 12 species known to be diagnostic of (i.e. endemic to) KZNSS, only 1 was found, namely *Eriosema populifolium* subsp. *populifolium* Benth. ex Harv., which occurred at all three sites. Three Category 1b IAPS (species which should be removed immediately as per the Department of Environmental Affairs (DEA) 2014) were found (Table 3): *Lantana camara* L. was in low abundance at IM; *Chromolaena odorata* L. was in low abundances at GGEP and SSNR but abundant in IM; and *Ageratum houstonium* Mill. was abundant in IM. Additionally, 7 naturalised exotic species (3 at GGEP, 4 at IM, and 5 at SSNR) as well as 4 non-native species (2 at GGEP, 1 at IM, and 3 at SSNR) were found (Table 3).

The highest value for Shannon's exponential index was found for SSNR, whilst the Simpson's inverse index was

highest for GGEP (Table 4). IM had the lowest values for both these alpha diversity indices (Figure 1 and Table 4). The Shannon's exponential index places emphasis on species richness whilst the Simpson's inverse index is known to give an estimate that emphasises evenness (Luis 1996; Nagendra 2002). Shannon's exponential index was highest for SSNR which also had the highest species richness of 111 based on quadrat sampling and increased to 121 species with transect sampling. Interestingly, GGEP had 98 species with quadrat sampling, which increased to 131 species with transect sampling, giving it the highest 'cumulative' species richness. IM had the lowest Shannon's exponential index value, explained by its low species richness for both quadrat (74) and transect (95) sampling. The Simpson's inverse index



**FIGURE 1:** Venn diagram based on quadrat and transect data showing species found within the three KwaZulu-Natal Sandstone Sourveld study sites: Giba Gorge Environmental Precinct (GGEP), Inanda Mountain (IM) and Springside Nature Reserve (SSNR). The total number of species recorded at each site is indicated in parentheses.

**TABLE 3:** Summary of notable alien and red list taxa found in each of the three sites examined (aliens based on DEA (2014) and red list taxa based on Red List of South African Plants (<http://redlist.sanbi.org/>)). Also given are observations on the relative abundance of each species (very rare = 1 individual per 100 m<sup>2</sup>, rare = less than 5 individuals per 100 m<sup>2</sup>, common = 10 to 50 individuals per 100 m<sup>2</sup>).

Taxa	Description	Species	Giba Gorge Environmental Precinct	Inanda Mountain	Springside Nature Reserve
Alien taxa	Invasive aliens (Category 1b)	<i>Ageratum houstonium</i> Mei ex. Krauss	-	Common	-
		<i>Chromolaena odorata</i> L.	Rare	Common	Rare
		<i>Lantana camara</i> L.	-	Rare	-
	Naturalised exotics	<i>Bidens pilosa</i> L.	Rare	-	Rare
		<i>Hypoxis decumbens</i> L.	Rare	Rare	Rare
		<i>Lactuca indica</i> L.	-	Rare	-
		<i>Paspalum notatum</i> Fluge	-	-	Very Rare
		<i>Poa annua</i> Steud.	Rare	Common	Rare
		<i>Rubus rosifolius</i> Sm.	-	-	Very Rare
	Non-native taxa	<i>Taraxacum officinale</i> F.H.Wigg.	-	Rare	-
		<i>Cymbopogon citratus</i> Stapf	-	-	Very rare
		<i>Desmodium ciliare</i> DC	Rare	Common	Rare
		<i>Hibiscus trionum</i> L.	-	-	Rare
		<i>Plantago major</i> L.	Very rare	-	-
Conservation concern taxa	Declining	<i>Hypoxis hemerocallidea</i> Fisch., C.A.Mey. & Avé-Lall.	Rare	Very rare	-
	Near threatened	<i>Aloe linearifolia</i> A.Berger & Reynolds	Common	-	-
	Vulnerable	<i>Alepidea amatymbica</i> Ecklon & Zeyher	Common	Very rare	-
	Endangered	<i>Eriosema populifolium</i> Benth. ex Harv.	Common	Rare	Common
		<i>Lotononis filiformis</i> B.-E.van Wyk	Common	Rare	-

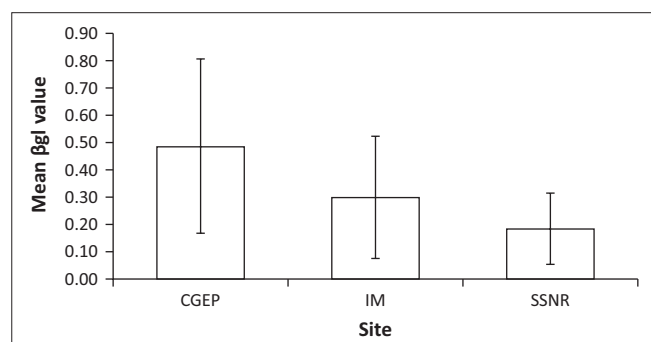
reflects higher evenness at lower values for this index (Luis 1996); IM had the lowest Simpson's inverse index, with higher values being recorded for SSNR and GGEP, respectively.

Three beta diversity analyses ( $\beta_{gl}$ ,  $\beta_3$  and  $\beta_j$ ) were used to compare quadrats within each site using presence-absence of species in each quadrat. Only  $\beta_{gl}$  which is a measure of species richness gradients, was found to be significantly ( $p < 0.05$ ) different across sites (Figure 2) with GGEP (which had the highest cumulative number of species) having the highest value, followed by IM and then SSNR (Figure 1).

The species richness gradient beta diversity measure,  $\beta_{gl}$  allows insights into the spread of species and species evenness (Koleff, Gaston & Lennon 2003). This measure has a minimum value of 0, indicating complete similarity and a maximum value of 2, indicating complete dissimilarity in species composition (Koleff, Gaston & Lennon 2003). The beta diversity results show that all sites have a fairly low richness gradient. SSNR had the lowest  $\beta_{gl}$  value (Figure 2) (i.e. quadrats reflect highest similarity in terms of species and evenness) and the highest value for Shannon's exponential index (Table 4), and second highest number of species in total (Figure 1). However, it should be noted that this number is only ten lower than GGEP, which had the highest cumulative number of species. Additionally, IM has a slightly higher species richness gradient (Figure 2), as well as the lowest number of species, which is supported by Shannon's exponential index (Figure 1 and Table 4), indicating that quadrats in the site are fairly similar and species are evenly distributed across the site. GGEP had the highest  $\beta_{gl}$  value (Figure 2) and thus the least similarity in terms of quadrats and evenness of species, which is supported by the high Simpson's inverse index value (Table 4). However, this

**TABLE 4:** Alpha diversity values for the Shannon's exponential and Simpson's inverse indices for the three KwaZulu-Natal Sandstone Sourveld sites based on quadrat data.

Site	Shannon's exponential index	Simpson's inverse index
Giba Gorge Environmental Precinct ( $n = 20$ )	43.48	30.06
Inanda Mountain ( $n = 18$ )	26.49	16.36
Springside Nature Reserve ( $n = 18$ )	50.64	28.62



**FIGURE 2:** Mean and standard deviation  $\beta_{gl}$  values found when comparing quadrats within each site (ANOVA,  $p < 0.05$ ). Giba Gorge Environmental Precinct (GGEP,  $n = 98$  comparisons for 20 quadrats), Inanda Mountain (IM,  $n = 74$  comparisons for 18 quadrats) and Springside Nature Reserve (SSNR,  $n = 111$  comparisons for 18).

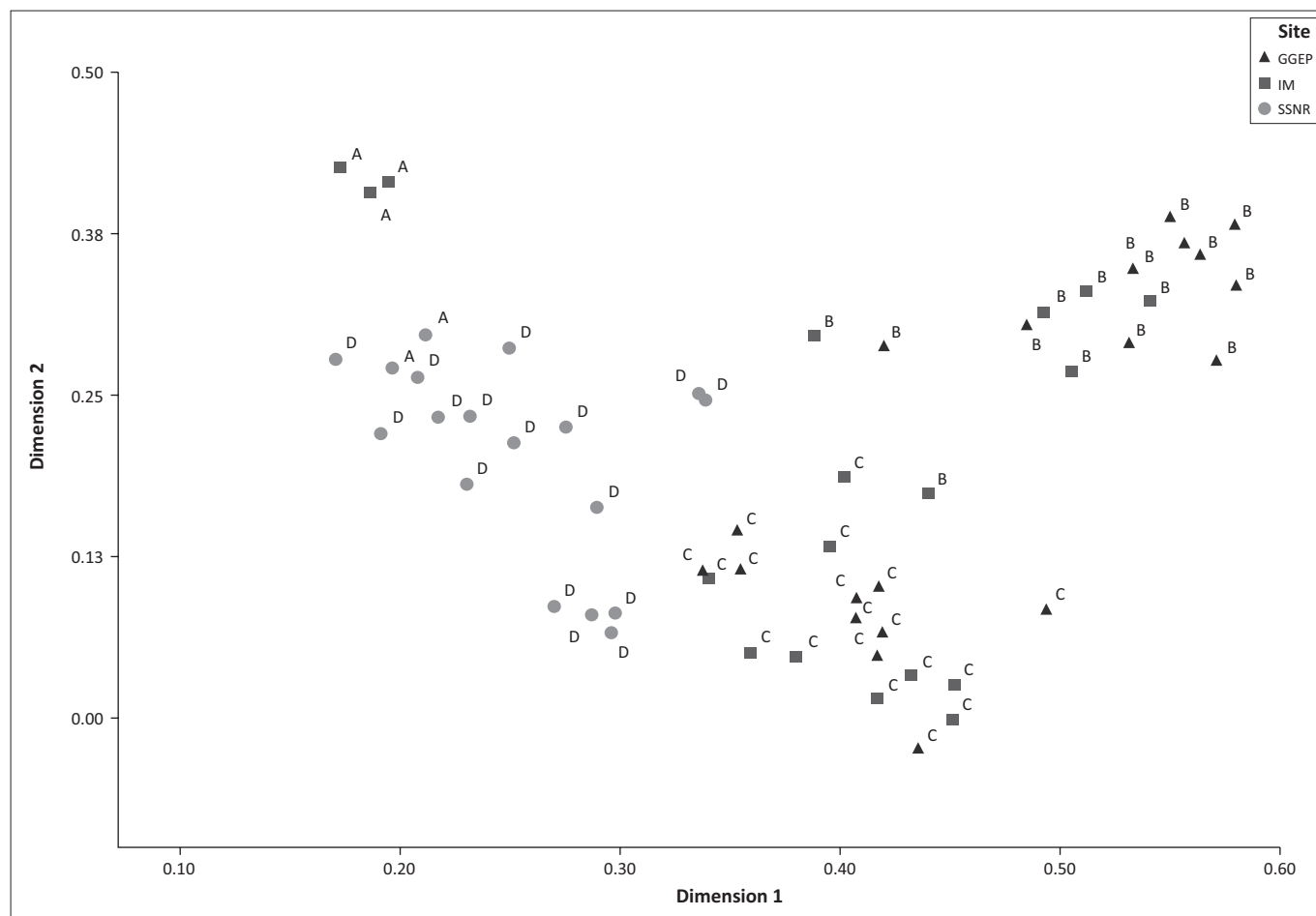
result may well be because of this site having the highest cumulative number of species with many less abundant species (see Luis 1996) (Figure 1), or alternatively because of temporal variations as a result of sampling occurring over different seasons.

The four clusters of the phenogram generated using UPGMA (not shown) were largely congruent with the NMDS results (Figure 3). Consequently, only the NMDS plot is shown in Figure 3. Alphabets (A-D) indicate the four clusters of quadrats in the UPGMA, and the number of quadrats from the respective sites are given below: A (GGEP = 0, IM = 3 and SSNR = 2), B (GGEP = 10, IM = 6 and SSNR = 0), C (GGEP = 10, IM = 9 and SSNR = 0) and D (GGEP = 0, IM = 0 and SSNR = 16). On the NMDS plot (Figure 3), it can also be seen that Clusters B and C are clearly distinct, whilst Clusters A and D are largely distinct, except for two quadrats from Cluster A that are close to those from Cluster D.

## Discussion

Both GGEP and SSNR fall within the altitudinal ranges described for KZNSS (Tables 1 and 2). However, IM's highest point (476 m.a.s.l.) is lower than the 500–1100 m.a.s.l. typically associated with KZNSS. However, the altitude can extend up to 800 m in some parts of IM. The underlying geology of all three sites is Ordovician Natal Group Sandstone (Bell & Lindsay 1999; Table 1). The IM site is affected by a variety of factors, most importantly the lack of controlled access and formal management which gives rise to many forms of disturbance. The IM site is also used as a thoroughfare, resulting in high levels of litter, is used for low intensity grazing, and experiences burns (usually in early autumn) (author's personal observations, 2012–2015) which are uncontrolled (Table 2).

Of the three sites examined, GGEP had the highest cumulative (i.e. quadrats and transect data combined) number of species ( $n = 131$ ; Figure 1) whilst also containing all 4 of the species of conservation concern found across the three sites (Table 3). This site is monitored and managed by the eThekweni Municipality and is therefore less prone to degradation and disturbance(s). With only a slightly lower cumulative number of species than GGEP, SSNR ( $n = 121$ , Figure 1) is also managed by the eThekweni Municipality and has more unique species than GGEP (Figure 1), which may be a consequence of its larger area than GGEP (Table 2). Based on the area effect of island biogeography theory, IM would therefore be expected to have the highest number of species (e.g. Bond, Midgley & Vlok 1988), but this was not the case. In fact, despite being the largest site (Table 2), IM exhibited the lowest cumulative number of species ( $n = 95$ ) across the three sites. Additionally, it is worth mentioning that geoxylic taxa (a characteristic feature of KZNSS) are well adapted to fire and persist underground for long periods of time (Maurin *et al.*, 2014), and many of these might have been undetected in the standing flora of the present study. Bond, Midgley & Vlok (1988) found that fire management plays a large role in



**FIGURE 3:** Non-parametric multidimensional scaling (NMDS) plot using quadrats of the three study sites: Giba Gorge Environmental Precinct (GGEp,  $n = 20$ ), Inanda Mountain (IM,  $n = 18$ ) and Springside Nature Reserve (SSNR,  $n = 18$ ). Alphabetical letters (A–D) represent the four clusters defined using UPGMA clustering (see text for details).

determining species richness of islands in the fire-dependent fynbos ecosystem; similarly, improper fire management coupled with degradation may be responsible for the deviation from island biogeography theory observed at IM. Fynn, Morris & Edwards (2004) found that annual burns, when combined with grazing, resulted in a decrease of forb species richness whilst grass species richness remained the same as compared with biennial burns, where burning occurs in winter. This finding may explain the deviation of IM from the area effect of island biogeography theory, with the lower species richness possibly being a consequence of annual as opposed to biennial burns as well as disturbance caused by grazing and footpaths at this site. The three most dominant families across the three sites were Asteraceae, Poaceae and Fabaceae which were found to contribute to 50% of the total species found. However, in a grassland study further inland in the Platberg region of the eastern Free State (in South Africa), 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, Brown & du Preez 2010). A possible reason for the differences in dominant families, particularly Cyperaceae, between the present study and that of Brand, Brown & du Preez (2010) is that, whilst the present study was performed purely within the grassland sections of

each site, Brand Brown & du Preez (2010) included wetlands which are expected to contain more Cyperaceae species.

All of the 4 taxa of conservation concern were found at GGEp whilst only 1 was found at SSNR and 3 at IM (Table 3). This is not congruent with the species richness nor size trends across sites, and could be as a result of historical differences across sites or the influence of adjacent vegetation types that may house these taxa. Interestingly, 6 of the 14 alien species found in this study were mostly rare (i.e. less than 5 individuals observed per 100 m<sup>2</sup>) at GGEp, 9 were rare to very rare (i.e. one individual observed per 100 m<sup>2</sup>) at SSNR, and 9 were rare to common (i.e. 10–50 individuals observed per 100 m<sup>2</sup>) at IM (Table 3). This finding suggests that the number of alien taxa found at a site may not be a proper reflection of the abundance of aliens at the sites or that the management at sites is sufficient to suppress alien plant infestations at sites where there are higher numbers of alien taxa, but in lower abundances (e.g. SSNR in this study). At IM, where there is uncontrolled access and annual burning (Table 2), all three of the Category 1b IAPS found were present, 2 of which were common at the site (Table 3). At GGEp and SSNR, where there is controlled access and biennial burning (Table 2), only 1 of the 3 Category 1b IAPS (viz., *Chromolaena odorata* L.) was found and its occurrence

was rare (Table 3). Additionally, the other alien taxa at GGEP and SSNR were mostly rare to very rare at all these sites (i.e. 1 – 5 individuals observed per 100 m<sup>2</sup>) (Table 3). These data suggest that the lack of appropriate management practices and relatively higher vulnerability to disturbances at KZNSS sites (as at IM) may not necessarily lead to increased alien species diversity, but can favour higher abundances of fewer existing alien species. As mentioned above, some endemics are confined to the cliffs. Despite this, only 1 of the 12 endemic KZNSS taxa was found in this study, which could be a reflection of the high levels of transformation that KZNSS patches have been subjected to over the years, as a consequence of anthropogenic pressures associated with urbanisation. The results of the present study further validate reports by SANBI that most of these endemic KZNSS taxa are rare or vulnerable (Source: <http://redlist.sanbi.org/>).

The alpha diversity results (Table 4) suggest that there may be more species that were not found in SSNR when compared with GGEP during the present study, as shown by the increase in the number of species when transect sampling is included. Additionally, factors such as quadrat placement and micro-environmental site differences could have yielded this result, despite careful quadrat and micro-environmental considerations. The IM site had the lowest number of species which are fairly evenly spread over the site. However, Luis (1996) noted that this evenness index (Simpson's inverse index) focuses more on abundant species; in the case of the present study, the most abundant species were grasses, suggesting that IM's grass species are evenly distributed across the site. For SSNR and GGEP, alpha diversity results can be explained in terms of the area effect of island biogeography as SSNR is larger in area than GGEP; but yet again, in contradiction of the effect, the largest site, of IM, exhibited the lowest richness. When the sites are compared in terms of the distance effect, the results still do not conform to what would be expected. As alluded to earlier, the poor (lack of) management at IM and its relatively higher vulnerability to disturbance may explain why it displayed the highest evenness and lowest species richness. Controlled fire (which is a disturbance) promotes seed germination in some species and this can be good for seedling recruitment (which could be the case at GGEP and SSNR); however, uncontrolled fires can damage sensitive seeds and reduce the opportunity for seed bank accumulation (Benson 1985). Therefore, sites with regular fire occurrences are likely to have lower levels of seedling recruitment and hence a reduction in species richness and increased evenness, which might have been the case for IM.

Beta diversity analyses support earlier indications that IM species were spread evenly across the site. Additionally, beta diversity analyses indicated that GGEP had the least even spread of species, which means that quadrats at GGEP (which exhibited the highest number of species) are likely to be less similar to each other in terms of species composition than those at IM. This observation suggests that the poor management practices at IM might have also led to increased

homogenisation of the remaining vegetation via the reduction of species in the germinable soil seed bank (Benson 1985).

Disturbances have been reported to lead to ecosystem degradation in a number of vegetation types (e.g. Brand, Brown & du Preez 2010; Jonas *et al.* 2006) and the open access, disturbances and improper burning appear to be leading to biodiversity loss and increased levels of species homogenisation at the IM site. In total, there were 45 families at all 3 sites (29, 33 and 33 at IM, GGEP and SSNR, respectively), with 64%, 73% and 73% of the total number of families being present in IM, GGEP and SSNR, respectively. Furthermore, of the 129 genera found in the study, 74, 92 and 85 were present at IM, GGEP and SSNR, respectively. This implies that IM, GGEP and SSNR had 57%, 71% and 66% generic representation, respectively. We also examined the ratio of grasses species (Poaceae) to species from all other families to check if IM differed from the other two sites in this aspect. The ratio of grass species to other species was 19:76 (1:4,0), 20:111 (1:5,6) and 20:101 (1:5,1) at IM, GGEP and SSNR, respectively (or 20%, 15% and 17%, respectively). This implies that IM had a slightly higher percentage of grass representation overall. The data described above further support the possibility of homogenisation at IM. However, it is encouraging to note that this degradation did not result in significant separation of most of the IM quadrats from those of the other two sites (Figure 3), and that 3 of the 4 taxa of conservation concern found in this study were present at IM (Table 3). The minor contradictions to this assertion shown in Figure 3 may also be explained by the sampling strategy adopted in the present study and differences in the timing and frequency of burning carried out at the three sites, as opposed to actual floristic differences. For example, burning at IM took place not only more frequently but also earlier, in autumn, as opposed to the early winter burns carried out biannually at GGEP and SSNR (Table 2).

Quadrats of Cluster A were from SSNR and IM and sampled post-burning, and only quadrats of IM in Cluster A separated out distinctly in the ordination. Quadrats of Cluster B were from IM and GGEP and were sampled pre-burning. Quadrats from Cluster C were sampled pre-burning from IM, as well as sampled both pre-and post-burning at GGEP. Lastly, quadrats from Cluster D were from SSNR, and sampled both pre-and post-burning. Furthermore, we noticed over the period 2012 to 2015 that IM was burnt annually in April or early to mid-May during the three years over which the present study was conducted, whilst GGEP and SSNR were only burnt in June 2014. The seasonality and frequency of burning influences the timing, type and abundance of species that emerge (and subsequently establish) in the season following a burn (Benson 1985). Furthermore, IM contained the least number of unique and cumulative number of species (Figure 1) and post-burn IM quadrats were floristically distinct from all other quadrats, including those of pre-burn IM, pre- and post-burn SSNR as well as GGEP (Figure 3). The intermediate disturbance effects of fire in grasslands has revealed that annual burns can reduce the number of species at a particular site to a subset of the species found in similar

sites where burning is less frequent (Collins, Glenn & Gibson 1995). The intermediate disturbance effect could therefore explain the results obtained here.

Additionally, IM, unlike the other two sites, is subject to regular grazing pressure (Table 2) and uncontrolled grazing can lead to altered species composition in grasslands (Fynn, Morris & Edwards 2004). Grazing occurs at IM and, to better facilitate this, fire is used in early autumn to encourage a flush of palatable grasses for cattle and goat livestock. The effects of burning time combined with simulated grazing in the long term (mowing in late summer and burning in winter) resulted in a 27% – 42% decrease in species richness in Southern Tall Grassveld at Ukulinga (Fynn, Morris & Edwards 2004). However, we cannot comment any further regarding how grazing and burning could have influenced the results of this study, as this study was not designed to study the effects of the timing, frequency and intensity of burning and grazing scenarios on floristic diversity. The findings of Fynn, Morris & Edwards (2004) and others, as well as the patterns observed in the present study do, however, suggest that the effects of fire management on floristics within KZNSS requires further investigation.

## Concluding remarks and recommendations

In terms of the future delimitations of KZNSS, the disturbances at IM indicate a possible shift in the floristic signature of improperly managed KZNSS sites: a reduction in species diversity and increased homogeneity relative to more properly managed and less disturbed sites (GGEP and SSNR). Studies on primary succession have revealed that disturbance in the short term leads to vegetation becoming less floristically distinct and, in the long term, leads to a unique, less diverse and more homogenous vegetation type (Walker & de Moral 2003). Despite the fact that IM contained the same number of diagnostic (endemic) taxa as the other sites, the use of endemic taxa as an indicator of site similarity is negated by the fact that all three sites contained only one of the 12 diagnostic taxa recognised for KZNSS. The absence of diagnostic species at all sites also indicated that past and present anthropogenic pressures associated with urbanisation might have altered the KZNSS floristic signature, making it less distinctive and more homogenous with other adjacent grassland types. However, this assertion will require extending the present study to other KZNSS patches and floristic comparisons between KZNSS patches and vegetation types such as KwaZulu-Natal Coastal Belt Grassland (CB3), which is floristically and environmentally similar to KZNSS (Mucina & Rutherford 2006).

Lastly, the results of the present study suggest that, given the geographic location of remnant patches of KZNSS (within urban and suburban matrix), the results of all subsequent floristic studies on KZNSS must be interpreted in relation to levels and types of management and disturbance. In this regard, given the highly transformed and limited extent of

KZNSS nationally as well as provincially, the impact of management practices on floristics within KZNSS represents a research priority.

## Acknowledgements

This research was supported by eThekweni Municipality through the Durban Research Action Partnership: KwaZulu-Natal Sandstone Sourveld Research Programme. The Wildlands Conservation Trust supported this research in part. Professor Ashley Nicholas and Mr Teddy Govender are thanked for their assistance in identification of difficult specimens. The officers in charge of the reserves are thanked for access: Thuthuka Majola of GGEP and Jabulani Khoza of SSNR. Numerous field assistants are thanked, especially Miss Saffron Mace for hours of fieldwork and data compilation assistance.

## Competing interests

The authors declare that they have no financial or personal relationships which may have inappropriately influenced them in writing this article.

## Authors' contributions

C.D. was the main author, undertaking data collection, species identification, data compilation, data analyses and writing of the manuscript. S.R., S.N. and C.C. contributed to conceptualisation, realisation of field work, species identification, guidance in and interpretation of data analyses, writing and editing. R.B. and P.M. contributed to field work, species identification, data collection and compilation.

## References

- Bell, F.G. & Lindsay, P., 1999, 'The petrographic and geomechanical properties of some sandstones from the newspaper member of the Natal Group near Durban, South Africa' *Engineering Geology* 53, 57–81. [http://dx.doi.org/10.1016/S0013-7952\(98\)00081-7](http://dx.doi.org/10.1016/S0013-7952(98)00081-7)
- Benson, D.H., 1985, 'Maturation periods for fire-sensitive shrub species in Hawkesbury Sandstone vegetation', *Cunninghamia* 1, 339–349.
- Bond, W.J., Midgley, J. & Vlok, J., 1988, 'When is an island not an island? Insular effects and their cause in fynbos shrublands', *Oecologia* 77, 515–521. <http://dx.doi.org/10.1007/BF00377267>
- Brand, R.F., Brown, L.R. & du Preez, P.J., 2010, 'A floristic analysis of the vegetation of Platberg, eastern Free State, South Africa', *Koedoe* 52, Article #710.
- Collins, S.L., Glenn, S.M. & Gibson, D.J., 1995, 'Experimental analysis of intermediate disturbance and initial floristic composition: Decoupling cause and effect', *Ecology* 76, 486–492. <http://dx.doi.org/10.2307/1941207>
- Colwell, R.K., 2013, 'EstimateS 9.1.0: Statistical estimation of species richness and shared species from samples', viewed 5 July 2014, from <http://viceroy.eeb.uconn.edu/EstimateS/EstimateSPages/EstimateSRegistration.htm>
- Curtis, J.T. & Cottom G., 1956, 'Plant ecology work book', *Laboratory field reference manual*, Burgess Publ. Co., MN, pp. 39.
- Department of Environmental Affairs, South African Government, 2011, 'National list of ecosystems that are threatened and in need of protection', *Government Gazette* 34809, 248–249.
- Department of Environmental Affairs (DEA), South African Government, 2014, *National environmental management: Biodiversity act (10/2004): Alien and invasive species list*, *Government Gazette* 37886.
- Fynn, R.W.S., Morris, C.D. & Edwards, T.J., 2004, 'Effect of burning and mowing on grass and forb diversity in a long-term grassland experiment', *Applied Vegetation Science* 7, 1–10. <http://dx.doi.org/10.1111/j.1654-109X.2004.tb00589.x>
- Jonas, Z., Rouget, M., Reyers, B., Mohamed, B., Rutherford, M.C., Mucina, L. et al., 2006, 'Vulnerability assessment of vegetation types', in L. Mucina & M.C. Rutherford (eds.), *The vegetation of South Africa, Lesotho and Swaziland*, pp. 739–747, *Strelitzia* 19, SANBI, Pretoria, South Africa.



- Kindt, R. & Coe, R., 2005, 'Tree diversity analysis', *A manual and software for common statistical methods for ecological and biodiversity studies*, World Agroforestry Centre (ICRAF), Nairobi.
- Koleff, P., Gaston, K.J. & Lennon, J.J., 2003, 'Measuring beta diversity for presence-absence data', *Journal of Animal Ecology* 72, 367–382. <http://dx.doi.org/10.1046/j.1365-2656.2003.00710.x>
- Luis, A.B., 1996, 'Chapter 6: Relationships between biotic diversity and primary productivity in savanna', in O.T. Solbrig, E. Medina & J.F. Silva (eds.), *Biodiversity and savanna ecosystem processes*, pp. 97–117, Springer, Berlin.
- Maurin, O., Davies, T.J., Burrows, J.E., Daru, B.H., Yessoufou, K., Muasya, A.M. *et al.*, 2014, 'Savanna fire and the origins of the 'underground forests' of Africa', *New Phytologist*, 204, 201–214. <http://dx.doi.org/10.1111/nph.12936>
- Mucina, L. & Rutherford, M.C., 2006, *The vegetation of South Africa, Lesotho and Swaziland*, Strelitzia 19, South African National Biodiversity Institute, Pretoria.
- Mucina, L., Scott-Shaw, C.R., Rutherford, M.C., Camp, K.G.T., Matthews, W.S., Powrie, L.W. *et al.*, 2006, 'Indian Ocean coastal belt', in L. Mucina & M.C. Rutherford (eds.), *The vegetation of South Africa, Lesotho and Swaziland*, pp. 569–583, Strelitzia 19, SANBI, Pretoria, South Africa.
- Nagendra, H., 2002, 'Opposite trends in response for the Shannon and Simpson indices of landscape diversity', *Applied Geography* 22, 175–186. [http://dx.doi.org/10.1016/S0143-6228\(02\)00002-4](http://dx.doi.org/10.1016/S0143-6228(02)00002-4)
- Parr, C.L., Lehmann, C.E.R., Bond, W.J., Hoffmann, W.A. & Andersen, A.N., 2014, 'Tropical grassy biomes: Misunderstood, neglected, and under threat', *Trends in Ecology and Evolution* 29, 205–213. <http://dx.doi.org/10.1016/j.tree.2014.02.004>
- Pinto, M.F., Nabinger, C., Boldrini, I.I., de Abreu Ferreira, P.M., Setubal, R.B., Trevisan, R., *et al.*, 2013, 'Floristic and vegetation structure of a grassland plant community on shallow basalt in southern Brazil', *Acta Botanica Brasiliica* 27, 162–179. <http://dx.doi.org/10.1590/S0102-33062013000100017>
- R Core Team, 2016, *R: A language and environment for statistical computing*, R Foundation for Statistical Computing, Vienna, Austria, viewed 10 April 2015, from <https://www.R-project.org/>
- Rouget, M., Jonas, Z., Cowling, R.M., Desmet, P.G., Driver, A., Mohamed, B., *et al.*, 2006, 'Ecosystem status and protection levels of vegetation types', in L. Mucina & M.C. Rutherford (eds.), *The vegetation of South Africa, Lesotho and Swaziland*, pp. 725–737, Strelitzia 19, SANBI, Pretoria, South Africa.
- Rutherford, M.C., Mucina, L., Lotter, M.C., Bredenkamp, G.J., Smit, J.H.L., Scott-Shaw, R. *et al.*, 2006, 'Savanna', in L. Mucina & M.C. Rutherford (eds.), *The vegetation of South Africa, Lesotho and Swaziland*, pp. 511–512, Strelitzia 19, SANBI, Pretoria, South Africa.
- South African National Biodiversity Institute (SANBI), 2015, 'Red list of South African plants', viewed 10 April 2015, from <https://redlist.sanbi.org>
- Walker, L. & del Moral, R., 2003, 'Chapter 7: Successional patterns', in L. Walker & R. del Moral (eds.), *Primary succession and ecosystem rehabilitation*, pp. 247, Cambridge University Press, New York.

Appendix starts on the next page →

## Appendix 1

Summary of species found in the present study. Alien and red list status of indigenous species are provided (according to the South African Biodiversity Institute Red List (SANBI, <http://www.redlist.sanbi.org>)) (abbreviations NE = not evaluated; LC = least concern; ; NT = near threatened; VU = vulnerable; EN = endangered), as well as herbarium details (Ward Herbarium; CCD = C.C. Drury) for specimens collected during the study (X denotes a species was found in a particular site; hyphen denotes absence).

Family	Species name and authorship	Invasive and alien status	Redlist status	Voucher details	IM	GGEP	SSNR	
Acanthaceae	<i>Barleria obtusa</i> Nees	Indigenous	LC		X	X	X	
	<i>Dicliptera clinopodia</i> Nees.	Indigenous	LC		-	-	X	
	<i>Ruellia cordata</i> Thunb.	Indigenous	LC		X	X	-	
	<i>Rutty ovata</i> Harvey	Indigenous	LC		X	X	-	
	<i>Thunbergia atriplicifolia</i> E.Mey.	Indigenous	LC		X	X	X	
	<i>Thunbergia natalensis</i> Hook.	Indigenous	LC		-	-	X	
Aizoaceae	<i>Zaleya pentandra</i> (L.) C.Jeffrey	Indigenous	LC		-	-	X	
Alliaceae	<i>Tulbaghia acutiloba</i> Harv.	Indigenous	LC	CCD 222	X	X	-	
Anacardiaceae	<i>Searsia dentata</i> (Thunb.) F.A.Barkley	Indigenous	LC		-	-	X	
Apiaceae	<i>Alepidea amatymbica</i> Ecklon & Zeyher	Indigenous	VU		X	X	-	
	<i>Centella eriantha</i> Rich.	Indigenous	LC		-	X	X	
Apocynaceae	<i>Asclepias albens</i> Schltr.	Indigenous	LC		X	X	X	
Asphodelaceae	<i>Aloe linearifolia</i> A.Berger & Reynolds	Indigenous	NT		-	X	-	
	<i>Kniphofia linearifolia</i> Baker	Indigenous	LC		-	-	X	
Asteraceae	<i>Ageratum houstonianum</i> Mill.	Alien	NE		X	-	-	
	<i>Aster bakerianus</i> Burt Davy ex C.A.Sm.	Indigenous	LC	CCD 176	X	X	X	
	<i>Athrixia phyllicoides</i> DC.	Indigenous	LC		-	X	X	
	<i>Baccharoides adoensis</i> H.Rob.	Indigenous	LC		-	X	-	
	<i>Berkheya echinacea</i> Burt Davy	Indigenous	LC		-	X	X	
	<i>Berkheya erysithales</i> Roessler	Indigenous	LC		-	X	-	
	<i>Berkheya insignis</i> Thellung	Indigenous	LC		-	X	X	
	<i>Berkheya multijuga</i> Roessler	Indigenous	LC		-	X	-	
	<i>Berkheya rhapontica</i> Burt Davy	Indigenous	LC		-	X	X	
	<i>Berkheya setifera</i> Candolle	Indigenous	LC		-	X	-	
	<i>Berkheya speciosa</i> (DC.)O.Hoffm.	Indigenous	LC		-	X	X	
	<i>Berkheya umbellata</i> DC.	Indigenous	LC		-	X	X	
	<i>Bidens pilosa</i> L.	Alien	NE		-	X	X	
	<i>Chromolaena odorata</i> L.	Alien	NE		-	X	-	
	<i>Chrysanthemoides monilifera</i> (L.) Norl.	Indigenous	LC		-	X	-	
	<i>Euryops laxus</i> (Harv.) Burt Davy	Indigenous	LC		CCD 213	X	X	X
	<i>Garuleum latifolium</i> Harv.	Indigenous	LC			X	-	-
	<i>Gazania krebsiana</i> Less.	Indigenous	LC			-	X	-
	<i>Gerbera ambigua</i> Sch. Bip	Indigenous	LC			X	X	X
	<i>Gerbera kraussi</i> (Cass.) Sch. Bip.	Indigenous	LC			-	X	-
	<i>Helichrysum adenocarpum</i> subsp. <i>adenocarpum</i> Candolle	Indigenous	LC		CCD 240	X	X	X
	<i>Helichrysum allioides</i> Less.	Indigenous	LC			-	X	-
	<i>Helichrysum appendiculatum</i> (L.f.)Less.	Indigenous	LC		CCD 112	-	-	X
	<i>Helichrysum asplenifolius</i> Less.	Indigenous	LC			-	-	X
	<i>Helichrysum aureonitens</i> Sch. Bip.	Indigenous	LC		CCD 118, 174 and 197	X	X	X
	<i>Helichrysum aureum</i> Merrill	Indigenous	LC			X	X	X
	<i>Helichrysum auriceps</i> Hilliard	Indigenous	LC		CCD 167	X	X	X
	<i>Helichrysum cymosum</i> D.Don	Indigenous	LC			-	-	X
	<i>Helichrysum herbaceum</i> (Andrews) Sweet	Indigenous	LC		CCD 171	-	X	X
	<i>Helichrysum inornatum</i> Hilliard & B.L.Burt	Indigenous	LC			-	X	-
	<i>Helichrysum nudifolium</i> (L.) Less.	Indigenous	LC		CCD 111	-	X	X
	<i>Helichrysum oreophillum</i> Klatt	Indigenous	LC		CCD 119 and 220	X	X	X
	<i>Helichrysum pallidum</i> DC.	Indigenous	LC			-	-	X
	<i>Helichrysum pillosellum</i> DC.	Indigenous	LC			-	X	-
	<i>Lactuca indica</i> L.	Alien	NE			X	-	-
	<i>Lactuca tysonii</i> Phillips	Indigenous	LC			-	X	X
	<i>Senecio brachypoda</i> DC.	Indigenous	LC			-	-	X
	<i>Senecio glaberrimus</i> E.Walker	Indigenous	NE			X	X	-
	<i>Senecio madagascariensis</i> Poir	Indigenous	LC			-	-	X
	<i>Taraxacum officinale</i> F.H.Wigg.	Alien	NE			X	-	-

Appendix1 continues on next page →

Family	Species name and authorship	Invasive and alien status	Redlist status	Voucher details	IM	GGEP	SSNR
	<i>Vernonia hirsuta</i> (DC.) Sch.Bip.	Indigenous	LC		-	-	X
	<i>Vernonia natalensis</i> Klatt	Indigenous	LC		-	X	X
	<i>Vernonia oligocephalus</i> Klatt	Indigenous	LC		X	X	X
	<i>Vernonia sutherlandii</i> Harv.	Indigenous	LC		-	X	X
<b>Brassicaceae</b>	<i>Heliophila elongata</i> (Thun.) DC.	Indigenous	LC		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	-
<b>Commelinaceae</b>	<i>Commelina africana</i> L.	Indigenous	LC	CCD 110 and 192	X	X	X
	<i>Commelina benghalensis</i> L.	Indigenous	LC	CCD 121	X	X	X
	<i>Cynotis speciosa</i> Hasskarl	Indigenous	LC		X	X	X
<b>Convolvulaceae</b>	<i>Ipomoea albivenia</i> Sweet	Indigenous	LC		-	X	-
<b>Crassulaceae</b>	<i>Crassula alba</i> Forsskal	Indigenous	LC		X	X	X
<b>Cyperaceae</b>	<i>Bulbostylis hispidula</i> Haines	Indigenous	LC		-	X	X
	<i>Cyperus compressus</i> L.	Indigenous	LC		X	-	X
	<i>Cyperus congestus</i> Vahl.	Indigenous	LC		-	-	X
	<i>Cyperus obtusiflorus</i> var. <i>obtusiflorus</i> Vahl	Indigenous	LC	CCD 115, 168 and 190	X	X	X
	<i>Cyperus sphaerocephalus</i> Vahl	Indigenous	LC		X	X	X
	<i>Kyllinga alba</i> Nees	Indigenous	LC		X	-	-
<b>Dennstaedtiaceae</b>	<i>Pteridium aquilinum</i> Decken	Indigenous	LC		-	X	X
<b>Dipsacaceae</b>	<i>Scabiosa columbaria</i> L.	Indigenous	LC		X	X	-
<b>Eriospermaceae</b>	<i>Eriospermum cooperi</i> Baker	Indigenous	LC		-	-	X
	<i>Eriospermum mackenii</i> (Hook.f.) Baker	Indigenous	LC		X	X	X
	<i>Eriospermum ornithogaloides</i> Baker	Indigenous	LC		-	X	-
<b>Euphorbiaceae</b>	<i>Acalypha punctata</i> Mei. ex Krauss	Indigenous	LC		-	-	X
	<i>Clutia affinis</i> Sond.	Indigenous	LC		-	X	X
	<i>Clutia pulchella</i> L.	Indigenous	LC		X	X	-
<b>Fabaceae</b>	<i>Albizia</i> sp.				-	X	-
	<i>Aspalathus altissima</i> Dahlgren	Indigenous	LC		-	X	-
	<i>Chamaecrista plumosa</i> E.Mey.	Indigenous	LC		X	X	X
	<i>Crotalaria lanceolata</i> E.Mey.	Indigenous	LC		X	-	-
	<i>Crotalaria pallida</i> Aiton	Indigenous	LC		X	-	-
	<i>Desmodium ciliare</i> DC.	Alien	NE		X	X	X
	<i>Desmodium setigerum</i> Harvey	Indigenous	LC		-	-	X
	<i>Eriosema cordatum</i> Sond.	Indigenous	LC	CCD 182 and 194	X	X	X
	<i>Eriosema populifolium</i> Benth. ex Harv.	Indigenous	EN		X	X	X
	<i>Indigofera dimiata</i> Vog. ex Walp.	Indigenous	LC		X	X	-
	<i>Indigofera hedyantha</i> Ecklon & Zeyher	Indigenous	LC		-	-	X
	<i>Indigofera hiliaris</i> Ecklon & Zeyher	Indigenous	LC	CCD 177	X	X	X
	<i>Indigofera obscura</i> N.E.Br.	Indigenous	LC		X	X	X
	<i>Indigofera velutina</i> E.Mey	Indigenous	LC		X	X	-
	<i>Lotononis</i> sp.				X	X	-
	<i>Ophrestia oblongifolia</i> (E.Mey.) H.M.L.Forbes	Indigenous	LC		-	-	X
	<i>Pseudarthria hookeri</i> Wight & Arn.	Indigenous	LC		-	-	X
	<i>Sphenostylis angustifolia</i> Sond.	Indigenous	LC		X	X	X
	<i>Tephrosia elongata</i> E.Mey.	Indigenous	LC		-	X	X
	<i>Tephrosia macropoda</i> Harvey	Indigenous	LC	CCD 169 and 198	X	X	X
	<i>Tephrosia marginella</i> Forbes	Indigenous	LC		-	X	X
	<i>Tephrosia polystachya</i> E.Mey.	Indigenous	LC		X	X	X
	<i>Vigna unguiculata</i> (L.) Walp.	Indigenous	LC		X	-	-
	<i>Zornia capensis</i> Pers.	Indigenous	LC	CCD 183	-	X	X
<b>Geraniaceae</b>	<i>Pelargonium pulchellum</i> Sims	Indigenous	LC		-	-	X
<b>Hyacinthaceae</b>	<i>Albuca setosa</i> Jacq.	Indigenous	LC		X	-	-
	<i>Ledobouria revoluta</i> (L.f.) Jessop	Indigenous	LC	CD 223	X	-	X
<b>Hypoxidaceae</b>	<i>Hypoxis argentea</i> Harv. ex Baker	Indigenous	LC	CCD 221	X	X	-
	<i>Hypoxis decumbens</i> L.	Alien	NE		X	X	X
	<i>Hypoxis filiformis</i> Baker	Indigenous	LC		-	X	-
	<i>Hypoxis hemerocallidea</i> Fisch., C.A.Mey. & Avé-Lall.	Indigenous	Declining		X	X	-
	<i>Hypoxis rigidula</i> Baker	Indigenous	LC		-	X	X
<b>Iridaceae</b>	<i>Aristea abyssinica</i> Engler	Indigenous	LC	CCD 162	-	X	X
	<i>Gladiolus inandensis</i> Baker	Indigenous	LC		X	X	-
	<i>Hesperantha baurii</i> Baker	Indigenous	LC		-	-	X
	<i>Watsonia densiflora</i> Baker	Indigenous	LC	CCD 109, 164 and 199	X	X	X

Appendix1 continues on next page →

Family	Species name and authorship	Invasive and alien status	Redlist status	Voucher details	IM	GGEP	SSNR
Lamiaceae	<i>Leonotis leonurus</i> (L.) R.Br.	Indigenous	LC		X	-	X
	<i>Leucas martinicensis</i> Brown	Indigenous	LC		-	-	X
	<i>Plectranthus rehmannii</i> Gurke	Indigenous	LC		X	X	-
	<i>Pycnostachys reticulata</i> Bentham	Indigenous	LC		-	X	-
	<i>Rabdosiella calycina</i> (Benth.) Codd	Indigenous	LC		-	X	-
	<i>Teucrium kraussii</i> Codd	Indigenous	LC		-	-	X
Lobeliaceae	<i>Lobelia flaccida</i> Condon	Indigenous	LC		-	-	X
	<i>Monopsis decipiens</i> (Sond.) Thulin	Indigenous	LC		-	-	X
Malvaceae	<i>Hibiscus trionum</i> L.	Alien	NE		-	-	X
	<i>Melhania didyma</i> Ecklon & Zeyher	Indigenous	LC		X	X	X
	<i>Triumfetta pilosa</i> Roth	Indigenous	LC		X	X	X
Melastomataceae	<i>Dissotis princeps</i> Triana	Indigenous	LC		-	-	X
Myrtaceae	<i>Cryptolepis oblongifolia</i> Sond.	Indigenous	LC		X	X	-
Orchidaceae	<i>Eulophia hians</i> Spreng.	Indigenous	LC		-	-	X
	<i>Eulophia parviflora</i> (Lindl.) A.V.Hall	Indigenous	LC		X	X	-
Orobanchaceae	<i>Alectra sessiliflora</i> (Vahl) Kuntze	Indigenous	LC	CCD 106	-	-	X
	<i>Buchnera simplex</i> Druce	Indigenous	LC	CCD 178	-	X	X
Oxalidaceae	<i>Oxalis semiloba</i> R.Monteiro	Indigenous	LC		X	X	-
Plantaginaceae	<i>Plantago major</i> L.	Alien	NE		-	X	-
Poaceae	<i>Alloteropsis semialata</i> Hitchc.	Indigenous	LC	CCD 216	X	X	-
	<i>Andropogon appendiculatus</i> Nees	Indigenous	LC	CCD 180 and 242	X	X	X
	<i>Andropogon gayanus</i> Kunth	Indigenous	LC		-	X	X
	<i>Aristida junciformis</i> Trinius	Indigenous	LC	CCD 120, 184 and 187	X	X	X
	<i>Ctenium connicum</i> Nees	Indigenous	LC	CCD 219 and 226	X	X	X
	<i>Cymbopogon citratus</i> Stapf	Alien	NE		-	-	X
	<i>Cymbopogon nardus</i> (L.) Rendle	Indigenous	LC		-	-	X
	<i>Digitaria eriantha</i> Steudel	Indigenous	LC	CCD 117 and 189	X	X	X
	<i>Elionurus muticus</i> (Spreng.) Kunth	Indigenous	LC		-	X	-
	<i>Eragrostis racemosa</i> Steudel	Indigenous	LC	CCD 179	X	X	X
	<i>Eragrostis superba</i> Peyritsch	Indigenous	LC	CCD 214	X	-	-
	<i>Hemarthria altissima</i> (Poir.) Stapf & C.E.Hubb.	Indigenous	LC		-	-	X
	<i>Heteropogon contortus</i> (L.) Roem. & Schult.	Indigenous	LC		X	X	-
	<i>Imperata cylindrica</i> Raeusch	Indigenous	LC		X	-	X
	<i>Loudetia simplex</i> Vog. ex Walp.	Indigenous	LC	CCD 107 and 165	-	X	X
	<i>Melinis repens</i> (Willd.) Zizka	Indigenous	LC	CCD 218	X	X	X
	<i>Monocymbium ceresiiforme</i> Stapf	Indigenous	LC	CCD 116, 163 and 186	X	X	X
	<i>Panicum natalense</i> Steudel	Indigenous	LC	CCD 108, 185 and 225	X	X	X
	<i>Panicum schinzii</i> Hackel	Indigenous	LC	CCD 241	X	X	X
	<i>Paspalum notatum</i> Fluge	Alien	NE		-	-	X
	<i>Poa annua</i> Steud.	Alien	NE		X	X	X
	<i>Rendlia altera</i> (Rendle) Chiov.	Indigenous	LC		X	X	-
<i>Setaria lindenberiana</i> Stapf	Indigenous	LC	CCD 191	X	-	-	
<i>Setaria sphaelata</i> var <i>sericea</i> Stapf & C.E.Hubb.	Indigenous	LC	CCD 114	-	-	X	
<i>Setaria verticillata</i> (L.) P.Beauv.	Indigenous	LC		X	X	-	
<i>Sporobolus fimbriatus</i> Nees	Indigenous	LC	CCD 224	X	X	X	
<i>Themeda triandra</i> Forsskal	Indigenous	LC		X	X	X	
<i>Tristachya leucothrix</i> Trin. ex Nees	Indigenous	LC		-	X	-	
Polygalaceae	<i>Polygala amatymbica</i> Burch. ex DC.	Indigenous	LC		-	X	-
	<i>Polygala refracta</i> Burch. ex DC.	Indigenous	LC		-	X	-
Proteaceae	<i>Protea roupelliae</i> Meier	Indigenous	LC		X	X	-
	<i>Protea welwitschii</i> subsp. <i>welwitschii</i> Engler	Indigenous	LC		X	X	-
Ranunculaceae	<i>Clematis brachiata</i> Thunb	Indigenous	LC		-	-	X
Rosaceae	<i>Rubus rosifolius</i> Sm	Alien	NE		-	-	X
Rubiaceae	<i>Anthospermum</i> sp.				-	-	X
	<i>Burchellia bubalina</i> (L.f.) Sims	Indigenous	LC		-	X	-
	<i>Conostomium natalense</i> (Hochst.) Bremek	Indigenous	LC		-	X	-
	<i>Kohautia amatymbica</i> Ecklon & Zeyher	Indigenous	LC		-	X	-
	<i>Pachystigma venosum</i> Hochst.	Indigenous	LC		-	X	X
	<i>Pavetta graciliflora</i> Wall	Indigenous	LC		-	-	X
	<i>Pentanisia angustifolia</i> Hochst	Indigenous	LC	CCD 105, 166 and 193	X	X	X
	<i>Rothmannia globosa</i> (Hochst.) Keay	Indigenous	LC		-	X	-

Appendix1 continues on next page →

Family	Species name and authorship	Invasive and alien status	Redlist status	Voucher details	IM	GGEP	SSNR
<b>Santalaceae</b>	<i>Thesium natalense</i> Sond.	Indigenous	LC	CCD 217	X	X	X
<b>Scrophulariaceae</b>	<i>Hebenstretia comosa</i> Hochst.	Indigenous	LC		X	X	-
	<i>Selago trausaldii</i> Killick	Indigenous	LC		X	X	X
	<i>Tetraselago natalensis</i> Rolfe	Indigenous	LC	CCD 170, 195 and 239	X	X	X
	<i>Zaluzianskya elongata</i> Hilliard & B.L.Burt	Indigenous	LC		X	X	X
<b>Sinopteridaceae</b>	<i>Cheilanthes viridis</i> Sw.	Indigenous	LC		-	-	X
<b>Smilacaceae</b>	<i>Smilax anceps</i> Willdenow	Indigenous	LC		-	-	X
<b>Thymelaeaceae</b>	<i>Gnidia burchellii</i> (Meisn.) Gilg	Indigenous	LC		-	-	X
	<i>Gnidia kraussiana</i> Meisn.	Indigenous	LC	CCD 215	X	X	-
	<i>Gnidia splendens</i> Meisn.	Indigenous	LC		-	X	-
	<i>Lasiosiphon capitatus</i> (L.f.) Burt Davy	Indigenous	LC		X	X	X
<b>Verbenaceae</b>	<i>Lantana camara</i> L.	Alien	NE		X	-	-
	Unknown Type 1				X	-	-
	Unknown Type 2				X	-	-
	Unknown Type 4				-	-	X