

A FLORISTIC ANALYSIS OF THE VEGETATION OF PLATBERG, EASTERN FREE STATE, SOUTH AFRICA

Authors:

Robert F. Brand¹
Leslie R. Brown¹
Pieter J. du Preez²

Affiliations:

¹Applied Behavioural Ecology and Ecosystem Research Unit, Department of Environmental Sciences, University of South Africa, Florida campus, South Africa

²Department of Plant Sciences, University of the Free State, South Africa

Correspondence to:

Leslie R. Brown

email:

lrbrown@unisa.ac.za

Postal address:

Department of Environmental Sciences, UNISA, Florida campus, Private Bag X6, Florida, 1710, South Africa

Keywords:

Drakensberg Alpine Centre; endemism; Platberg; Red Data species; species richness

Dates:

Received: 18 June 2009
Accepted: 11 Oct. 2009
Published: 29 Mar. 2010

How to cite this article:

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(1), Art. #710, 11 pages, DOI: 10.4102/koedoe.v52i1.710

This article is available at:

<http://www.koedoe.co.za>

© 2010. The Authors.
Licensee: OpenJournals Publishing. This work is licensed under the Creative Commons Attribution License.

ABSTRACT

A checklist of vascular plants of Platberg was compiled to determine species richness, rarity and endemism. The floristic analysis is part of the Department of Economic, Tourism and Environmental Affairs Free State biodiversity assessment programme and conservation management plan for Platberg.

The analysis identified a total of 669 species belonging to 304 genera and 95 families, with 214 species belonging to the Monocotyledoneae and 438 species to the Dicotyledoneae. The largest family is Asteraceae with 126 species, followed by Poaceae with 73 species, Cyperaceae with 39 species, Fabaceae with 33 species, and Scrophulariaceae with 27 species. Various fynbos species were found, as well as 26 endemic/near-endemic species belonging to the Drakensberg Alpine Centre or Eastern Mountain Region.

The results of this study revealed that Platberg shares inselberg floral richness and endemism that can be tracked via the Afromontane archipelago-like string of inselbergs and mountains, which stretch north through the Chimanmani Mountains, into Malawi, the Eastern Arc Mountains via Tanzania and north through Ethiopia, into Eurasia.

Conservation implications: Platberg, as an inselberg, is a site of significant biological diversity, with high species richness, vegetation selection and ecosystem complexity. It shares floral richness and endemism via inselbergs and mountains throughout Africa. The high species richness, Red Data species and ecosystems make this area an important conservation site that should be legislated and protected.

INTRODUCTION

With the human population steadily on the rise, the natural environment is under greater pressure than ever before (Huntley 1991). Natural areas act as reservoirs for plant and animal populations (IUCN 1980). *Platberg*, overlooking the town of Harrismith in the Free State, is an *inselberg* that presents a refuge for indigenous plants and animals (Burke 2001; Gröger *et al.* 1996; Mutke *et al.* 2001; Porembski *et al.* 1997, 1998; Porembski & Brown 1995). Vegetation surveys provide information on the different plant communities and plant species present and form the basis of any management plan for a specific area (Brown *et al.* 1996).

Little is known about the different taxa of Platberg and hence a detailed floristic and ecological survey was undertaken to quantify threats to the native flora and to establish whether links exist with higher-altitude Afro-alpine flora occurring on the Drakensberg. No extensive vegetation surveys had been undertaken on Platberg prior to this study; only limited opportunistic floristic collections were done in the mid-1960s by Mrs. Jacobs (these vouchers were mounted and authenticated in 2006 and are now housed at the Geo Potts Herbarium, Botany Department, University of the Free State). Similarly, 50 relevés were sampled between 1975 and 1976 by Professor H.J.T. Venter, Department of Genetics and Plant Sciences, University of the Free State.

Study area

Location

The town of Harrismith is located at the foot of Platberg (29°10' S and 28°16' E), along the N3 highway between Johannesburg and Durban (Figure 1).

Platberg's altitude ranges from 1 900 m to 2 394 m. The surface area covers approximately 3 000 ha. The slopes are steep with numerous vegetated gullies and boulder scree slopes below vertical cliffs that are 20 m to 45 m high. Waterfalls cascade down the southern cliffs after rain. A permanent stream arising from the Gibson Dam on the undulating plateau flows off the escarpment and cascades as a waterfall (Figure 2).

From a distance, Platberg appears to have a distinct flat top. However, once on the summit the plateau is found to be undulating, with rolling grass-covered slopes. The vegetation of the plateau is dominated by grassland, with a few rocky ridges, sheet rock and rubble patches, as well as numerous seasonal wetlands and a permanent open playa (pan) on its far western side.

Woody patches of the genera *Leucosidea*, *Buddleja*, *Kiggelaria*, *Polygala*, *Heteromorpha* and *Rhus* shrubs, as well as the indigenous Mountain bamboo *Thamnochalamus tessellatus*, grow along the base of the cliffs. The shrubland vegetation is concentrated on the cool side of Platberg, on sandstone of the Clarens Formation, in gullies, on scree slopes, mobile boulder beds, and on rocky ridges. Shrubs and trees also occur in a riparian habitat in the south-facing cleft, in which the only road ascends steeply to the summit.

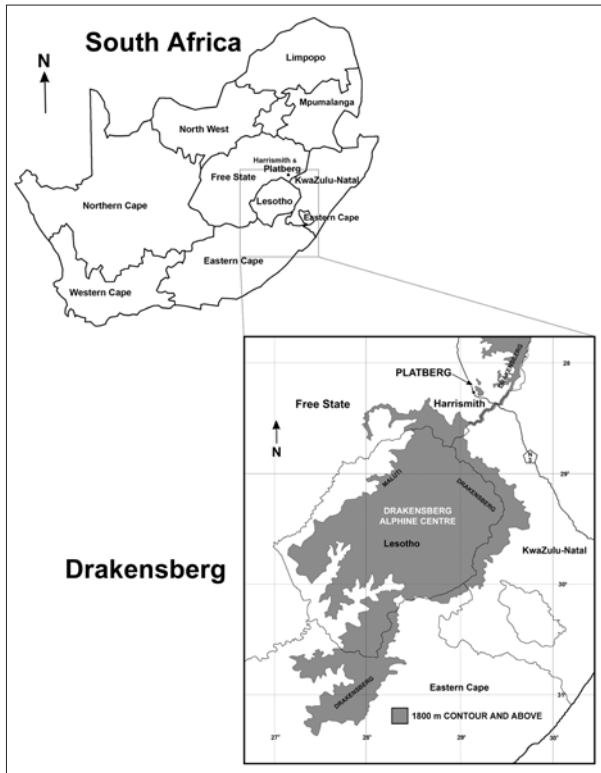


FIGURE 1
Location of Platberg, Free State

Platberg falls within the Grassland Biome, generally containing short to tall sour grasses (Acocks 1988; Low & Rebelo 1996). The vegetation map of Mucina and Rutherford (2006) shows Platberg as a prominent isolated vegetation 'island' with affinities to the Drakensberg Grassland Bioregion, embedded in a lower lying matrix of Eastern Free State Sandy Grassland (Gm 4). Platberg also has elements of Fynbos (Brand *et al.* 2008; Mucina & Rutherford 2006), False Karoo (Acocks 1998) and Succulent Karoo (Low & Rebelo 1996), as well as elements of Temperate and Transitional Forest, specifically Highland Sourveld (44a, Acocks 1988) veld types.

Geology

Platberg consists of layers of the Karoo Supergroup, which stratigraphically lie immediately below the volcanic rocks of the Drakensberg Formation, the youngest unit of the Stormberg Group. The 1 900 m contour marks the initiation of the footslopes of Platberg and is constituted by the aeolian and waterborne sediments of the Clarens Formation (Du Toit 1954; Look *et al.* 1991; Norman & Whitfield 1998; Truswell 1970). Several dolerite dykes intersect Platberg, with a close-set sequence of parallel dykes forming the woody/shrub community on the northern and southern slopes. A dolerite dyke is evident just below the Gibson Dam and is exposed by a borrow pit used for quarrying. Numerous other dykes are visible on aerial photographs. These dyke swarms occur mostly on the flat terrain at lower altitudes, with only a few intersecting Platberg itself. These dykes are also visible in plantation road-cuts on the southern side of Platberg.

Topography and soils

The steep slopes are composed of shale and mostly sandstone of the Clarens Formation, intersected by dolerite dykes, resulting in benches, deep ravines and terraces. Numerous sandstone and basalt boulders form scree and boulder slopes, resulting in miscellaneous soils forms, characteristic of the Ib land type, specifically Mispah (Ms) and Glenrosa (Gs) soil forms (du Preez 1991; MacVicar *et al.* 1991; Mucina & Rutherford 2006). There are affinities with Fa land types' undulating rocky landscape dominated by shallow Ms and Gs soil forms (Land Type Survey Staff 1991; Smit *et al.* 1993).

The summit plateau is composed of igneous rock, specifically basalt and dolerite. These soils are generally shallow (20 mm – 200 mm), with the deepest being < 500 mm. Soils are derived from basalt and are shown to have even proportions of coarse sand, fine sand, clay and silt, with moderate to high organic matter content. The main land type is Ea (clay vertic, melanic or red diagnostic horizons) (MacVicar 1991; Mucina & Rutherford 2006; Smit *et al.* 1993) with a clay content of 8% to 60%, depending on the soil series (Land Type Survey Staff 1991).

Climate

The mean annual precipitation for the study area ranges between 800 mm and 1 200 mm, with the mean daily maximum temperature fluctuating between 22 °C and 24 °C for the hottest month of January. During the coldest months (June and July) the daily mean temperature ranges from -2 °C to 0 °C. Rainfall occurs throughout the year; the highest rainfall is recorded in the summer months (October to March; Figure 3). The daily mean relative humidity for the most humid month, March, varies between 68% and 72%, and the daily minimum relative humidity for July and August varies between 32% and 38% (Mucina & Rutherford 2006; Schulze 1997; South African Weather Service 2007; Van Zinderen Bakker 1973).

Snow occurs on the top of Platberg during most winters and can remain on the ground for up to two weeks, while water in south facing gullies may be frozen for several weeks at a time (Mucina & Rutherford 2006; Van Zinderen Bakker 1973). Possible heavy soils are present on Mtabazwe, the highest point on Platberg (Hilliard & Burt 1987) and may be a significant factor affecting vegetation at high altitudes (Hilliard & Burt 1987; Mucina & Rutherford 2006).

The climate of Platberg and the Drakensberg is part of a continental, north-south trending Austro-Afro-alpine climate, with noticeably higher precipitation than the surrounding lowland. Precipitation along the Drakensberg Escarpment is over 1 400 mm in some areas, with a gradual decrease both to the north and south, as well as westwards (560 mm) to the drier sub-humid continental climate towards Bloemfontein, some 400 km away (Scott 1988; Van Zinderen Bakker 1973). Precipitation is orographic, not only from violent thunderstorms in summer, but also from dense mist and fog (Smit *et al.* 1993) as well as snow. According to Cowling *et al.* (1992), climatic heterogeneity associated with montane landscape is a more important determinant of plant diversity than geological heterogeneity.

METHOD

Ad hoc plant collections and reconnaissance surveys commenced in 2003 and 2004. The main collections associated with the Braun-Blanquet survey on Platberg were made from October 2005 through to January 2007. These collections were of plants growing exclusively in the 393 sample plots, which comprised the entire survey for this study. All specimens were pressed, dried and labelled according to standard field and herbaria practices. Identification was done at the Geo Potts Herbarium, UFS. Problematic material was identified at the National Herbarium of the South African National Biodiversity Institute (SANBI) in Pretoria. All floristic material currently resides at the Geo Potts Herbarium.

The final species list was compiled from material collected at Platberg for this study. This species list was compiled from all collections of Platberg housed at the UFS and SANBI-Pretoria Herbaria, supplemented by information contained in numerous reference books. For trees and wildflowers the following books were consulted: Hilliard (1990, 1992), Hilliard and Burt (1987), Killick (1990), Pooley (1997, 1998, 2003), and Van Wyk and Smith (2001); for grasses: Gibbs-Russell *et al.* (1991), Moffett (1997) and Van Oudtshoorn (1999); and for the sedges: Gordon-Grey (1995). Information compiled by Germishuizen *et al.* (2006) was used for nomenclature, the latest taxonomic changes and arrangement, as well as an author update. Alien species (introduced exotics) are

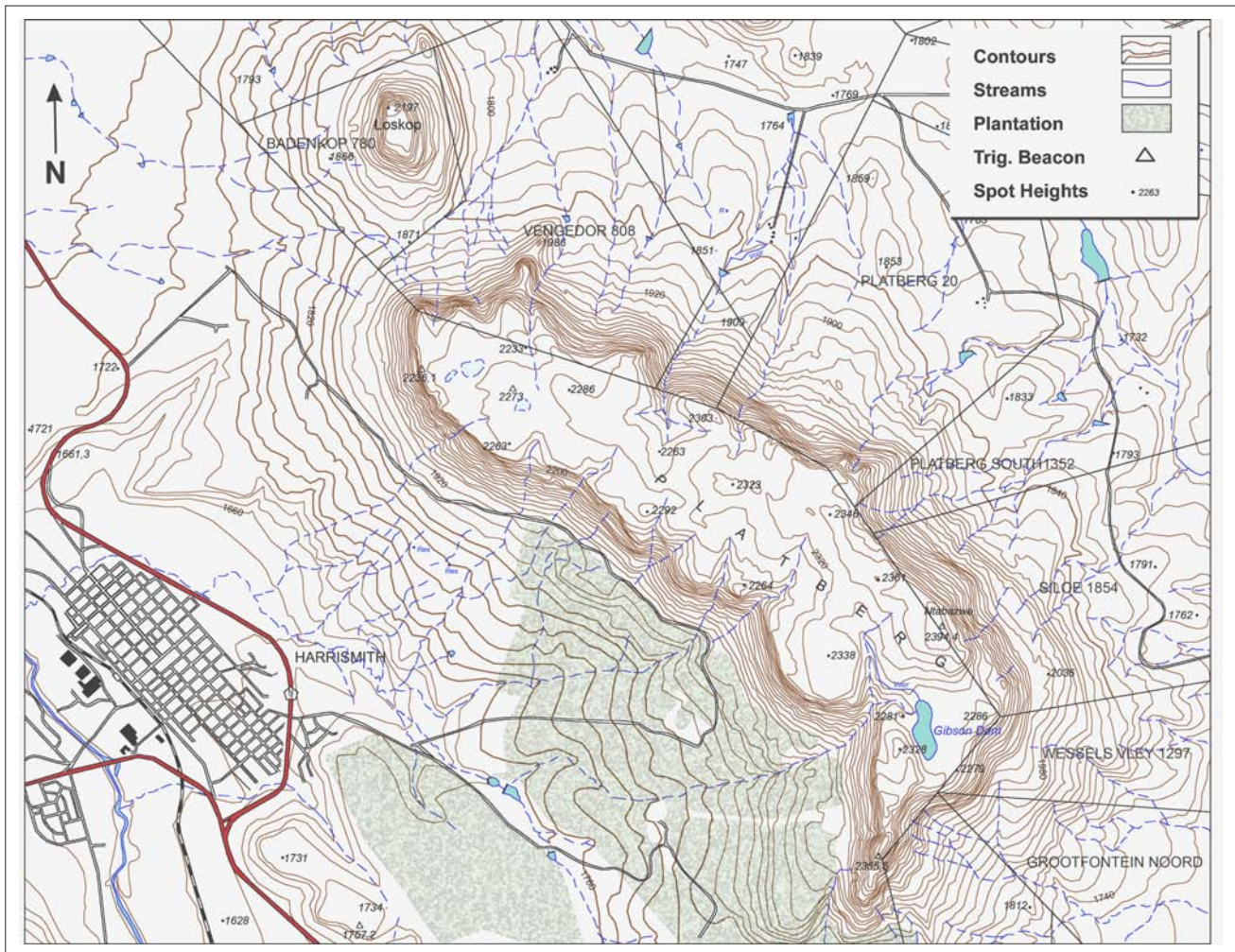


FIGURE 2
Topography of the study area

marked with an asterisk (*). The conservation status of plants was checked against the National Red List of South African Plants (2009), as well as Golding (2002), Hilton-Taylor (1996) and Scott-Shaw (1999). Endemic or near-endemic classification was ascertained from Carbutt & Edwards (2004, 2006), Pooley (2003) and Scott-Shaw (1999).

The complete species list for Platberg (Tables 2–4 in online Appendix) was sorted according to the Englerian system (SANBI–Pretoria) that conforms to the system used by Arnold and De Wet (1993). Red Data status was included, where applicable. Throughout this discussion the term Drakensberg Alpine Centre (DAC) will be used in line with the terminology and updated nomenclature as followed by Carbutt and Edwards (2006).

RESULTS

An assumption and basic hypothesis has been that Platberg is linked, phytosociologically to, and is a floristic extension of, the DAC. The phytosociological analysis of Platberg as described by Brand (2007) and Brand *et al.* (2008) shows strong links with the DAC and supports this assumption. The DAC is regarded as the only true Alpine region in southern Africa (Carbutt & Edwards 2004; Killick 1963, 1978a) and, together with the Cape Floristic Region (CFR), contributes significantly to the flora of Africa (Hilliard & Burtt 1987), via east and west coast mountain tracks (Mutke *et al.* 2001). The flora of the DAC and, by extension, Platberg is an amalgamation of numerous floras from both temperate and subtropical as well as Afromontane

sources (Hilliard & Burtt 1987) and contains significant taxonomic influences from the CFR (Goldblatt & Manning 2000). The DAC and CFR link is reported in studies of the Eastern Cape Drakensberg region by Hoare and Bredenkamp (2001), in studies of the Stormberg and Drakensberg and the grasslands of southern KwaZulu-Natal by Bester (1998), and in studies of the adjacent Drakensberg regions by Perkins (1997) and Perkins *et al.* (1999a, 1999b).

According to Van Wyk and Smith (2001) the total number of species for the DAC is about 2 200, with no endemic/near-endemic families, four endemic/near-endemic genera, and > 400 endemic/near-endemic species/taxa (18.2%), with 5% succulents amongst the endemics. Other surveys have covered smaller regions. There exists no complete survey for the entire Drakensberg that provides comprehensive and accurate figures. Table 1 presents a summary of regional floras of the DAC and includes the most recent figures for a total of 2 520 species, with no endemic families and six near-endemic genera (Carbutt & Edwards 2004).

Floristic analysis of Platberg

The Platberg vascular plant species list comprised a total of 669 species, represented by 304 genera and 95 families (Table 1 in online Appendix). The flowering plants are represented by Monocotyledoneae with 214 species from 23 families (23% of total number of families) and Dicotyledoneae with 438 species from 63 families (67%). Pteridophytes are represented by 16 species and eight families (8.4%), and Gymnosperms by one

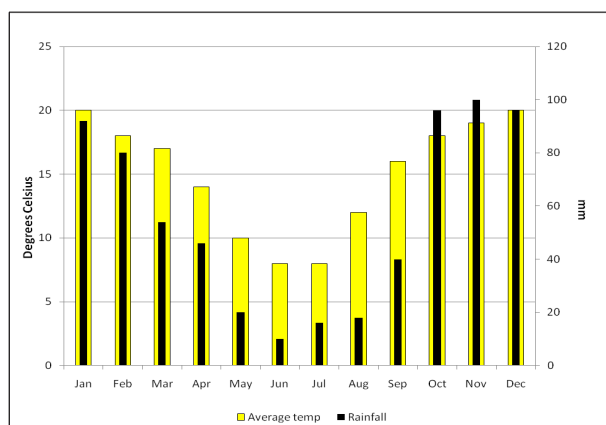


FIGURE 3
The average rainfall and temperatures for the study area

TABLE 1
A summary of regional floras of the Drakensberg Alpine Centre

DAC site (collector and date)	Families	Genera	Species
[†] Drakensberg Alpine Centre (Carbutt & Edwards 2004)	134	630	2530
QwaQwa, Free State Drakensberg (Moffett <i>et al.</i> 2001)	117	439	1074
Eastern Cape Drakensberg (Bester 1998)	116	506	1926
Eastern Mountain Region (Phillips 1917)	91	466	1553
Cathedral Peak (Killick 1963)	91	373	861
Lesotho (Jacot Guillarmod 1971)	95	526	1052
Southern Drakensberg (Hilliard & Burt 1987)	91	404	1375
Platberg (Brand 2007)	95	304	669

[†]Carbutt and Edwards (2004) exclude Pteridophytes and Gymnosperms.

family and one species (1%). The complete species list, separated into the different divisions and sorted by family, appears in the online Appendix.

Largest plant families on Platberg

The 13 largest families comprised 411 species from 158 genera, which represented 50.7% of the Angiosperms and 61.4% of the total flora thus far recorded for Platberg, while the remaining 82 families reflected the other 38.6%.

The two largest families were Asteraceae with 126 species from 40 genera, constituting 18.8% of the total flora, and Poaceae with 73 species from 39 genera, constituting 10.9% of the total flora. With a significantly lower number of species, the next 11 largest families (in descending order) were the following:

- Cyperaceae with 39 species from 18 genera (5.8%)
- Fabaceae with 33 species from 13 genera (4.9%)
- Scrophulariaceae with 27 species from 13 genera (4.0%)
- Hyacinthaceae with 21 species from 10 genera (3.1%)
- Orchidaceae with 16 species from eight genera (2.4%)
- Iridaceae with 17 species from six genera (2.5%)
- Crassulaceae with 13 species from three genera (1.9%)
- Geraniaceae with 12 species from three genera (1.8%)
- Thymelaeaceae with 12 species from three genera (1.8%)
- Lobeliaceae with 12 species from three genera (1.8%)
- Campanulaceae with 10 species from two genera (1.5%).

All other families had fewer than 10 species.

TABLE 2
Ranking of the 17 most dominant genera for Platberg

Rank and genus	Taxonomic status	Number of species
1 <i>Helichrysum</i>	D	31
2 <i>Senecio</i>	D	30
3 <i>Crassula</i>	D	13
4 <i>Wahlenbergia</i>	D	9
4 <i>Lotononis</i>	D	9
5 <i>Gnidia</i>	D	8
5 <i>Erica</i>	D	8
6 <i>Sebaea</i>	D	7
7 <i>Asparagus</i>	M	6
7 <i>Eragrostis</i>	M	6
7 <i>Polygala</i>	D	6
7 <i>Hypoxis</i>	M	6
8 <i>Aristida</i>	M	5
8 <i>Bromus</i>	M	5
8 <i>Kniphofia</i>	M	5
8 <i>Schoenoxiphium</i>	M	5
8 <i>Zaluzianskya</i>	D	5

M, Monocotyledons; D, Dicotyledons.

The Pteridophytes comprised 8.5% of the total number of families for Platberg and Gymnosperms comprised 1%. Angiosperms represented 90.5%, with a breakdown into Monocotyledons constituting 26.7% and Dicotyledons constituting 73.3% of vascular plants.

The largest 17 genera each had five species or more, with the genera *Helichrysum* and *Senecio* each having a considerably larger number of species (31 and 30 species, respectively) than any of the other genera (Table 2).

Twenty-nine Red Data, endemic or near-endemic species were found to represent 4.3% of the total flora for Platberg, all of which were Angiosperm (Table 3). Introduced species (see Tables 2–4 in online Appendix) amounted to 22, which represented 3.3% of the total plant species.

Three of the six near-endemic genera for the DAC were found on Platberg, two of which were Monocotyledoneae: the mountain bamboo *Thamnochalamus* (Poaceae) and *Rhodohypoxis* (Hypoxidaceae), and one the Dicotyledoneae *Craterocapsa* (Campanulaceae). The other remaining three near-endemic genera, not recorded on Platberg, were *Guthriea* (Achariaceae), *Huttonaea* (Orchidaceae) and *Glekia*, which made a total of 11 endemic or near-endemic genera for the DAC (Carbutt & Edwards 2004).

DISCUSSION

An analysis of the flora for Platberg (online Appendix 1) shows that the largest family is Asteraceae, with 126 species (18.8% of the total species). This is not unusual for the Grassland Biome or the DAC (Carbutt & Edwards 2004), or even for South Africa, where in semi-arid to arid areas Asteraceae is the largest family (Goldblatt & Manning 2000). The Poaceae is the next largest family (10.9%), with the majority of grasses using C4 metabolism, which is characteristic of adaptations to high temperatures and low rainfall. This is somewhat analogous for Platberg, with its higher altitude and rainfall as well as its close proximity to the Drakensberg massif. However, a more detailed analysis shows



TABLE 3
A compilation of endemic/near-endemic and threatened taxa, and their conservation status for Platberg

Endemic/near-endemic and threatened taxa	Conservation status
Monocotyledoneae (N = 15)	
<i>Aloe aristata</i> [†] Haw.	EMR endemic, lower risk, uncommon, CITES 2, traditional medicinal use, LC.
<i>Aloe pratensis</i> Baker	EMR endemic, at lower risk, LC.
<i>Aristida monticola</i> Henrard	EMR endemic, no threat, LC.
<i>Bowiea volubilis</i> [†] Harv. Ex Hook.f.	Becoming rare, high priority conservation status, VU.
<i>Bromus firmior</i> (Nees) Stapf.	EMR endemic, no threat, LC.
<i>Dioscorea sylvatica</i> [†] (Kunth) Eckl.	Near-threatened, uncommon, traditional medicinal use, VU.
<i>Disperis tysonii</i> Bolus	EMR endemic, southern Drakensberg, E. Cape, LC.
<i>Disperis wealii</i> Rchb.f.	DAC near-endemic taxa, lower risk, LC.
<i>Eucomis autumnalis</i> [†] (Mill.) Chitt.	Vulnerable, uncommon, protected, medium priority, declining.
<i>Euryops evansii</i> E. Phillips	EMR endemic, no threat, LC.
<i>Kniphofia evansii</i> [†] Baker	EMR endemic, near-threatened, uncommon, protected. Range extension: Cathedral Peak, Giant's Castle.
<i>Merrillia plumbea</i> [†] Planch.	EMR endemic, near-threatened, traditional medical use.
<i>Thamnocalamus tessellatus</i> (Nees) Soderstr. & R.P.Ellis	EMR near-endemic genus, lower risk, uncommon, LC. Nearest member E. African mountains and Himalayas.
<i>Rhodohypoxis baurii</i> (Baker) Nel	DAC near-endemic genus, LC.
<i>Schizochilus flexuosum</i> Harv. Ex Rolfe	EMR endemic, no threat, LC.
Dicotyledoneae (N = 14)	
<i>Alepidea pusilla</i> Weim.	EMR endemic, LC.
<i>Cliffortia spathulata</i> L.	DAC, rare, Orange List (Carbutt & Edwards 2004), LC.
<i>Craterocapsa tarsodes</i> Hilliard & B.L.Burt	EMR, near-endemic genus, LC.
<i>Cyphia natalensis</i> E. Phillips	EMR endemic, insufficient data, LC. Found Stormberg and Amatoles, E. Cape.
<i>Erica thodei</i> Guthrie & Bolus	EMR endemic, lower risk, LC.
<i>Gnidia renniana</i> Hilliard & B.L.Burt	EMR endemic, LC.
<i>Helichrysum album</i> N.E.Br.	EMR endemic, insufficient data, rare.
<i>Helichrysum aureum</i> (Houtt.) Merr.	EMR endemic, LC.
<i>Lessertia harveyana</i>	EMR endemic, LC.
<i>Monsonia natalensis</i> R.Knuth	EMR endemic, LC.
<i>Schizoglossum bidens</i> E.Mey.	Data deficient, last collected in KZN in 1964, LC.
<i>Senecio erubescens var incisus</i> Aiton	EMR endemic, LC.
<i>Struthiola angustiloba</i> B.Peterson & Hilliard	EMR endemic, uncommon, range extension on Platberg, LC.
<i>Wahlenbergia cuspidata</i> Brehmer	EMR endemic, at lower risk (Carbutt & Edwards 2004), LC.

Sources: Carbutt and Edwards 2004, 2006; Pooley 2003; Red Data List 2009; Scott-Shaw 1999
EMR, Eastern Mountain Region; DAC, Drakensberg Alpine Centre; LC, least concern; VU, vulnerable.
Angiosperm flora N = 29. DAC, EMR endemic/near-endemic taxa N = 26.
[†]Threatened due to collection for traditional medical use.

the composition of grasses to be a mix of C3 and C4, with about a quarter using a combination of the metabolic pathways of both (Brand 2007). The position of Fabaceae (fourth largest, 4.9%) and Scrophulariaceae (fifth largest, 4%) is also a reflection of their position globally, as well as across drier parts of Africa (Goldblatt & Manning 2000). The high value of Cyperaceae is not unexpected; it shows similar patterns for South Africa and related areas. A comparison of Cyperaceae for inselbergs (Brand 2007) confirms these high values for Cyperaceae, which may be a result of the harsh conditions found on inselbergs that favour Cyperaceae development and radiation (Gröger & Barthlott 1996).

A comparison of the ratio of Monocotyledoneae to Dicotyledoneae for Platberg (Table 2) is 1:2.15, which is almost identical to that for Korannaberg of 1:2.16 (Du Preez 1992). However, the ratio for Mountain Zebra National Park, Eastern Cape, is 1:8 (Pond *et al.* 2002), which is higher than the average for the CFR of 1:3

(Goldblatt & Manning 2000). The latter is the average for floras worldwide (Goldblatt & Manning 2000). A comparison of the five largest Angiosperm families of Platberg, the DAC and other relevant areas shows striking similarities.

Twenty-nine Red Data, endemic and near-endemic species (all of which are Angiosperms) comprise 4.3% of the total flora of Platberg (Table 3), which is lower than for the DAC at 7.2% (Carbutt & Edwards 2004).

Platberg: Environmental conditions on inselbergs and floristic comparisons

Inselbergs represent sites with extreme environmental conditions (Gröger & Barthlott 1996), which include high levels of daily temperature change, namely 8 °C to 28 °C for December and -2 °C to 18 °C for July (Schulze 1997). Frost is another important environmental factor for inselbergs; the average

number of days with frost is between 61 and 120 days (Schulze 1997). Shallow soils, characteristic of large sections of inselbergs, have limited water retention, which results in harsh conditions for the vegetation; intermittent water is a major limiting factor, resulting in edaphic and micro-climatic xeric islands (Gröger & Barthlott 1996; Körner 2003).

A comparison of the inselberg vegetation of Platberg and Korannaberg is shown in Table 4, with a close correlation of taxa and their numbers. There is a clear topographic diversity pattern associated with inselbergs. Climate and topography are only part of the explanation for high biodiversity; it is rather the diversity of plant communities that provides a measure of habitat diversity (Cowling & Lombard 2002) and is a reflection of the response to climate change (Mucina & Rutherford 2006; Scott *et al.* 1997).

There is a high degree of similarity between the Angiosperm flora of Platberg and Korannaberg (Table 4), with the higher numbers for Korannaberg possibly the result of its much larger area (Cowling & Lombard 2002; MacArthur & Wilson 2001) – as the surface area increases more species can be supported (Gröger & Barthlott 1996; Linder 2003). Additionally, it was noted that the higher species numbers for Korannaberg could be due to its position, which has strong Afromontane, Nama Karoo and Savanna floristic influences (Du Preez 1991, 1992; Du Preez *et al.* 1991; Du Preez & Bredenkamp 1991).

Compared to other regional floras, Platberg has one of the highest species-to-area ratios (Figure 4). For the Bourke's Luck site, the figure of 5.244 is converted from 524.4 hectares, selected from the total Reserve size of 26 818 hectares, with similar rainfall (700 mm – 1 400 mm per annum), slightly higher temperatures, and situated on the Escarpment at 1 640 m to 1 900 m (Brown *et al.* 2005; Mucina & Rutherford 2006).

Endemism, species richness and floristic links with the DAC

Phytosociologically, geologically, topographically, climatically and biogeographically, Platberg may be seen as an extension of the DAC. It would then be expected that strong floristic affinities would be seen between the two sites (Table 5). The DAC is seen as a transition zone, a migratory pathway and repository for taxa of diverse regions and biomes (Carbutt & Edwards 2004; Hilliard & Burt 1987; Killick 1963, 1978a, 1978b; Mucina & Rutherford 2006). The DAC has close affinities with the CFR. This is particularly seen in the fynbos vegetation unit elements found on Platberg and the DAC, and described as the Gd 9 Drakensberg–Amathole Afromontane Fynbos, as well as the Northern Escarpment Afromontane Fynbos (Gm 24; Mucina & Rutherford 2006). Other floristic affinities are seen with the Magaliesberg, with the Gm 29 Waterberg–Magaliesberg Summit Sourveld (Mucina & Rutherford 2006), and the surrounding Bankenveld, Witwatersrand areas (Behr & Bredenkamp 1988; Bredenkamp & Brown 2003; Grobler *et al.* 2002, 2006). Floristic links between the DAC, KwaZulu-Natal and the CFR are elucidated in studies by Bester (1998), Hill (1996), Hoare and Bredenkamp (2001), Pond *et al.* (2002), Perkins (1997), Perkins *et al.* (1999a), Smit *et al.* (1993, 1995), and described as the Gs 1 Northern Zululand Mistbelt Grassland (Mucina & Rutherford 2006).

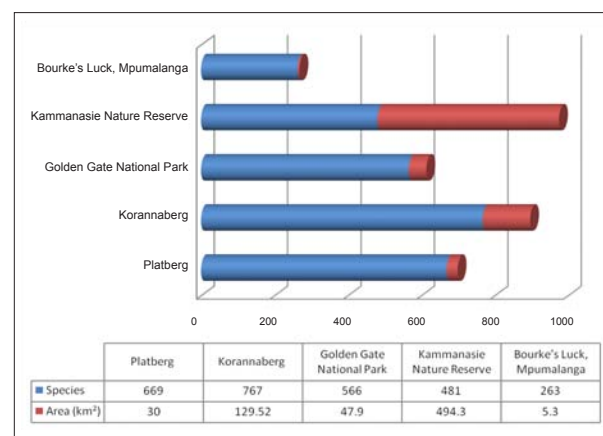
The ecological survey undertaken by Kay *et al.* (1993) of the Golden Gate National Park does not give a floristic analysis with the breakdown into the numbers of families, genera and species. The phytosociological table given lists a total of 114 species and makes no reference to a total species count. The paper by Roberts (1969) on the vegetation of the Golden Gate Park lists a total of 331 vascular plants and is 'a list of the more abundant species present' (Roberts 1969). It is thus not possible to make comparisons with the flora of the only other site that has high-altitude grasslands in the proximity of Platberg.

The floristic composition for Platberg and the related DAC shows Asteraceae as the largest family (Table 5). This is also the case for the Cape flora, with significant correlation within the top 12 to

20 families (Goldblatt & Manning 2000). Fabaceae is the second largest family, followed by Aizoaceae, Ericaceae and Iridaceae, which is a unique aspect of the Cape flora (Goldblatt & Manning 2000). These families are thus represented in the top 10 for Platberg as well as the DAC. The second most speciose family, Poaceae, followed by Cyperaceae, reflects Platberg's position in the Grassland Biome with similar floral composition to the DAC (Carbutt & Edwards 2004, 2006; Mucina & Rutherford 2006) and the more grassy regions to the west and north (Du Preez 1991; Du Preez & Bredenkamp 1991; Eckhardt *et al.* 1993a, 1993b, 1995; Fuls 1993; Kooij *et al.* 1990a, 1990b, 1990c; Malan 1998). This is in contrast to the Cape flora, where Poaceae and Cyperaceae are poorly represented, with Restionaceae filling the environmental and floristic position of the Poaceae (Table 5; Goldblatt & Manning 2000).

Platberg and affinities with Fynbos and other Cape floral elements in high-altitude floras (DAC)

South Africa has about 20 500 vascular plant taxa (Germishuizen *et al.* 2006; Goldblatt & Manning 2000; National Red List of South African Plants 2009). The CFR has the richest flora for its area, with 9 000 species (Goldblatt & Manning 2000), as it is an important centre of endemic species and radiation for genetic material (Linder 2003). As the CFR is confined to the southern tip of the African continent and thus at a 'dead end', species are forced to migrate to the north (Linder 2003; Mucina & Rutherford 2006). A floristic comparison with the CFR would elucidate links with high-altitude taxa that may have migrated out of the CFR, through the DAC, and further north.



Sources: Brown *et al.* 2005; Cleaver *et al.* 2005; Du Preez 1991; Potgieter 1983

FIGURE 4
A comparison of regional floras and their surface areas

TABLE 4
Summary of the relationship between numbers of families, genera and species for Platberg and Korannaberg

	Platberg			Korannaberg		
	Families	Genera	Species	Families	Genera	Species
Pteridophyta	8	10	16	16	20	28
Gymnosperms	1	1	1	N/a	N/a	N/a
Angiosperms	86	293	652	99	365	739
(Monocotyledons)	(23)	(104)	(214)	(22)	(113)	(234)
(Dicotyledons)	(63)	(189)	(438)	(77)	(252)	(505)
Totals	95	304	669	115	385	767



TABLE 5
A comparison and ranking of the larger families on Platberg and the DAC that contribute 1% or more species to the total Angiosperm flora in both regions

Platberg families	Total species	Percentage of total	Total genera	Percentage of total	Drakensberg Alpine Centre families	Total species	Percentage of total	Total genera	Percentage of total
1. Asteraceae	126	18.8	40	13.1	1. Asteraceae	430	17.1	65	10.3
2. Poaceae	73	10.9	39	12.8	2. Poaceae	267	10.6	86	13.7
3. Cyperaceae	39	5.8	18	5.9	3. Fabaceae	136	5.4	32	5.1
4. Fabaceae	33	4.9	13	4.3	4. Scrophulariaceae	133	5.3	31	4.9
5. Scrophulariaceae	28	4	13	4.3	5. Orchidaceae	130	5.2	22	3.5
6. Hyacinthaceae	21	3.1	10	3.3	6. Cyperaceae	122	4.8	20	3.2
7. Iridaceae	17	2.5	8	2.6	7. Iridaceae	97	3.8	14	2.2
8. Orchidaceae	16	2.4	6	2	8. Asclepiadaceae	87	3.5	22	3.4
9. Crassulaceae	13	1.9	3	1	9. Hyacinthaceae	55	2.2	16	2.5
10. Geraniaceae	12	1.9	3	1	10. Asphodelaceae	50	2	5	0.8
11. Thymelaeaceae	12	1.8	3	1	11. Lamiaceae	47	1.9	14	2.2
12. Lobeliaceae	12	1.8	3	1	12. Apiaceae	38	1.5	15	2.4
13. Asphodelaceae	12	1.8	1	0.3	13. Mesembryanthemaceae	38	1.5	5	0.8
14. Apocynaceae	10	1.5	6	2	14. Geraniaceae	37	1.5	3	0.5
15. Campanulaceae	10	1.5	2	0.7	15. Rubiaceae	36	1.4	20	3.2
16. Apiaceae	10	1.5	8	2.6	16. Ericaceae	35	1.4	2	0.3
17. Rubiaceae	9	1.3	7	2.3	17. Hypoxidaceae	35	1.4	4	0.6
18. Caryophyllaceae	9	1.2	4	1.3	18. Crassulaceae	34	1.3	3	0.5
19. Euphorbiaceae	8	1.2	2	0.7	19. Santalaceae	32	1.3	3	0.5
20. Hypoxidaceae	8	1.2	2	0.7	20. Euphorbiaceae	30	1.2	8	1.3
21. Polygalaceae	8	1.2	1	0.3	21. Gentianaceae	28	1.1	3	0.5
22. Ericaceae	7	1	1	0.3	22. Brassicaceae	27	1.1	7	1.1
23. Gentianaceae	7	0.9	1	0.3	23. Amaryllidaceae	26	1	2	0.3
24. Asparagaceae	6	0.9	1	0.3	24. Campanulaceae	26	1	2	0.3

To conform to Carbutt and Edwards (2004), only Angiosperms have been considered for Platberg.

The CFR is also the largest contributor to DAC flora in the KwaZulu-Natal Drakensberg, with 67 genera (Carbutt & Edwards 2004). The number of CFR elements decrease further northwards from the DAC (Carbutt & Edwards 2004). However, unlike the CFR (Table 6), the largest families for the DAC show similar trends with Mount Mulanje and the Nyika Plateau, with the exception of Orchidaceae (which is the most plentiful family), represented by 122 and 200 species respectively for these centres (Burrows & Willis 2005). The next three highest species-rich families are Asteraceae, Poaceae and Fabaceae, with Rubiaceae the fifth largest family (82 and 90 species respectively). A further floristic comparison of endemics and near-endemics with the DAC and the Afromontane archipelago, compiled by Burrows & Willis (2005), shows the following:

- Nyika Plateau (Malawi) comprises 1 891 total species, of which 46 are endemic or near-endemic.
- Mount Mulanje (Malawi) comprises 1 303 total species, of which 94 are endemic or near-endemic.
- Chimanimani Mounatins (Mozambique) comprises 859 total species, of which 70 are endemic or near-endemic.

- Simien Highlands (Ethiopia) comprises 550 total species, of which 12 (plus) are endemic or near-endemic.
- Mount Cameroon (Cameroon) comprises 2 435 total species, of which 49 are endemic or near-endemic.

The largest family for all three regions is Asteraceae, with 18.9% for Platberg, 17.1% for the DAC, and 11.5% for the Cape. Comparing the density of Asteraceae within South Africa (11%) to other regions of the world, we find that Hawaii comprises 15.9%, the Sonora Desert 15%, Texas 13.4%, eastern North America 12.7%, New Zealand 12.5% and Europe 12% (Goldblatt & Manning 2000; Hilliard & Burt 1987). The DAC has a significantly higher percentage than the Cape. The percentage for Platberg is higher than for the DAC, which is significantly higher than for Hawaii (which has the largest percentage globally). Asteraceae show significant spread in the DAC and more so on Platberg. These areas have been geologically stable for a considerable time (McCarthy & Rubidge 2005), and have many different abiotic parameters that are an important for high speciation (Mutke *et al.* 2001). Terrain heterogeneity and a relatively stable quaternary climate (Scott *et al.* 1997) may

TABLE 6
A comparison of the largest families for Platberg, Drakensberg Alpine Centre and Cape Floral Region

Ranking by family for Platberg	Number of species	Ranking by family for DAC ¹	Number of species	Ranking by family for CFR ²	Number of species
1. Asteraceae	126	1. Asteraceae	430	1. Asteraceae	1036
2. Poaceae	73	2. Poaceae	267	2. Fabaceae	760
3. Cyperaceae	39	3. Fabaceae	136	3. Iridaceae	661
4. Fabaceae	33	4. Scrophulariaceae	133	4. Aizoaceae	660
5. Scrophulariaceae	28	5. Orchidaceae	130	5. Ericaceae	658
6. Hyacinthaceae	21	6. Cyperaceae	122	6. Scrophulariaceae	418
7. Iridaceae	16	7. Iridaceae	97	7. Proteaceae	330
8. Orchidaceae	16	8. Asclepiadaceae	87	8. Restionaceae	318
9. Crassulaceae	13	9. Hyacinthaceae	55	9. Rutaceae	273
10. Geraniaceae	12	10. Asphodelaceae	50	10. Orchidaceae	227
11. Thymelaeaceae	12	11. Lamiaceae	47	11. Poaceae	207
12. Lobeliaceae	12	12. Apiaceae	38	12. Cyperaceae	206
13. Asphodelaceae	12	13. Mesembryanthemaceae	38	13. Hyacinthaceae	192
14. Apocynaceae	10	14. Geraniaceae	37	14. Campanulaceae	184
15. Campanulaceae	10	15. Rubiaceae	36	15. Asphodelaceae	158
16. Apiaceae	10	16. Ericaceae	35	16. Geraniaceae	141
17. Rubiaceae	9	17. Hypoxidaceae	35	17. Polygalaceae	141
18. Caryophyllaceae	9	18. Crassulaceae	34	18. Rhamnaceae	137
19. Euphorbiaceae	8	19. Santalaceae	32	19. Thymelaeaceae	124
20. Hypoxidaceae	8	20. Euphorbiaceae	30	20. Crassulaceae	123
21. Polygalaceae	8	21. Gentianaceae	28		
22. Ericaceae	7	22. Brassicaceae	27		
23. Gentianaceae	7	23. Amaryllidaceae	26		
		24. Campanulaceae	26		

¹Carbutt and Edwards (2004) list only angiosperms.
²Goldblatt and Manning (2000).

have enabled this genus to spread and establish so successfully at altitude (Linder 2003). Alternatively, this may be a recent phenomenon, where new taxa respond rapidly to a new environment and fill available niches (Linder 2003), or perhaps it is a response to climate change over longer periods, possibly from the start of the Holocene epoch 30 million years ago.

The low species numbers for Poaceae in the CFR is explained by it being a replacement genus for Restionaceae that fills its niche and thus is more plentiful (Carbutt & Edwards 2006; Haaksmā & Linder 2001; Linder 2003). In the CFR, Restionaceae also displaces Cyperaceae (Goldblatt & Manning 2000), which may partially explain the low number of Cyperaceae species and its ranking at twelfth for the CFR, third for Platberg and sixth for the DAC (Table 6) as the environmental parameters for all regions are analogous (Stock *et al.* 2004).

Conservation implications for Platberg

The floristic analysis of Platberg shows its value as both a site of diversity and endemism. This value is also linked to the DAC flora and shows its position as the main inselberg in the chain of such prominent landscape features. The high plant diversity of Platberg and its main genetic source, the DAC, is because it includes elements of Mesic Karoo-Nama vegetation,

the Afromontane *Podocarpus* elements, mesic KwaZulu-Natal escarpment, and drier Eastern Cape Stormberg and Lesotho floras.

Platberg has high terrain heterogeneity, with steep contours, deeply incised gullies and numerous slope orientations. According to Cowling *et al.* (1992), Low & Rebelo (1996), Mucina and Rutherford (2006), Perkins (1997) and van Wyk and Smith (2001) this provides more habitats for species and is more important than other factors in determining high biodiversity. In addition, Platberg is the single largest and best preserved high-altitude grassland in the Free State (Mucina & Rutherford 2006). Immediate threats are from the invasion of *Pinus patula* on the footslopes and plateau area of Platberg to the south and east. This poses a considerable conservation problem because *Pinus patula* is in the process of rapidly out-competing the local indigenous vegetation, particularly on the cool south slope and in the stream flowing down the gully on the south side of Platberg.

The threats to genetic diversity (Anderson 2001) also influenced by global warming are key considerations for conservationists and highlight the importance of mountains and the associated inselbergs as areas of refuge to plant species. This, therefore,



stresses the urgent need for their protection. Additionally, high-altitude vegetation, specifically alpine flora as defined by White (1983) and Körner (2003), is the only biogeographic unit on land with a global distribution, accounting for nearly 3% of the land surface and including about 10 000 species, or about 4% of higher order plants (Körner 2003).

The threat posed by global warming to the world's alpine regions, including Africa, was predicted by Peters (1992), who indicated that as little as a 3 °C increase in temperature over 100 years would be equivalent to a 500 m upward shift in altitudinal zones. In the Afromontane and Afro-alpine biota, this would cause a significant reduction in the distribution of plants, changing their structure and composition, and forcing some taxa to higher altitudes (Taylor 1996). Furthermore, in some cases (e.g. Platberg), a significant reduction of the taxa could possibly occur where the altitude is under 2 500 m.

CONCLUSION

Platberg is centred in the Grassland Biome, with a lesser mix of Fynbos, Nama-Karoo and Forest Biomes. Platberg consists of 3 000 ha of high-altitude grassland composed of a mix of C3 and C4 grasses and other plant families that use this metabolic pathway. Between 30% and 55% of the Grassland Biome has been transformed, only 5.5% of which is under protection. Numerous abiotic environmental factors (soil, altitude, slope, aspect, moisture availability, temperature range, fire, modern and palaeoclimatic factors) and biotic interactions between plants and plants, plants and pollinators, and herbivores and plants have resulted in a relatively high species richness and diversity. The Drakensberg Alpine Centre is the main floristic influence on Platberg, with strong affinities with the Cape Floral Region.

The result of this study has shown that Platberg is a centre of significant biological diversity, with high species richness, vegetation structure and ecosystem complexity, and a centre of genetic diversity and variation. It occurs as an island in the Grassland 'sea' and shares inselberg floral richness and endemism that can be tracked via the Afromontane archipelago-like string of inselbergs and mountains, which stretches north through the Chimanimani Mountains, into Malawi, the Eastern Arc Mountains via Tanzania and north through Ethiopia, into Eurasia. It also shows a western tract via the Congo, Ivory Coast and Cameroon inselbergs and mountains.

The current vegetation patterns on Platberg reflect changes in palaeo-environmental cycles of cooling and warming, which, since Miocene times, have had the greatest influence on the texture and composition of plants and speciation on Platberg. Current trends towards climate change will alter the composition and species numbers of grasses as well as other plant families on Platberg.

As an important high-altitude grassland, it is imperative that Platberg be provided with protection legislated on at least a provincial level.

REFERENCES

- Acocks, J.P.H., 1988, 'Veld types of South Africa', 3rd edn., *Memoirs of the Botanical Survey of South Africa* 57, 1–146.
- Anderson, J.M. (ed.), 2001, *Towards Gondwana alive*, National Botanical Institute, Pretoria.
- Arnold, T.H. & de Wet, B.C. (eds.), 1993, 'Plants of southern Africa: Names and distribution', *Memoirs of the Botanical Survey of South Africa* 62.
- Behr, C.M. & Bredenkamp, G.J., 1988, 'An analysis of the flowering plants and ferns of the Witwatersrand National Botanic Garden', *South African Journal of Botany* 54(6), 515–524.
- Bester, S.P., 1998, 'Vegetation and flora of the southern Drakensberg escarpment and adjacent areas', MSc thesis, University of Pretoria.
- Brand, R.F., 2007, 'Phytosociology of Platberg mountain, eastern Free State, South Africa', PhD thesis, University of the Free State.
- Brand, R.F., du Preez, P.J., & Brown, L.R., 2008, 'A floristic description of the Afromontane fynbos communities on Platberg, eastern Free State, South Africa', *Koedoe* 50(1), 202–213.
- Bredenkamp, G.J. & Brown, L.R., 2003, 'A reappraisal of Acocks' Bankenveld: Origin and diversity of vegetation types', *South African Journal of Botany* 69(1), 7–26.
- Brown, L.R., Bredenkamp, G.J. & van Rooyen, N., 1996, 'The phytosociology of the northern section of the Borakalalo Nature Reserve, South Africa', *Koedoe* 39(1), 9–24.
- Brown, L.R., Marais, H., Henzi, S.P. & Barrett, L., 2005, 'Vegetation classification as the basis for baboon management in the Bourke's Luck section of the Blyde Canyon Nature Reserve, Mpumalanga', *Koedoe* 48(2), 71–92.
- Burke, A., 2001, 'Determinants of inselberg floras in arid Nama Karoo landscape', *Journal of Biogeography* 22, 1211–1220.
- Burrows, J. & Willis, C. (eds.), 2005, 'Plants of the Nyika Plateau: An account of the vegetation of the Nyika National Parks of Malawi and Zambia', SABONET Report 31, Southern African Botanical Diversity Network, Pretoria.
- Carbutt, C. & Edwards, T.J., 2004, 'The flora of the Drakensberg Alpine Centre', *Edinburgh Journal of Botany* 60(3), 581–607.
- Carbutt, C. & Edwards, T.J., 2006, 'The endemic and near-endemic angiosperms of the Drakensberg Alpine Centre', *South African Journal of Botany* 72, 105–132.
- Cowling, R.M., Holmes, P.M. & Rebelo, A.G., 1992, 'Plant diversity and endemism', in R.M. Cowling (ed.), *The ecology of fynbos: Nutrients, fire and diversity*, Oxford University Press, Cape Town.
- Cowling, R.M. & Lombard, A. T., 2002, 'Heterogeneity, speciation/ extinction history and climate: Explaining regional plant diversity patterns in the Cape Floristic Region', *Diversity and Distributions* 8, 163–179.
- Du Preez, P.J., 1991, 'A syntaxonomical and synecological study of the vegetation of the south-eastern Orange Free State and related areas with special reference to Korannaberg', PhD thesis, University of the Orange Free State.
- Du Preez, P.J., 1992, 'The classification of the vegetation of Korannaberg, eastern Orange Free State. I. Afromontane fynbos communities', *South African Journal of Botany* 58(3), 165–172.
- Du Preez, P.J. & Bredenkamp, G.J., 1991, 'Vegetation classes of the southern and eastern Orange Free State (Republic of South Africa) and the highlands of Lesotho', *Research of the Bloemfontein National Museum, Bloemfontein* 7, 477–526.
- Du Preez, P.J., Bredenkamp, G.J. & Venter, H.J.T., 1991, 'The syntaxonomy and synecology of the forests in the eastern Orange Free State, South Africa. I. The *Podocarpetalla latifolii*', *South African Journal of Botany* 57, 198–206.
- Du Toit, A.L., 1956, *The geology of South Africa*, Oliver and Boyd, Edinburgh.
- Eckhardt, H.C., van Rooyen, N. & Bredenkamp, G.J., 1993a, 'The phytosociology of the thicket and woodland vegetation of the north-eastern Orange Free State', *South African Journal of Botany* 59(4), 401–409.
- Eckhardt, H.C., van Rooyen, N. & Bredenkamp, G.J., 1993b, 'The vegetation of the north-eastern Orange Free State, South Africa: Physical environment and plant communities of the Ea land type', *Bothalia* 23(1), 117–127.
- Fuls, E.R., 1993, 'Vegetation ecology of the northern Orange Free State', PhD thesis, University of Pretoria.
- Germishuizen, G., Meyer, N.L., Steenkamp, Y. & Keith, M. (eds.), 2006, 'Plants of southern Africa: An annotated checklist', SABONET Report 41, National Botanical Institute, Pretoria.
- Gibbs-Russell, G.E., Watson, L., Koekemoer, M., Smook, L., Barker, N.P., Anderson, H.M. et al., 1991, 'Grasses of southern Africa', *Memoirs of the Botanical Survey of South Africa* 58.
- Goldblatt, P. & Manning, J., 2000, 'Cape plants: A conspectus of the Cape flora of South Africa', *Strelitzia* 9.

- Golding, J.S., 2002, Southern African plant red data lists, report no. 14, National Botanical Institute, Pretoria.
- Gordon-Gray, K.D., 1995, 'Cyperaceae in Natal', *Strelitzia* 2.
- Grobler, C.H., Bredenkamp, G.J. & Brown, L.R., 2002, 'Natural woodland vegetation and plant species richness of the urban open spaces in Gauteng, South Africa', *Koedoe* 45(1), 19–34.
- Grobler, C.H., Bredenkamp, G.J. & Brown, L.R., 2006, 'Primary grassland communities of the urban open spaces in Gauteng, South Africa', *South African Journal of Botany* 72, 367–377.
- Gröger, A. & Barthlott, W., 1996, 'Biogeography and diversity of the inselbergs (Laja) vegetation of southern Venezuela', *Biodiversity Letters* 3, 165–179.
- Haaksmma, E.D. & Linder, H.P., 2000, *Restios of the fynbos*, The Botanical Society of South Africa, Cape Town.
- Hill, T.R., 1996, 'Description, classification and ordination of the dominant vegetation communities, Cathedral Peak, KwaZulu-Natal Drakensberg', *South African Journal of Botany* 62, 263–269.
- Hilliard, O.M., 1990, *Flowers of the Natal Drakensberg*, University of Natal Press, Pietermaritzburg.
- Hilliard, O.M., 1992, *Trees and shrubs of the Natal Drakensberg*, University of Natal Press, Pietermaritzburg.
- Hilliard, O.M. & Burtt, B.L., 1987, *The botany of the southern Natal Drakensberg*, National Botanical Gardens, Cape Town.
- Hilton-Taylor, C., 1996, *Red data list of southern African plants*, National Botanical Institute, Pretoria.
- Hoare, D.B. & Bredenkamp, G.J., 2001, 'Syntaxonomy and environmental gradients of the grasslands of the Stormberg/Drakensberg mountain region of the Eastern Cape, South Africa', *South African Journal of Botany* 67, 595–608.
- Huntley, B.J. (ed.), 1991, 'Challenges to maintaining biotic diversity in a changing world', in *Biotic diversity in southern Africa*, pp. xii–xix, Oxford University Press, Cape Town.
- IUCN, 1980, *World conservation strategy: Living resource conservation for sustainable development*, IUCN:UNEP/WWF, Gland, Switzerland.
- Jacot Guillarmod, A., 1971, *Flora of Lesotho*, Verlag von J. Cramer, Lehre.
- Kay, C., Bredenkamp, G.J. & Theron, G.K., 1993, 'The plant communities of the Golden Gate Highlands National Park in the north-eastern Orange Free State', *South African Journal of Botany* 59(4), 442–449.
- Killick, D.J.B., 1963, 'An account of the plant ecology of the Cathedral Peak area of the Natal Drakensberg', *Memoirs of the Botanical Survey of South Africa* 34.
- Killick, D.J.B., 1978a, 'The Afro-alpine region', in M.J.A. Werger (ed.), *Biogeography and ecology of southern Africa*, pp. 515–560, Junk, The Hague.
- Killick, D.J.B., 1978b, 'Notes on the vegetation of the Sani Pass area of the southern Drakensberg', *Bothalia* 12, 537–542.
- Killick, D.J.B., 1990, *A field guide to the flora of the Natal Drakensberg*, Jonathan Ball and Ad Donker Publishers, Johannesburg.
- Kooij, M.S., Bredenkamp, G.J. & Theron, G.K., 1990a, 'Classification of the vegetation of the B land type in the north-western Orange Free State', *South African Journal of Botany* 56(3), 309–318.
- Kooij, M.S., Bredenkamp, G.J. & Theron, G.K., 1990b, 'The vegetation of the deep sandy soils of the A land type in the north-western Orange Free State, South Africa', *Botanical Bulletin Academia Sinica* 31, 235–243.
- Kooij, M.S., Bredenkamp, G.J. & Theron, G.K., 1990c, 'The vegetation of the north-western Orange Free State, South Africa', *Bothalia* 20(2), 214–248.
- Körner, C., 2003, *Alpine plant life: Functional plant ecology of high mountain ecosystems*, Springer-Verlag, Berlin.
- Land Type Survey Staff, 1991, *Land types of the map 2828, Harrismith*, Soil and Irrigation Research Institute, Department of Agriculture, Pretoria.
- Linder, H.P., 2003, 'The radiation of the Cape flora, southern Africa', *Biological Reviews of the Cambridge Philosophical Society* 78, 597–638.
- Loock, J.C., Praekelt, H.E., van der Westhuizen, W.A. & Welman, J., 1991, *The Dewetsdorp-Thaba Nchu Mountain excursion*, Bloemfontein National Museum, Bloemfontein.
- Low, A.B. & Rebelo, A.G. (eds.), 1996, *Vegetation of South Africa, Lesotho and Swaziland*, Department of Environmental Affairs & Tourism, Pretoria.
- MacArthur, R.H. & Wilson, E.O., 2001, *The theory of island biogeography*, Princeton University Press, Princeton.
- MacVicar, C.N., Loxton, R.F., Lambrechts, J.J.N., le Roux, J., de Villiers, J.M., Verster, E., et al., 1991, *Soil classification: A taxonomic system for South Africa*, Department of Agricultural Development, Soil and Irrigation Research Institute, Pretoria. (*Memoirs on the Agricultural Natural Resources of South Africa* 15).
- Malan, P.W., 1998, 'Vegetation ecology of the southern Free State', PhD thesis, University of the Orange Free State.
- McCarthy, T. & Rubidge, B., 2005, *The story of earth and life*, Struik Publishing, Cape Town.
- Moffett, R., 1997, 'Grasses of the eastern Free State', UNIQUA, QwaQwa campus of the University of the North, Phuthaditjhaba.
- Moffett, R.O., Daemane, M.E., Pitso, T.R., Lentsoane R. & Taoana, T.R.N., 2001, 'A checklist of the vascular plants of QwaQwa and notes on the flora and vegetation of the area', *Uniqwa Research Chronicle* 3(2), 32–83.
- Mucina, L., & Rutherford, M.C., 2006, 'The vegetation of South Africa, Lesotho and Swaziland', *Strelitzia* 19.
- Mutke, J., Kier, G., Braun, G., Schultz, C.H.R. & Barhloot, W., 2001, 'Patterns of African vascular plant diversity – a GIS based analysis', *Systematic Geography Plantae* 71, 1125–1136.
- Norman, N. & Whitfield, G., 1998, *Geological journeys: A traveller's guide to South Africa's rocks and landforms*, De Beers, South Africa.
- Perkins, L., 1997, 'Aspects of the syntaxonomy and synecology of the grasslands of southern KwaZulu-Natal', MSc thesis, University of Pretoria.
- Perkins, L., Bredenkamp, G.J. & Granger, J.E., 1999a, 'The phytosociology of the incised river valleys and dry upland savannah of the southern KwaZulu-Natal', *South African Journal of Botany* 65(5&6), 321–330.
- Perkins, L., Bredenkamp, G.J. & Granger, J.E., 1999b, 'Wetland vegetation of the southern KwaZulu-Natal, South Africa', *Bothalia* 30(2), 175–185.
- Peters, R.L., 1992, 'Conservation of biological diversity in the face of climatic change', in R.L. Peters & T.E. Lovejoy (eds.), *Global warming and biological diversity*, pp. 15–30, New Haven.
- Phillips, F.P., 1917, 'A contribution to the flora of the Leribe plateau and environs', *Annals of the South African Museum* 16, 1–379.
- Pond, U., Beesley, B.B., Brown, L.R. & Bredenkamp, H., 2002, 'Floristic analysis of the Mountain Zebra National Park, Eastern Cape', *Koedoe* 45(1), 35–57.
- Pooley, E., 1997, *A complete field guide to trees of Natal Zululand and Transkei*, Natal Flora Publications Trust, Durban.
- Pooley, E., 1998, *A field guide to wild flowers of KwaZulu-Natal and the eastern Region*, Natal Flora Publications Trust, Durban.
- Pooley, E., 2003, *Mountain flowers: A field guide to the flora of the Drakensberg and Lesotho*, Natal Flora Publications Trust, Durban.
- Porembski, S. & Brown, G., 1995, 'The vegetation of inselbergs in the Comoé National Park (Ivory Coast)', *Conservatoire et Jardin Botaniques de Geneve* 50(2), 351–365.
- Porembski, S., Fisher, E. & Biedenger, N., 1997, 'Vegetation of inselbergs, quartzitic outcrops and ferricretes in Rwanda and eastern Zaire (Kivu)', *Bulletin du Jardin Botanique National de Belgique* 66, 81–95.
- Porembski, S., Martinelli, G., Ghlemüller, R. & Barthlott, W., 1998, 'Diversity and ecology of saxicolous vegetation mats on inselbergs in the Brazilian Atlantic rainforest', *Diversity and Distribution* 4, 107–119.
- Roberts, B.R., 1969, 'The vegetation of the Golden Gate Highlands National Park', *Koedoe* 12, 15–28.



- SANBI, 2009, *National red list of South African plants*, viewed 23 February 2009, from <http://www.sanbi.org/biodiversity/Redlist/2003-02-2009>
- Schulze, R.E., 1997, 'South African atlas of agrohydrology and climatology', WRC Report TT 82/96, Water Research Commission, Pretoria.
- Scott, L., 1988, 'Late quaternary vegetation history and climatic change in the eastern Orange Free State, South Africa', *South African Journal of Botany* 55(1), 107–116.
- Scott, L., Anderson, H.M. & Anderson, J.M., 1997, 'Vegetation history' in R.M. Cowling, D.M. Richardson & S.M. Pierce, (eds.), *Vegetation of southern Africa*, pp. 62–84, Cambridge University Press, Cambridge.
- Scott-Shaw, R.C., 1999, *Rare and threatened plants of KwaZulu-Natal and neighbouring regions*, KwaZulu-Natal Nature Conservation Services Biodiversity Division, Scientific Services Directorate, Pietermaritzburg.
- Smit, C.M., Bredenkamp, G.J. & van Rooyen, N., 1993, 'Phytosociology of the Ac land type in the foothills of the low Drakensberg in north-western Natal', *South African Journal of Botany* 59, 203–214.
- Smit, C.M., Bredenkamp, G.J. & van Rooyen, N., 1995, 'The grassland vegetation of the low Drakensberg escarpment in the north-western KwaZulu-Natal and north-eastern Orange Free State border area', *South African Journal of Botany* 61, 9–17.
- South African Weather Service, 2007, 'Climate of South Africa'. Climate statistics for Bethlehem from 1961–1990', WB 40, Government Printer, Pretoria.
- Stock, W.D., Chuba, D.K. & Verboom, G.A., 2004, 'Distribution of South African C3 and C4 species of Cyperaceae in relation to climate and phylogeny', *Austral Ecology* 29, 313–319.
- Taylor, D., 1996, 'Mountains', in W.M. Adams, A.S. Goudie & A.R. Orme (eds.), *The physical geography of Africa*, pp. 287–306, University Press, Oxford.
- Truswell, J.F., 1970, *An introduction to the historical geology of South Africa*, Purnell Press, London.
- Van Oudtsthoorn, F., 1999, *Guide to grasses of southern Africa*, Briza Publications, Cape Town.
- Van Wyk, A.E. & Smith, G.F., 2001, *Regions of floristic endemism in southern Africa: A review with emphasis on succulents*, Umदाus Press, Pretoria.
- Van Zinderen Bakker Jr., E.M., 1973, 'Ecological investigation of forest communities in the eastern Orange Free State and the adjacent Natal Drakensberg', *Vegetatio* 28, 299–334.
- White, F., 1983, *The vegetation of Africa: A descriptive memoir to accompany the UNESCO/AETFAT/UNSO vegetation map of Africa*, Volume XX, UNESCO, Paris.