Biodivers Conserv (2007) 16:4051–4079
DOI 10.1007/s10531-007-9207-1

ORIGINAL PAPER

Rare and infrequent southern African grasses: assessing their conservation status and understanding their biology

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Received: 6 February 2007 / Accepted: 14 June 2007 / Published online: 20 July 2007

Abstract The taxonomic treatment for the grasses of southern Africa was one of the first to be based on computerised data and the DELTA system. These data, based on over 70,000 herbarium records, are amenable for analysis of species parameters including abundance, frequency and distribution. This information is suitable for the allocation of species into the seven categories of rarity proposed by Rabinowitz using a combination of habitat specificity ("Narrow" or "Broad"), population structure ("Sparse" or "Abundant") and distribution ("Restricted" or "Widespread"). We compare the species lists obtained for each combination of these three aspects to published Red Data Lists (RDLs) for southern and South Africa. Ninety-three species are placed in the most sensitive or potentially threatened category (Narrow habitat, Sparse populations and Restricted distributions; RSN). This is substantially more than the number of species listed in current RDLs for the region. Chi-square tests indicate a statistically significant bias in taxa from the Fynbos Biome for three of the categories (RSN, RAN and WSN), from the Savanna Biome for the WAN category and from the arid Succulent Karoo and Desert Biomes for the RAB category. Analyses of habitat requirements indicate that many grasses listed (especially those associated with a "Narrow" habitat) are found in some form of wetlands (ephemeral or permanent), especially those at higher altitudes (montane). Despite concerns about the subjective nature in determining the boundaries between the categories, this method is shown to provide a meaningful and valuable list of taxa that require prioritisation for more detailed assessment according to the IUCN criteria.

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Keywords Rabinowitz categories · Grasses · Hygrophytes · Poaceae · Rarity · Red Data List · Southern Africa · Wetlands

Introduction

Red Data Lists (RDLs) document a region or nation's rare and threatened species, and act as the starting point for conservation incentives. The first attempt to document the extent of rare and threatened plant taxa of the Flora of Southern Africa region (FSA; an area including South Africa, Botswana, Namibia, Lesotho and Swaziland) was that of Hall et al. (1980). However, with over 23,000 plant taxa currently recorded from the FSA (De Wet et al. 1990) these early works are little more than annotated lists of poorly known species (Ferrar 1989). The first comprehensive effort to document the Red Data species from the FSA region resulted in the allocation of 3435 species to the old IUCN categories (Hilton-Taylor 1996a, and subsequent updates, 1996b, 1997). This list was also captured in a data base, and provided the platform for current RDL activities, and in 2002 Golding published an updated RDL for the region (Golding 2002).

The documentation of rare and threatened species in South Africa is now the mandate of the South African National Biodiversity Institute (SANBI), and this organisation has made major strides towards the compilation of a Red Data List according to the IUCN's latest criteria (i.e., versions 3.0 and 3.1; IUCN 2001). The provisional RDL for land plants is now available online (http://www.sanbi.org/biodiversity/reddata.htm). This list (which is an interim assessment) contains 3036 species (approximately 12% of the regional flora) as of August 2006.

The current version of the IUCN Red Data Categories require what is in essence a Population Viability Assessment (PVA) of each species prior to being able to allocate it to a category. This goes a long way towards making the allocation of a species to a particular category more objective, but also has major implications on person-power allocations towards conservation assessment and monitoring, an issue that is probably beyond most developing countries' budgetary allocations.

Plant RDLs are generally compiled from herbarium records. Hall (1989) felt that herbaria were never intended to be used in conservation biology, but Robbirt et al. (2006) make a strong case for the unique value of herbaria and museum holdings for conservation assessment purposes, especially if these are captured in databases in appropriate formats. However these resources are only as good as the past collection efforts, and many geographical areas, and in some instances, taxonomic groups, are under-collected, especially in southern Africa (Gibbs Russell et al. 1984; Robertson and Barker 2006). Furthermore, the effective management of these collections is critical if these resources are to be properly utilised. From a southern African context, Hall (1989) and later Baijnath and Nicholas (1994), Golding and Smith (2001) and Golding (2001) have all asserted that herbarium taxonomists (and taxonomy) lend vital support to conservation biology. There is thus a clear role for herbaria and taxonomists in compiling RDLs, and recommendations as to the role of both herbaria and taxonomists in streamlining RDL assessments have been made for the southern African region (Golding and Smith 2001; Golding 2001). However, as noted by Robbirt et al. (2006), collection intensity must also be factored in when using herbarium data. Problems such as limited collections, and poorly understood species, and the globally recognised “taxonomic impediment” (the decline in numbers of expert taxonomists; Klopper et al. 2002) must thus receive urgent attention if herbaria are to play a role in conservation initiatives and RDL assessments.

Golding and Smith (2001) note that there is a role for, and value in, regional taxonomic treatments and floras in aiding in the identification of RDL species, and they urge taxonomists writing floras to include data suitable for use in RDL development. However, the vast majority of floras (especially for Africa) are old, produced well before the concepts of the modern IUCN system, and thus contain no mention of rarity, population parameters or detailed distribution information. Furthermore, they are also only available in print form, a severe limitation when it comes to using these to obtain information useful in assessing whether a species requires RDL status.

Willis et al. (2003) married the skills of an expert taxonomist with herbarium records and a GIS system to assess IUCN RDL parameters (especially those relating to distribution and population structure) during the preparation of a taxonomic revision of the genus *Plectranthus* in eastern and southern Africa. They note that herbarium data alone is not adequate for RDL assessment, and comment that field knowledge is vital. Golding (2004) states that the use of herbarium records can influence the RDL process, as there is an uncertainty that is associated with the translation of herbarium label data to the new IUCN red list system. This uncertainty stems in particular from a lack of information on population and distribution parameters, supporting the call by Willis et al. (2003) for improvements in the recording of botanical data for herbarium labels. Ponder et al. (2001) have similar sentiments about museum data, especially if it is to be used in GIS applications.

Recent computer developments have seen the initiation of online floras, such as Flora Zambeziaca (http://www.rbgkew.org.uk/floras/fz/intro.html) and the Flora of Australia Online (http://www.environment.gov.au/biodiversity/abrs/online-resources/flora/main/index.html). However, at present the online Flora Zambesiaca only allows visitors to search using taxonomic key words (i.e., names) and a few environmental or habitat parameters, and not any other terms such as those referring to rarity. Nonetheless, the online Flora Zambesiaca does have an option to list regional endemics. The Australian online Flora is similar, but does allow one to search for taxa according to conservation status. There are also a number of taxonomic keys and identification aids in electronic format (CD-ROMs and DVDs) based on the DELTA system (Descriptive Language for Taxonomy; Dalwitz and Paine 1986). Examples of these include the revision of the Restionaceae (Linder 2001, http://www.systbot.unizh.ch/datenbanken/restionaceae/restionaceae.php?l=e), Flora of the British Isles (Stace et al. 2004), for the Flora of Europe (http://nlbif.eti.uva.nl/bis/flora.php?menuentry=inleiding) and AusGrass (Sharp and Simon 2002) for the Australian grasses (http://www.environment.gov.au/biodiversity/abrs/publications/ausgrass/index.html). In many of these electronic data bases and resources “IUCN-friendly” data are available, but presentation of taxonomic data in such electronic formats has by and large yet to be undertaken for the flora of the African continent. Thus, while the flora of the FSA region (and Africa in general) is covered at least in part by various printed flora treatments, there is no easy way to retrospectively access data suitable for RDL activities from them.

In this paper, we propose a different approach towards identifying potential RDL species, using both Flora treatments or taxonomic revisions and herbarium records as a means to compile data on species rarity. From this, RDL scientists can identify and prioritise categories of taxa for formal RDL assessments.

The system we utilise here is based on Rabinowitz’s (1981) system of categories of rarity that allow for the utilisation of demographic, geographic and habitat data. These categories record the geographic distribution, demographic structure and habitat requirements in a two-state form; restricted or widespread, sparse or abundant, wide or narrow respectively. The demographic component can thus reflect, to a certain extent, the biological aspects of rarity of the taxa. It is interesting to note, however, that this apparently simple system of assessing rarity has not been extensively utilised, despite the interesting issues it raises about the biology of rarity (see for example Kruckeberg and Rabinowitz 1985). The main reason for this probably lies in the universal adoption of the IUCN criteria (in all their historical forms; Mace 1994). Pärtel et al. (2005) also comment on the limited number of studies utilising Rabinowitz's system, and ascribe this to the fact that this approach is largely theoretical, not intimately linked to conservation, and ignores anthropocentric issues. Nonetheless, the Rabonowitz categories have been utilised for a range of purposes in a number of studies on plants and animals (e.g., Goerck 1997; Pitman et al. 1999; Yu and Dobson 2000; Lozano et al. 2003; Broennimann et al. 2005; Pärtel et al. 2005).

According to Victor and Keith (2004), the elements of distribution range and population structure are incorporated into the IUCN system in the form of various values of "extent of occurrence" (EOO) and "area of occupancy" (AOO) etc. Obviously, those taxa with restricted distributions, sparse population structure and narrow habitat requirements are the most "sensitive", and thus may require some form of positive conservation action. The information required for applying these categories to taxa is a distribution map (either already available in a flora treatment, or easily created using herbarium records), as well as information on habitat specificity and population structure. Very often, good plant collectors will include this as a matter of course when writing herbarium labels. Thus the combination of herbarium specimens and geographic information from floras or herbarium specimens can be used for placing species within the Rabinowitz scheme. The final requirement is the experience and knowledge from the taxonomists themselves.

Here we use such data for allocating the grass species of Southern Africa into the Rabinowitz categories. Data for these three categories are known for most of the southern African grass taxa, as they were recorded during the production of the volume that is considered to be the grass flora of southern Africa, the "Grasses of southern Africa" (Gibbs Russell et al. 1990). Furthermore, with over 1000 species recorded from the FSA area (Gibbs Russell et al. 1990), the Poaceae represent a considerable contribution to the plant diversity in the region, and thus a large group to use in this assessment. Despite its comparatively recent publication and the large number of specimens contributing to this data set, new grass taxa are still being found and described from the FSA region, and some genera have been revised (Barker 1993, 1995, 1999; Barker and Ellis 1991; Linder and Davidse 1997; Linder and Ellis 1990a, Verboom and Linder 1998).

The use of the DELTA programs allowed for the recording of both specific (qualitative and quantitative) characters as well as comment or text data for each southern African grass taxon. For the production of the "Grasses of southern Africa", 28 characters were coded for each grass taxon of species rank or lower. This information was encoded by the various contributors based on over 70,000 grass specimens housed in the National Herbarium (PRE), as well as on observations and experience from field work. Of relevance to RDL construction is the information on relative abundance and rarity of each species that was recorded, and is thus available via the DELTA system. In addition, the flora included a distribution map for every species.

An overview of Red-listed grasses

Interestingly, the grasses receive scant attention in the IUCN Plant Red Data Book (Lucas and Synge 1978) with a total of seven species listed world wide, none of which occur in southern Africa. However, as noted by Davis et al. (1986), this Red Data Book contains only examples, chosen to show the types of threats and the habitats and areas affected. Davis et al. (l.c.) provide data indicating that (as of mid September 1985) the Poaceae is ranked ninth in a list of the families with the most threatened species. The current IUCN RDL (www.iucnredlist.org, downloaded on 24 August 2006) lists 77 species of grasses worldwide.

Within the southern African context, Hall et al. (1980) listed 16 grass species, at least two of which occur quite abundantly to the north of the FSA area. In a later Red Data list restricted to the Karoo and Fynbos biomes, Hall and Veldhuis (1985) list 11 grass species. Each is provided with an IUCN category, limited distribution information as well as an assessment of the level of threat the populations or species are under. These two works are, however, biased in favour of the flora of the Cape region, in particular the Cape Floristic Region, and the accuracy of these "Red Data" lists is limited by the accuracy of the taxonomic treatments of the day, as several genera have undergone taxonomic revision resulting in changes to species concepts and names.

Hilton-Taylor (1996a) listed all vascular plant species in alphabetical order by genus, and then species. It is thus time consuming to assess the entries for the Poaceae as a whole, as they are scattered throughout the list. However, as this list was the precursor for the regional RDL published in both print and electronic format by Golding (2002), it is assumed that the contents are similar. Golding (2002) lists 88 grasses from South Africa, and 120 from the FSA region.

The most recent RDL produced by SANBI (http://www.sanbi.org/biodiversity/reddata.htm) lists only 35 grass species from South Africa, some of which are given the categories Near Threatened (NT) or Least Concern (LC). This latter category or term is somewhat confusing, being used in version 3.1 of the IUCN system for rare species that are not under threat. However, the South African RDL specialists have developed a separate descriptor based on Victor and Keith's (2004) system in which a separate and additional descriptor of rarity status is given for those taxa falling into the IUCN's LC category (Lize Agenbag pers. comm.). For the grass species listed as LC, this additional descriptor is either "rare" or "rare—sparse". More recent listings than 2002 are not available for the other countries of the FSA region.

Methods

During the preparation of the species descriptions published by Gibbs Russell et al. (1990), either or both the conservation status (based on the 1986 IUCN categories) and abundance of each taxon could be entered as two separate DELTA characters. The abundance categories were modified from Radford et al. (1974). This latter character was modified by omitting the "rare" category, as it was recorded under "conservation status" rather than under "abundance". The biomes in which species were found were coded according Rutherford and Westfall's (1986) categorisation. In addition, the distribution outside southern Africa was also noted, with "endemic" being used to signify that the taxon was known only from within the boundaries of the FSA area.

This species data set was interrogated by means of the INTKEY program (Watson et al. 1989). This program, part of the DELTA package, enables the user to search for specific characters, words or phrases in the character list of each taxon. Thus lists of taxa matching or overlapping the given characters may be built up during the interactive interrogation of the database. Once a taxon list has been obtained, additional details may be listed.

In this manner, lists of indigenous taxa (at the species level or lower) which fell into one of the categories "endemic", "infrequent" or "rare" were obtained. A few additional taxa were appended, either because they were described subsequently to Gibbs Russell et al. (1990), have been subsequently revised, or were not found by the search but were thought to be suitable candidates. It must be noted that the taxonomic status of certain of the listed species, and sometimes entire genera (for example *Helictotrichon*) is uncertain. These taxa are marked accordingly in the accompanying tables by a # symbol.

Details concerning the biome distributions as well as life form and habitat information were obtained for these species from the database. Data in this latter category was then augmented by the examination of collector's notes on herbarium specimens in PRE and personal observations by a number of grass systematists. It must be noted that the biome concept in use at the time the data was coded for DELTA was that proposed by Rutherford and Westfall (1986), who recognised only eight biomes. However, an additional unit was included by Gibbs Russell et al. (1990); "Afromontane" which refers to the afromontane grassland areas at high altitudes. Subsequent to the publication of the Grasses of Southern Africa, biomes and biome concepts for the region have been reviewed, the most recent assessment being that of Mucina and Rutherford (2006). Thus the Forest biome concept applied here refers to what are now considered as afrotemperate forests. Two additional biomes (the Thicket Biome and the Indian Ocean Coastal Belt; IOCB) are also now recognised (Mucina and Rutherford 2006), but are not considered here. It must be noted that the IOCB falls into what Rutherford and Westfall (1986) considered to be the Savanna Biome.

Following the creation of this initial list, taxa that were not endemic (or almost so) to the FSA region were excluded. The remaining taxa were then allocated to one of the seven Rabinowitz categories. In many instances, the placing of the taxa into these categories was not problematic, but in borderline instances it was decided to favour a conservative option.

The allocation of the taxa to either of the "wide / restricted" geographic range categories was carried out largely by means of examination of the distribution maps published in Gibbs Russell et al. (1990). The maps in Gibbs Russell et al. (1990) were created using PRECIS (National Herbarium, Pretoria (PRE) Computerised Information System) data recorded in a quarter-degree grid square format (Edwards and Leistner 1971). As these maps were of necessity published as small figures, these distributions were further reduced to half-degree resolution. Rabinowitz (1981) did not provide a guide to how large an area has to be before it could be construed as "wide", so it was arbitrarily decided that any taxon recorded from nine or more half-degree squares (contiguous or otherwise) had a wide distribution. Nine contiguous half-degree grids would represent an area of approximately 27,250 km^2. This area corresponds favourably with areas used in other studies that have used Rabinowitz's categories. Pitman et al. (1999) used a cut-off of 78,415 km^2 for Amazon forest trees, while a mammal study used 10,000 km^2 (Yu and Dobson 2000) and a study on the birds of the Brazillian Atlantic forest considered a restricted range to comprise an area of <50,000 km^2 (Goerck 1997). Hartley and Kunin (2003) contextualise the sizes of these areas by noting that according to the IUCN criteria, taxa with an Area of Occurrence (AAO) of <20,000 km^2 are considered to be eligible for the Vulnerable category. Applications of the Rabinowitz system in smaller regions and countries have used smaller grids: 10×10 km for the Iberian flora, where occupation of 10 grids or less was considered a "narrow distribution" (Lozano et al. 2003). In a study of rare plants of Switzerland, Broennimann et al. (2005) utilised grids of 16 × 16 km, and considered the occupation of two or less grids to be a narrow range.

Allocation to one of the population categories was carried out on the basis of information recorded by collectors onto herbarium specimen labels, as well as information obtained from field observations of grass taxonomists. This is thus subjective, as aspects such as the size of the plants in question may dictate the perceived population structure. For example, *Merxmuellera arundinacea* is a large plant (1.5 m tall and up to 1 m in diameter), and is thus conspicuous. In contrast, *Prionanthium dentatum* is a small annual, and it seldom reaches 25 cm in height, and is obscured by other vegetation. A population of *M. arundinacea* may thus appear to be abundant, but an equivalent area will contain a great many more individuals of *P. dentatum*. A similar point was made by Yu and Dobson (2000) who applied the Rabinowitz categories to mammals. This issue of conspicuousness and size thus has to be kept in mind during the allocation of the taxa to the population categories.

The assessment and placing of taxa into one of the two habitat categories was carried out on the basis of herbarium label information, expert experience and data from various floras and taxonomic treatments too numerous to list here. Keith (1998) notes that habitat specificity has always been an important element of "rarity", as well as potential risk of extinction, and argues that aspects of habitat specialisation and/or ephemerality should be built in to the IUCN criteria, and proposes specific criteria for this. However, these have not been included in the IUCN criteria.

In the list of species resulting from our application of the Rabinowitz categories, we present a generalised summary of information obtained from herbarium labels (of specimens housed in PRE). These represent repeated observations (in the case where multiple specimens are available) or singular notes when taxa are represented by a single or few specimens from a single locality. Applying this criterion required discipline and careful discernment, particularly in the instances where the taxa were placed in the geographically widespread category, where it is tempting to erroneously assume that a wide distribution indicates a broad habitat specificity. For instance, *Stipagrostis amabilis* has a widespread geographic distribution, as it is found on Kalahari sands that cover a relatively large area of the FSA region. It is, however, restricted to the crests of dunes of Kalahari sand, and is thus considered to have a restricted habitat requirement.

In order to compare the Rabinowitz lists to existing RDLs, lists of grass species published in the 2002 RDL (Golding 2002) were extracted from the CD-ROM that accompanied that work, and the 2006 Interim RDL (August 2006) was downloaded from the SANBI Threatened Species Programme web site (http://www.sanbi.org/biodiversity/reddata.htm, accessed on the 28th August 2006).

To determine if the species in each category were found more frequently than expected in a particular biome, a χ^2-test was done on the biome data for each category.

Results and discussion

The taxa allocated to each of the Rabinowitz categories are listed in seven tables (Tables 1–7). Each table provides distribution data at the biome level and limited habitat and life form data for each species, and indicates if any taxa are listed in either or both the 2002 and 2006 RDLs. Table 8 lists the number of taxa in each category, and compares these to the 2002 and 2006 RDLs.

Table 1 Category RSN (Species of Restricted geographic range, Sparse local populations, Narrow habitat specificity)

Species	RDL 2002	RDL 2006	Life form	Biome								Habitat
				Fy	Sa	Gr	NK	SK	De	Fo	Af	
Agrostis polypogonoides			P	X				X				Wetlands (vleis, streambeds & river banks, in water)
Agrostis schlechterii			A	X								Wetlands in mountains (streamsides)
Agrostis subulifolia	DD		P			X					X	Wetlands (High mountain bogs; humic / peaty, shallow soils)
Aristida canescens subsp. ramosa			P				X					Dolerite slopes
Aristida dasydesmis			P					X				Granite slopes in arid regions
Aristida dewinterii			A				X					Steep, dry, rocky water courses
Brachiaria psammophila			A		X				X			Sand dunes and dry river beds
Brachychloa fragilis		STBA	A		X							Coastal dunes
Brachychloa schiemanniana			P		X							Sandy soils, dunes and forest margins
Bromus firmior #	DD		P			X						Moist grassy slopes of the Drakensberg at high altitudes
Chloris flabellata			P						X			Coastal marshes and reed beds; potholes in granite inselbergs
Digitaria polyphylla			P			X						Sandy and stony soils in low rainfall regions; red sands over rocky hills and marshy ground
Dregeochloa calviniensis	R	LC	P				X	X				Limestone outcrops in the Calvinia district
Dregeochloa pumila	VU/DD		P					X	X			Loose sand and rocky habitats (e.g. crevices)
Ehrharta eburnea	R		P	X								Mainly renosterveld; mountain slopes
Ehrharta longifolia			P	X								Mountain slopes
Ehrharta longigluma	CR (C2a)		P								X	Mountain grasslands; peaty soil
Ehrharta microlaena			P	X								Wetlands in Fynbos (moist, peaty depressions, seepage lines, streams)
Ehrharta rehmannii subsp. filiformis			P	X								Wetlands (muddy depressions, river and stream banks, marshes & seepages on humic or sandy soils derived from sandstone)
Ehrharta rehmannii subsp. rehmannii			P	X								Mountain slopes, stream banks and rocky habitats

Table 1 continued

Species	RDL 2002	RDL 2006	Life form	Biome								Habitat
				Fy	Sa	Gr	NK	SK	De	Fo	Af	
Ehrharta rupestris subsp. dodii			P	X								Wetlands on mountain slopes (southern slopes and moist shady ledges at base of cliffs, marshes & stream banks)
Ehrharta rupestris subsp. rupestris			P	X								Rocky mountain slopes
Ehrharta rupestris subsp. tricostata			P	X								Wetlands on mountain slopes (South & East facing slopes in marshes & stream banks)
Ehrharta setacea subsp. disticha		LC	P	X								Dry rocky mountain slopes
Ehrharta setacea subsp. scabra			P	X								Rocky mountain areas; seeps
Ehrharta setacea subsp. setacea			P	X								Mountain slopes, particularly shale bands and marshy habitats
Ehrharta setacea subsp. uniflora			P	X								Wetlands and forest margins (seepages, marshy banks along water course & shady damp places)
Enneapogon spathaceus	IK		P		X							Sandveld
Enneapogon sp. (=Ellis 3208)			P		X							Malvernia limestone
Eragrostis aristata			A				X		X			Unjab River mouth delta, & springs along seasonal river bed, near stream and springs
Eragrostis elatior			P	X								Rocky river banks and other periodically inundated habitats
Eragrostis pygmaea			A						X			Shallow depressions within sandy flats and dunes
Eragrostis stenothyrsa			P				X					Wetlands (especially pans)
Festuca vulpioides			P			X						High-altitude grassland
Helictotrichon barbatum #	R	VU	P					X				Lower mountain slopes
Helictotrichon galpinii #			P			X						Humic soils in wetlands (bogs in alpine grassland & spongy ground, head waters of streams on basalt)
Helictotrichon leoninum #			P	X								Mountain slopes & humic seepage habitats
Helictotrichon namaquense #	I	NT	P				X					Sandy flats in renosterveld

Table 1 continued

Species	RDL 2002	RDL 2006	Life form	Biome								Habitat
				Fy	Sa	Gr	NK	SK	De	Fo	Af	
Helictotrichon quinquesetum #	IK	CR	P	X								Slopes of Table Mountain (near hot springs; very little information available)
Helictotrichon sp. (=Ellis 4663) #			P	X								Humic soils in pockets on limestone outcrops
Merxmuellera cincta subsp. sericea*	CR*		P	X								Coastal aeolian sands with water table close to surface
Merxmuellera dura			P				X	X				Stony and sandy soils in arid regions
Merxmuellera papposa		NT	P	X								Sandy and rocky soil of fluvial origin
Merxmuellera rangei			P					X				Dry sand of seasonal river beds and washes in Namibia
Merxmuellera setacea*			P	X								Montane fynbos seeps (only two known localities)
Mosdenia leptostachys	IK		P		X	X						Sandy soil in bushveld
Oxyrachis gracillima			P		X							Wetlands (stream banks and in rivers)
Panicum dewinteri	IK	NT	P		X							Rocky outcrops, crevices, forest margins and wooded slopes (Soutpansberg)
Pentameris glacialis*			P	X								Humic soils in outh-facing gullies of the Groot Swartberg
Pentameris longiglumis subsp. gymnocolea*	R	VU	P	X								Steep, moist south-facing slopes of the Kogelberg
Pentameris longiglumis subsp. longiglumis*	VU	LC	P	X								Seepage areas and moist rocky slopes of Table Mountain
Pentameris swartbergensis*		LC	P	X								Damp, south-facing cliff bases in the Klein Swartberg
Pentameris uniflora*		LC	P	X								Damp, south-facing slopes and cliffs of the Langeberg
Pentaschistis alticola			P	X								Rocky upper slopes on sandstone in mountains
Pentaschistis aspera			P	X								Slightly disturbed areas (scree slopes, next to paths, along water courses & roadsides)
Pentaschistis aurea subsp. aurea			P	X								Marshlands on sandstone-derived soils

Table 1 continued

Species	RDL 2002	RDL 2006	Life form	Biome								Habitat
				Fy	Sa	Gr	NK	SK	De	Fo	Af	
Pentaschistis barbata subsp. orientalis	I	CR	P	X								Coastal dunes
Pentaschistis basutorum			P								X	Shallow soils over sandstone
Pentaschistis calcicola var. calcicola		NT	P	X								Limestone pavements
Pentaschistis calcicola var. hirsuta	R	VU	P	X								Limestone pavements
Pentaschistis caulescens			P	X								Shale bands on dry stony slopes
Pentaschistis chippindalliae	IK		P								X	Sour high-altitude grasslands (Mpumalanga Province)
Pentaschistis ecklonii	I	EN	P	X								Lowland soils (stony sandy slope, loamy soil, seasonal wet loamy soils, black sandy hollows, & open areas)
Pentaschistis elegans	R	CR	P	X								Coastal sand flats
Pentaschistis heptamera			P		X							Coastal sands
Pentaschistis holciformis		LC	P	X								Sandstone-derived soils in mountains
Pentaschistis lima	R	NT	P	X				X				Granitic soils
Pentaschistis longipes		VU	P	X								Coastal sands (around Port Elizabeth)
Pentaschistis microphylla			P								X	Arid montane grassland in the Stormberg
Pentaschistis papillosa	NT		P	X								On sandstone at low altitudes
Pentaschistis praecox	DD		P								X	Montane sour grassland
Pentaschistis pseudopallescens			P	X								Seeps and streams of the Cape Fold Mountains
Pentaschistis pungens			P	X								Damp sands at high altitudes
Pentaschistis reflexa			P	X								Arid fynbos
Pentaschistis rosea subsp. purpurascens			P	X								High-altitude sand flats
Pentaschistis rosea subsp. rosea			P	X								Deep sandy soils

Table 1 continued

Species	RDL 2002	RDL 2006	Life form	Biome								Habitat
				Fy	Sa	Gr	NK	SK	De	Fo	Af	
Pentaschistis rupestris	NT		P	X								Sandstone-derived soils of the Cedarberg
Pentaschistis scandens		VU	P	X								Sandy soils of the Agulhas Plain
Pentaschistis velutina			P	X								Gravel flats and shale bands in mountains
Pentaschistis veneta			P	X								Black sands in seeps of the Cape Fold Mountains
Pseudopentameris caespitosa*			P	X								Lowland sand fynbos
Pogonarthria leiarthra	LR-LC		A		X							Red sands
Puccinellia acroxantha			P			X						Saline periodically flushed depressions (Karoo)
Sartidia jucunda	R/DD	NT	P		X							Rocky hillsides in the Waterberg
Sartidia sp. (= Muller 2174)	R/DD		P			X						Hillslopes on serpentine soils around Barberton
Schismus pleuropogon #		STBA	P	X								Moist habitats in Renosterveld
Secale africanum (=S. strictum subsp. africanum)	V	CR	P				X					Undisturbed river banks
Setaria obscura	DD		P			X					X	Stream banks in high-altitude grasslands
Sporobolus bechuanicus			P		X							Brackish soils of seasonal pans
Stipagrostis namibensis	LR-LC		A				X					Temporary water-filled depressions (pools) and dry streams in semiarid regions
Stipagrostis proxima	R	LC	P				X					Sandy soils in disturbed habitats (e.g. old lands) and riverine bush
Tribolium brachystachyum*			P	X								Damp habitats, seepages and cool south-facing ledges in montane fynbos
Tribolium ciliare*		LC	A	X								Limestone outcrops in the Bredasdorp surrounds

Key to the biome codes: Fy = Fynbos, Sa = Savanna, Gr = Grassland, NK = Nama-Karoo, SK = Succulent Karoo, De = Desert, Fo = Forest & Af = Afromontane grassland. Key to RDL codes: CR = Critically Endangered, DD = data deficient, EN = Endangered, I = Indeterminate, IK = Insufficiently Known, LC = Least Concern, LR = Lower Risk, NT = Near Threatened, R = Rare, VU = Vulnerable. Codes in parentheses indicated IUCN (2001) subcategories . Species with "*" were described or revised subsequent to Gibbs Russell et al. (1990). P = Perennial, A = annual life forms. The # symbol indicates taxa with uncertain taxonomic status and requiring taxonomic revision

Table 2 Category RAN (Species of Restricted geographic range, Abundant local populations, Narrow habitat specificity). See the footnote to Table 1 for key to the biome, life form and RDL codes

Species	RDL 2002	RDL 2006	Life form	Biome								Habitat
				Fy	Sa	Gr	NK	SK	De	Fo	Af	
Aristida hubbardiana			A		X							Calcareous, clayey soils around vleis and flooded depressions
Aristida monticola	DD		P			X						Moist shady habitats of stream banks and seepages
Brachiaria dura var. pilosa	R		P		X							White sand dunes (Witsand)
Chaetobromus involucratus subsp. sericeus*			P					X				Coastal sands of Northern Cape (and possibly also Namibia)
Chaetobromus involucratus subsp. involucratus*			P	X								Dune slacks, sand dunes, beach dunes, granite outcrops, disturbed & drier areas on limestone hilltops of West Coast Strandveld
Colpodium drakensbergense	T	LC	P			X						Sedge meadows, streams and other wetlands at high altitudes
Eragrostis sabinae			P		X							Calcareous loamy sands and saline soils around pans, vleis and springs (Okondeka region, Namibia)
Eragrostis sabulosa			P	X				X				Coastal sands
Eriochrysis brachypogon	NT		P			X						Vleis and riverbanks
Festuca killickii	DD		P			X						Subalpine grasslands; on sandstones (Clarens Formation) and basalt
Merxmuellera aureocephala	DD		P								X	High-altitude steep grassy slopes of the Drakensberg
Merxmuellera decora			P	X								Sandy soils of mountain slopes of southwestern Cape
Merxmuellera guillarmodiae	DD		P								X	Rocky grassland at high altitudes in the Drakensberg
Merxmuellera lupulina			P	X								Sandy mountain slopes; after fire
Merxmuellera rufa			P	X								Sandy mountain slopes; after fire
Merxmuellera setacea	R	NT	P	X								Seeps and stream banks
Merxmuellera stereophylla			P								X	Xeric alpine grasslands; crevices in basalt cliffs
Pentameris hirtiglumis		LC	P	X								High-altitude shale bands of the Stellenbosch Mountains
Pentameris oreophila			P	X								Altimontane fynbos of the Hex River Mountains
Pentaschistis capensis			P	X								In water of rocky streams
Pentaschistis pallescens			P	X								Lower slopes of sandstone mountains

Table 2 continued

Species	RDL 2002	RDL 2006	Life form	Biome								Habitat
				Fy	Sa	Gr	NK	SK	De	Fo	Af	
Pentaschistis triseta			P	X								Sandy soils below 600 m; only after fire
Phacelurus franksiae	DD		P								X	High-altitude mountain grassland
Polevansia rigida			P			X						Rocky outcrops, often near water
Prionanthium dentatum	V	CR	A					X				Disturbed habitats (damp roadside ditches)
Prionanthium ecklonii	EN	EN	A	X								Low-altitude coastal renosterveld
Prionanthium pholiuroides	V	NT	A	X								Seasonally wet depressions (vernal pools); slightly saline
Pseudopentameris brachyphylla	R		P	X								Rocky or sandy lower slopes of the Cape Fold Mountains (surrounds of Caledon)
Pseudopentameris macrantha			P	X								Rocky and sandy slopes; on both sandstone and limestone
Pseudopentameris obtusifolia	R		P	X								Lower rocky slopes of mountains in the surrounds of Caledon
Stipagrostis dregeana	DD		P					X				Coarse sandy soils, between rocks and along roads
Stipagrostis lutescens var. lutescens			P					X				Sandy soils
Tribolium pusillum*			A					X				On clayey soils derived from shales of Karoo Sequence (northern Cederberg)

Table 3 Category RSB (Species of Restricted geographic range, Sparse local populations, Broad habitat specificity). See the footnote to Table 1 for key to the biome, life form and RDL codes

Species	RDL 2002	RDL 2006	Life form	Biome								Habitat
				Fy	Sa	Gr	NK	SK	De	Fo	Af	
Agrostis eriantha var. planifolia #	R		P			X		X				No data available
Aristida spectabilis			P		X	X						Shallow, sandy, quartzitic soils on mountain slopes
Bromus natalensis			P			X						Rocky hillsides
Helictotrichon capense #			P	X	X							Sandy soils
Helictotrichon longum #			P	X				X				Sandy flats of coastal fynbos; occasionally moist areas
Helictotrichon natalense #			P		X	X						Rocky hillsides and wetlands
Holcus setiger			P	X				X				Damp, sheltered habitats; on sandy-loamy soils
Stipagrostis gonatostachys	LR-LC		P					X	X			Sandy mountain slopes; water-filled depressions
Stipagrostis hermannii	LR-LC		A					X	X			Sandy flats with water-filled depressions, watercourses in Namibia
Stipagrostis ramulosa			P				X		X			Sandy soils between dunes, in river beds; near water
Stipagrostis schaeferii			P				X	X	X			Sandy soils in rocky areas, gravel plains, and dry watercourses

Table 4 Category RAB (Species of Restricted geographic range, Abundant local populations, Broad habitat specificity). See the footnote to Table 1 for key to the biome, life form and RDL codes

Species	RDL 2002	RDL 2006	Life form	Biome								Habitat
				Fy	Sa	Gr	NK	SK	De	Fo	Af	
Aristida engleri var. engleri			P				X	X				Rocky outcrops
Eragrostis kingesii			A						X			Disturbed habitats in gravel, sand or limestone; also sandy hollows, drainage depressions, roadsides
Kaokochloa nigrirostris			A				X		X			Sandy and gravel flats, dry river beds & water courses
Lophacme digitata	IK		P		X	X						Open highveld sourveld
Schismus scaberrimus			P	X				X				Sandy areas; dry river beds
Stipagrostis brevifolia			P				X	X				Roadside drainage line on flats, sand dunes, dry water courses & rocky hillsides
Stipagrostis garubensis	LR-LC		P					X				Between granite rocks on hill sides and riverbeds
Stipagrostis geminifolia			P					X				Coarse sandy soils on rocky slopes, dry sandy water courses, dry sandy flats
Stipagrostis lutescens var. marlothii			P					X	X			Dry river courses on gravel substrate
Stipagrostis sabulicola	LR-LC		P					X	X			Dune ridges, sandy gullies and sandy river beds
Tricholaena capensis subsp. arenaria			P				X					Dry, sandy habitats

Table 5 Category WSN (Species of Wide geographic range, Sparse local populations, Narrow habitat specificity). See the footnote to Table 1 for key to the biome, life form and RDL codes

Species	RDL 2002	RDL 2006	Life form	Biome								Habitat
				Fy	Sa	Gr	NK	SK	De	Fo	Af	
Bromus speciosus			P			X						Steep, moist mountain slopes; shady habitats along streams
Ehrharta bulbosa			P	X								Low-altitudes in open grassland, flat well drained habitats e.g. amongst rocks & gravel on steep southwstern slopes
Ehrharta dura			P	X								Seasonally moist mountain fynbos
Ehrharta melicoides			P	X				X				Mountain slopes supporting renosterveld and overgrazed grassland
Ehrharta rehmannii subsp. subspicata			P	X								Moist sand and gravel habitats; close to sea level
Ehrharta villosa var. maxima			P	X								Coastal dunes
Ehrharta villosa var. villosa			P	X								Coastal dunes
Eragrostis laevissima			P		X							Sandy and brackish soils around pans and vleis
Eriochloa meyeriana subsp. grandiglumis #					X							Lowveld riverbanks and floodplains
Helictotrichon dodii #			P	X								Wetlands (coastal sandy flats, swamp & vlei margins)
Merxmuellera arundinacea			P	X								Dry north-facing slopes of the Cape Fold Mountains
Merxmuellera cincta subsp. cincta*			P	X								Seeps and stream banks of south-facing slopes
Merxmuellera cincta subsp. sericea*	CR (1&B2a, c-e, C2a)	VU	P	X								Coastal sand dunes with groundwater level close to surface (E Cape)
Panicum bechuanense #	DD		P		X							Seepage habitats, river beds and pans
Pentaschistis aurea subsp. pilosogluma			P								X	Streams and seepage habitats on Clarens sandstone or basalt
Pentaschistis tomentella			P					X				Old lands, river banks, roadside gravel, sandy flats, hillsides at higher altitudes of Namaqualand
Polypogon griquensis			A		X							Wetlands (riverbeds & river banks)

Table 5 continued

Species	RDL 2002	RDL 2006	Life form	Biome								Habitat
				Fy	Sa	Gr	NK	SK	De	Fo	Af	
Puccinellia angusta			P	X		X			X			Disturbed habitats on moist, saline soils
Sorghastrum friesii			P		X							Wetlands (river banks, vleis, forest swamp clearings, seasonally inundated grassland floodplains, shallow water)
Sporobolus oxyphyllus (=S. sp1; Smook 3429)			P		X		X					Brackish soils around salt pans
Stipagrostis fastigiata			P				X	X	X			Sandy, alkaline soils
Thamnocalamus tessellatus	VU (D1)		P								X	Wetlands (water courses, stream banks, water falls in sheltered ravines of mountain sides)
Tragus pedunculatus			A		X							Shallow sands over limestone
Tribolium obliterum*			P	X								Seasonally waterlogged sands and clays, sometimes on limestone

Table 6 Category WAN (Species of Wide geographic range, Abundant local populations, Narrow habitat specificity). See the footnote to Table 1 for key to the biome, life form and RDL codes

Species	RDL 2002	RDL 2006	Life form	Biome								Habitat
				Fy	Sa	Gr	Nk	Sk	De	Fo	Af	
Aristida sciurus			P			X						Moist, sandy soils of mountain sourveld
Eragrostis walterii	LR-LC		P				X	X	X			Sandy and brackish soils around seeps, pools and water springs
Festuca dracomontana	R	LC	P			X					X	High-altitude sourveld
Hordeum capense			P	X	X	X	X					Wetlands (streamsides, riverbanks, swamps, moist mountain slopes)
Megaloprotachne albescens			A		X							Kalahari sands
Panicum pilgerianum	DD		A		X							Dams, pans, vleis; in clay soils
Pentameris thuarii			P	X								Stream banks and seeps of the Cape Fold mountains
Setaria finita			A		X							Shady habitats along rivers
Setaria rigida			P		X							Stream banks and swamps
Sporobolus albicans			P			X	X					Limestone pans and other dry depressions
Sporobolus ludwigii			P		X	X						Damp calcareous soils of vleis and pans
Sporobolus salsus			P		X		X					Seasonal brackish pans, hot springs and rivers
Sporobolus tenellus			P		X		X					Shallow soils at pan edges and similar depressions
Sporobolus welwitschii			P		X							Brackish soil of pans, dry river beds and banks, open grassland
Stipagrostis amabilis			P		X		X					Crests of sand dunes (Kalahari)
Stipagrostis damarensis	LR-LC		P		X				X			River beds and drainage lines
Thinopyrum distichum			P	X	X			X				Coastal sand dunes

Table 7 Category WSB (Species of Wide geographic range, Sparse local populations, Broad habitat specificity). See the footnote to Table 1 for key to the biome, life form and RDL codes

Species	RDL 2002	RDL 2006	Life form	Biome								Habitat
				Fy	Sa	Gr	NK	SK	De	Fo	Af	
Anthephora argentea			P		X		X					Sand dunes (Kalahari Thornveld)
Cynodon bradleyi #			P			X						Well-drained, nutrient-rich soils on edges of pans & floodplains (limited information available)
Festuca longipes			P			X						Grassy slopes and shady forest margins; above altitude of 1500 m
Tarigidia aequiglumis			P		X	X						Vleis, dry river beds, rocky ridges (limited information available)
Tetrachne dregei			P			X	X					Sandy riverbanks, rocky outcrops or mountain slopes; at altitudes above1250 m
Tribolium amplexum			P	X								Disturbed habitats on sand soils
Tribolium obtusifolium			P	X								Sandy habitats

Table 8 The numbers of grass species allocated to each of the seven Rabinowitz categories, and a comparison of these to the 2002 and 2006 RDL's. Bias in biome representation is given when χ^2 test is significant (**=p < 0.01, ***=p < 0.001)

Rabinowitz category	No. of taxa	Number of these taxa listed in 2002 RDL (out of 120)	Number of these taxa listed in 2006 RDL (out of 35)	Significant biome bias
RSN (Restricted, Sparse, Narrow habitat)	93	30	25	Fynbos***
RAN (Restricted, Abundant, Narrow habitat)	33	16	6	Fynbos**
RSB (Restricted, Sparse, Broad habitat)	11	3	0	Not significant
RAB (Restricted, Abundant, Broad habitat)	11	3	0	Arid biomes (Succulent Karoo and Desert)**
WSN (Widespread, Sparse, Narrow habitat)	24	3	1	Fynbos***
WAN (Widespread, Abundant, Narrow habitat)	17	4	1	Savanna***
WSB (Widespread, Sparse, Broad habitat)	7	0	0	Not significant
TOTAL	196	58	33	

Category 1 Taxa with Restricted geographic range, Sparse population structure and Narrow habitat requirements (RSN).

This is the most sensitive category of the Rabinowitz codes and contains those taxa that may require some fairly urgent form of assessment and monitoring. There are 93 taxa listed in this category (Table 1), and a closer examination of the species included reveals some interesting taxonomic and phytogeographic implications. No less than 44% of the taxa listed belong to one subfamily, the Danthonioideae, and 29% of the taxa listed belong to one genus in this subfamily, *Pentaschistis*. The Danthonioideae has undergone substantial radiation in the austral regions (Barker et al. 2007; Linder and Barker 2000, 2005), and this radiation has occurred extensively in the south-western Cape, predominantly in the Fynbos Biome. These grasses are C_3 and are thus able to out-compete the C_4 grasses, which are poorly suited to the nutrient poor status of the soils and the winter rainfall regime (Cowling et al. 1997). In addition, many of these species occurring in the Fynbos have evolved a variety of underground perennating organs in order to survive fire (Linder and Ellis 1990b).

Many of the taxa listed in this category are found in the fynbos biome (56% of the taxa), especially the montane fynbos on sandstone of the Table Mountain Formation of the Cape Fold Mountains. As such, these species are under little threat of extinction, provided the natural vegetation is managed appropriately. Rebelo and Siegfried (1990) provide figures indicating that a total of 35% of the original area of the Fynbos Biome vegetation is protected, with a further 9% proposed for protection. It is also worth noting that the montane fynbos areas are sometimes not well known botanically, and new populations (and new species) may well be found when they are further explored, or when visited after a fire event, which generally triggers grass germination, growth and flowering in the fynbos. When this happens, some grasses may be abundant for one or a few years post-fire, then die or become moribund and not be recorded in mature vegetation. Herbarium records may relate this information in an obscure way, such as (for example) including generally logically unrelated comments like “flowering after burn” and “locally common at this locality”. Connecting the biological reality of these species life history in relation to fire requires experience in the form of field observations and taxonomic expertise.

The Savanna Biome contains 12.9% of the taxa appearing in this category, Grassland 9.6%, Nama-Karoo 10.7%, Succulent Karoo 8.6%, afromontane grassland 75%, Desert 6.4% and Forest 0%, (Table 1). In terms of habitat specialisations, 31.8% of the taxa in this category are associated with wetland habitats, such as water bodies, marshes, stream and river banks, seeps, vleis, pans etc.

Of the 93 species in this category, 30 (32%) were placed on the 2002 RDL and 25 (26.8%) in the 2006 RDL. Clearly, species in this category are the most urgently in need of detailed assessment for inclusion in future RDLs, and should form the “priority list” for the region’s RDL scientists.

Category 2 Taxa with Restricted geographic range, Abundant population structure and Narrow habitat requirements (RAN).

Thirty three species are placed in this category (Table 2). Once again, representatives of the subfamily Danthonioideae are common, accounting for 63.6% of the taxa listed. Just under half (48.5%) of the species are found in the Fynbos Biome, 18.2% in the Succulent Karoo Biome, 15% in the Grassland Biome, 12% in the afromontane grassland, and 9% from the Savanna Biome. This bias of taxa from the Fynbos Biome is statistically significant when tested by means of a χ^2-test.

It is interesting to compare the proportion of annual species in this list against that reported in the RSN category (above). In this category, 15% of the species are annuals, while only 9% of the species in the RSN category are annuals. This may be a reflection of the demographic structure, in that annual species may be more abundant where they occur. Rutherford and Westfall (1986) state that therophytes (i.e., annual species) dominate in areas with low rainfall and extended summer drought. However, despite the ease with which these taxa can become established, the plants are susceptible to adverse environmental conditions for the remainder of their life span. Despite the association of therophytes to arid areas, most of the annual species listed in this category occur in the fynbos. Furthermore, these species do not appear to prefer arid microclimates within the Fynbos, as 29% of the taxa are associated with moist habitats.

Category 3 Taxa with Restricted geographic range, Sparse population structure and Broad habitat requirements (RSB).

Eleven species fall into this category (Table 3). All except one of these species is found in more than one biome, an indication of their broader habitat requirements. 63.6% are found in the more arid biomes (Nama-Karoo, Succulent Karoo and Desert), but this is not statistically significant. Only one species is associated with a moist habitat. However, as these regions are severely undercollected (Gibbs-Russell et al. 1984; Robertson and Barker 2006), it is quite probable that many of these taxa could have wider geographic ranges, and thus could potentially be removed from this category. Only three of the species in this category appeared in the 2002 RDL (one considered as “Rare”, the other two as “Least Concern”) and are in the 2006 list (Table 8).

Category 4 Taxa with Restricted geographic range, Abundant population structure and Broad habitat requirements (RAB).

The above pattern of wider biome distributions of the species with broader habitat requirements is repeated in this category, with 91% of the species being found in the three arid biomes, a statistically significant distribution when tested by means of a Chi-square test (Table 4). The Succulent Karoo in particular contains a high proportion of the species in this category (63.6%). Comments made above pertaining to the low collection intensity from these arid regions are also applicable here. This category has 18.2% annual species while the RSB category (Table 3) has only 9.1% annual species. In this instance, the higher proportion of taxa in the arid regions may account for this feature, as all the annual taxa in the RAB category are found in the three arid biomes. Furthermore, none of the species in this category are restricted to moist habitats.

Category 5 Taxa with Wide geographic range, Sparse population structure and Narrow habitat requirements (WSN).

Twenty four taxa are placed in this category, of which 50% are found in the Fynbos, 21% in the Savanna, and the remainder spread over the other biomes (Table 5). Twenty nine percent of the taxa are from one or more of the arid biomes. 8.3% of the taxa are annual species. The majority (67%) of the species in this list are associated with moist or damp habitats, which is why they are considered to have narrow habitat requirements. Somewhat surprisingly, only two species listed here appear in the 2002 RDL, and one on the 2006 list (Table 8).

Category 6 Taxa with Wide geographic range, Abundant population structure and Narrow habitat requirements (WAN).

Seventeen taxa fall into this category, 52.9% of which are found in the Savanna Biome, 35.2% Nama-Karoo, 17.6% Succulent Karoo, 11.7% Desert and 5.9% in afromontane grassland, a statistically significant bias (Table 6). A total of 47.1% of the taxa are found in one or more of the three arid biomes. 17.6% of the taxa are annual species. As in the previous category with a narrow habitat requirement (WSN) 70.6% of the species in this list are associated with moist environments. Four taxa appeared in the 2002 RDL, but only one is in the 2006 listing (Table 8).

Category 7 Taxa with Wide geographic range, Sparse population structure and Broad habitat requirements (WSB).

This category is the one of least concern for consideration in any RDL. Only seven taxa were placed in this category, 57.1% of which are found in the Grassland Biome. This biome is considered to be under great threat from agriculture and urbanisation, and with only 2% of it under some form of conservation (O'Connor and Bredenkamp 1997; Reyers et al. 2001). Of the remaining taxa 28.6% are found in each of the Fynbos, Nama-Karoo and Savanna Biomes (Table 7). No annual species are placed in this category, and no species are associated with moist habitats.

Comparison of Rabinowitz categories and existing Red Data Listings

Table 8 summarises the number of species listed here using the Rabinowitz codes, compared to how many of these species are also listed in the 2002 and 2006 RDLs. It must be reiterated that the 2006 RDL covers only South African taxa, making direct comparisons between the lists difficult, and highlighting the problems of using national and regional boundaries when compiling RDLs, a problem also noted by Milner-Gulland et al. (2006) for the Central Asian republics region. This also explains the decline in number of recognised RDL grass species in South Africa from 88 to 35 between the 2002 and current (2006) online assessments.

Of the 35 species listed in the 2006 RDL, 33 appear in the Rabinowitz categories presented here. Further investigation of the two species apparently not included revealed that one of them (*Colpodium drakensbergense*) is not listed under this name in the grass flora (Gibbs Russell et al. 1990). Instead, it appears as *C. hedbergii*, which is a misapplied name. For this analysis, these two names are considered here under the former name. The other species (*Anthoxanthum brevifolium*) is listed by Gibbs Russell et al. (1990), but is cited as being indistinguishable from *A. ecklonii*, and the genus as a whole is in need of taxonomic revision. Apart from these two explainable differences, it is satisfying to find that all the taxa in the 2006 RDL are placed in one of the Rabinowitz categories.

When comparing the lists obtained here with the FSA region's RDL (Golding 2002), 58 out of the 120 RDL listed species (48.3%) are detected using the Rabinowitz system. This is less satisfying, and reasons need to be sought to explain why just over 50% of the 2002 RDL species were not detected. In order to determine the reasons for their omission, the grass flora (Gibbs Russell et al. 1990) was consulted for information on each of the 62 undetected species. Thirty seven of these are not included here as they are not endemic, occurring in countries to the north of the FSA region, and even beyond the continent.

A further 14 were considered as widespread and/or common. Three species are considered taxonomically problematic or very poorly known, a further one is thought to possibly be a hybrid, and five species listed by Golding (2002) are not listed at all by Gibbs Russell et al. (1990).

The remaining two species are thus genuine omissions from the process used to allocate species to the Rabinowitz categories. These species are:

1. *Helictotrichon natalense* (Stapf) Schweick. which is listed as Not Threatened by Golding (2002), but which is considered infrequent to locally common, restricted to wet places such as streamsides. It is, however, distributed over quite a large area (KwaZulu-Natal to Mpumalanga; Gibbs Russell et al. 1990). It should thus be allocated to the WSN category.
2. *Danthoniopsis scopularum* (J.B. Phipps) J.B. Phipps, which is known from a locality south of Swaziland, where it is found on rock faces.

There is thus considerable overlap between the 2002 and 2006 IUCN lists, which suggests that the Rabinowitz system highlights the relevant taxa and their particular biologies that make them potentially rare and threatened. However, more taxa were identified using Rabinowitz system than are currently (or previously) on IUCN RDLs. This implies that the other taxa listed here but not in the latest IUCN list deserve to be reconsidered with some urgency.

Are rare grasses associated with specific habitats?

As already noted above, a considerable proportion of species in any of the Rabinowitz categories with Narrow habitat requirements appear to be associated with moist habitats and wetlands of various forms. For many taxa, this moisture requirement is in the form of montane seeps, but for others that are found near streams, rivers and bodies of standing water, there is a potential threat from anthopogenic activities. As noted by a number of authors, there are many kinds of wetlands in southern Africa (Cowan 1995; Kotze et al. 1995; Rogers 1997; Mucina and Rutherford 2006). In this assessment (summarised in Tables 1–7), we have tried to be as specific as possible about the nature of the wetland habitat of the grasses listed. Many of the wetlands associated with the listed taxa are small in size, and face different threats than do larger wetland areas. Also, many of the "wetlands" associated with the more arid inland areas are ephemeral, and thus grasses associated with sandy river beds or temporary pans (for example) must be considered to have some specialisation to these ephemeral wetland systems.

Grenfell et al. (2005) recognised this when they noted that wetlands can be divided into three zones of varying wetness: temporarily saturated, seasonally saturated and permanently saturated. Further investigation of some of the grass species listed here could no doubt categorise their specific habitat into these zones. Any land use practises that change the balance of water input and output from wetlands will affect these zones (Grenfell et al. 2005). Lowland aquatic habitats are threatened with pollution, drainage, diversion and physical destruction, but as noted by O'Keefe (1986), it is very difficult to conserve catchments and river systems. Small wetlands in the arid interior plateau zone of southern Africa (which are probably important habitats to those grass species listed here, especially those in the Savanna biome) are also under threat, but accurate information on these wetlands is lacking (Kotze et al. 1995). For South Africa, the National Water Act (Act 36 of 1998) charges catchment managers with the duty of protecting aquatic resources and their biodiversity. Thus, in principle, all species listed here that are associated with aquatic or wetland habitats should be protected.

Difficulties in using the Rabinowitz system when based on herbarium records

The system proved to be generally easy to apply when suitable data was available. However, it must be noted that concepts of "wide" and "restricted" geographic ranges are subjective, and had to be subjectively specified here (in this case, the cut-off was a herbarium record from nine half-degree squares). This subjectivity has also been recognised by others who have applied the Rabinowitz system (e.g., Pitman et al. 1999; Yu and Dobson 2000). Furthermore, it must be noted here that this is a rather crude assessment of distribution area, and is difficult to relate to the IUCN's concept of Extent of Occurrence (EOO), and should not be considered as exchangeable concepts. As noted above, the IUCN cut-off for the EOO is 20,000 km^2, and nine contiguous half-degree grids would represent an area of approximately 27,250 km^2. One could reduce the choice of nine half-degree squares in order to become more rigorous and more in line with the IUCN's cut-off, but this method or measure is still not comparable to that required by the IUCN for assessing the EOO of a species (see http://intranet.iucn.org/webfiles/doc/SSC/RedList/RedList-Guidelines.pdf). Hartley and Kunin (2003) analyse the effects of scale on rarity and extinction risks, and note that the EOO does not provide any information about the distribution of a species' populations within its range, and that outlier populations greatly affect the EOO as a measure of distribution. In contrast, the Area of Occupancy (AOO) can be calculated using a grid system, but that the size of the grid chosen can affect the values obtained for a species' AOO (Hartley and Kunin 2003).

Some subjectivity also creeps into dividing taxa into "narrow" and "broad" habitat requirements. The likelihood of a "narrow" habitat requirement can be determined from common sets of information from herbarium records, where a series of similar observations are made. However, the problem can arise when considering the term "narrow habitat specificity"; it can refer to taxa either restricted to one specific habitat type (with associated problems of how detailed and specific this could get to be) or found in more than one habitat type which is restricted in terms of area. Often, the two will coincide, as specialist habitat may be limited in area. However, generally it is relatively easy not to conflate habitat and area in this regard.

Similarly, the distinction between "abundant" and "sparse" population structure is not always readily apparent, and is probably the most subjective of the three Rabinowitz criteria as it is not simple to obtain a meaningful cut-off value with accurate census data for all the listed species. The best assessment of this requires the opinion of a botanist familiar with the taxon in the field. Furthermore, as noted by Robbirt et al. (2006), detection (i.e., the initial noting, followed by collection and incorporation into a collection system) is a function of density, distribution, habitat and visibility. Thus species in sparse populations may not be collected that frequently, and these taxa may not be as "rare" as collections data suggests.

It must also be emphasized that herbarium records represent a historical record of plant distributions, and not a contemporaneous view. Thus a distribution record from a specimen collected 200 year ago does not indicate that the species may still be found at that locality; as anthropogenic or natural factors may have caused local extinction. Distribution data based on herbarium collections must thus be considered to be potentially over-informative.

Conclusions

To the best of our knowledge, this is the first use of a digital flora treatment for assessing and listing species for conservation action. Based on herbarium label data and taxonomic expertise, it is entirely possible for flora treatments and taxonomic revisions and monographs to be used to generate lists of species as candidates for RDL membership. The Rabinowitz categories appear to be well suited for the sort of data available from these sources, and the fact that the species placed in recent RDLs were also almost completely included in the Rabinowitz categories is reassuring. However, the additional taxa listed here and not on any IUCN list are cause for concern, and these species require further attention by RDL specialists in conjunction with taxonomic experts.

In terms of the grass family, it appears that many (194, or about 19%) of the grass species found in southern Africa are at best infrequent. Furthermore, 163 were associated with some form of narrow habitat requirement (often associated with water or moisture), suggesting that specific habitats are in need of monitoring and protection. The RSN set of species can be considered as genuinely rare, and it is thus recommended that the latest IUCN RDL for South Africa be updated by adding the species from the RSN category. In so doing, these taxa can be prioritised for some form of population level investigation and the initiation of monitoring programmes. However, the remaining categories (especially those with Narrow habitat requirements) should also not be ignored, and must be flagged for some form of conservation action.

Even in the face of concerns about subjectivity, we believe that (when based on data obtained from sufficient collections and the relevant experts) the Rabinowitz categories are an excellent system that complements the IUCN criteria. Using the grasses (an uncharismatic and often overlooked group of plants), we have demonstrated that these categories can provide lists of candidate species (with interesting and differing biology) for further detailed assessment as required by the IUCN criteria. As it is herbarium-based, the method requires little or no field work. Even in the absence of an electronic flora or database, it can be used to create a working list of species that have differing elements of rarity as part of their biology. As long as herbarium records are considered to be sufficient and collection intensity generally adequate, the method is suitable (especially when harnessed with taxonomic expertise) as a first step for developing nations with limited technical and human resources which are endeavouring to complete national RDL's.

Acknowledgements We thank Lize Agenbag (Threatened Species Programme of the South African National Biodiversity Institute) and Prof. H. Peter Linder (Institute for Systematic Botany, Zürich, Switzerland) for comments on a previous draft, and two anonymous reviewers for their valuable comments and suggestions. Anjanette Haller-Barker is thanked for her careful reading of the manuscript.

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