Distribution and protection of endemic or threatened rodents, lagomorphs and macroscelidids in South Africa

D.N. Mugo and A.T. Lombard*
Percy FitzPatrick Institute of African Ornithology, University of Cape Town, Private Bag Rondebosch, 7700 Republic of South Africa

G.N. Bronner
Department of Mammals, Transvaal Museum, P.O. Box 413, Pretoria, 0001 Republic of South Africa

C.M. Gelderblom and G.A. Benn
Percy FitzPatrick Institute

Received 16 February 1995; accepted 4 May 1995

Distribution patterns and protection status of endemic or threatened Lagomorpha, Macroscelidea, and Rodentia were analysed using museum point locality data and a geographic information system (GIS). The study area comprised the greater South Africa (including Lesotho and Swaziland). Species richness of the target species is highest in the south-western parts of the country, and hotspots of endemism coincide with those of species richness. However, Red Data Book species hotspots are confined to the north-eastern parts of the country. One species richness hotspot in the Succulent Karoo contains no existing reserves, whereas all Red Data Book species hotspots are protected. In general, all target species are well protected within existing reserves, but those found in the Succulent and Nama-Karoo, especially the Namaqua dune molerat (*Bathyergus janetta*), the riverine rabbit (*Bunolagus monticularis*), Brants' whistling rat (*Parotomys brantsii*), and the pygmy rock mouse (*Petromyscus collinus*), are threatened by a paucity of reserves in these biomes. A heuristic reserve selection algorithm was used to identify a more representative reserve system for the protection of all target species. Ten representative reserves were identified, six of which already contain existing reserves. An analysis of biome specificity of all species revealed that *Myomyscus verreauxii* is endemic to the fynbos, *Bathyergus janetta* to the Succulent Karoo, *Zelotomys woosnami* to the arid savanna, and *Steatomys parvus* to the savanna woodlands. No species are endemic to the Nama-Karoo or grasslands, although several species do show strong preferences for these habitats. It is recommended that hotspots, representative reserves, and species that are currently not protected, be awarded more protection, and that existing reserves which coincide with hotspots and representative reserves be managed for their mammal fauna. It is also recommended that the Red Data Book status of four species, and six subspecies, should be changed.

Verspreidingspatrone en beskermingstatus van endemiese of bedreigde Lagomorpha, Macroscelidea, en Rodentia is geanaliseer met behulp van museumpunt-liggingsdata en 'n geografiese informasiesisteem (GIS). Die studiegebied het die groter Suid-Afrika (insluitend Lesotho en Swaziland) ingesluit. Die spesierykheid van teikenspesies was die hoogste in die suidwestelike gedeeltes van die land. Die brandpunte van endemisme het met dié van spesierykheid oorvleuel. Die brandpunte van Rooi Data-boekspesies is egter beperk tot die noordoostelike gedeeltes van die land. Een spesierykheidbrandpunt, in die Sukkulente Karoo, bevat geen bewaringsgebiede nie, terwyl al die brandpunte vir Rooi Data-boekspesies bewaar word. In die algemeen word alle teikenspesies goed beskerm in bewaringsgebiede, maar die wat in die Sukkulente en Nama-Karoo aangetref word, in besonder die Namakwa-duinmol (*Bathyergus janetta*), die oewerkonyn (*Bunolagus monticularis*), Brants se fluitrot (*Parotomys brantsii*), en die dwergklipmuis (*Petromyscus collinus*) word deur 'n gebrek aan bewaarde gebiede in hierdie biome bedreig. 'n Proefondervindelike seleksieprosedure vir bewaringsgebiede is gebruik om 'n meer verteenwoordigende bewaringsgebiedsisteem vir die beskerming van al die teikenspesies te identifiseer. Tien verteenwoordigende bewaringsgebiede is geïdentifiseer, waarvan ses reeds bestaande bewaringsgebiede insluit. 'n Ontleding van die bioomspesifisiteit van al die spesies het aangetoon dat *Myomyscus verreauxii* endemies is aan die fynbos, *Bathyergus janetta* aan die Sukkulente Karoo, *Zelotomys woosnami* aan die dorre savanna en *Steatomys parvus* aan die savannabosland. Geen spesie is endemies aan die Nama-Karoo of die grasland nie, alhoewel verskeie spesies sterk voorkeur verleen aan hierdie habitats. Daar word aanbeveel dat aan brandpunte, verteenwoordigende bewaringsgebiede, en spesies wat op die oomblik onbeskermd is, groter beskerming toegeken word, en dat bestaande bewaringsgebiede wat met brandpunte en verteenwoordigende bewaringsgebiede saamval vir hulle soogdierfauna bestuur word. Daar word ook aanbeveel dat die Rooi Data-boekstatus van vier spesies en ses subspesies, verander moet word.

*To whom correspondence should be addressed

The present system of publicly owned protected areas (= reserves) in South Africa is not the result of a national plan to conserve all aspects of biodiversity, but of historical *ad hoc* decisions (Siegfried 1989). Pressey (1994) lists the reasons for *ad hoc* designation of reserves as: the relative lack of value of selected sites for profitable exploitation by humans; impressive scenery; recreation potential; influence of lobby groups; and the protection of historical uses (such as hunting). In South Africa, existing reserves are heavily biased towards areas with large mammal faunas, mainly because of their tourism and hunting appeal. The *ad hoc* designation of reserves has two main disadvantages. First, it tends to exclude certain species, communities or ecosystems (Pressey 1994). Second, it makes the establishment of representative reserves

more expensive, thus reducing the likelihood of their establishment (Pressey & Tully 1994).

It is often assumed that reserves designated to protect large mammal faunas will also provide adequate protection for small mammals and other faunas. However, the validity of this assumption has not been adequately tested. Gelderblom (1993) used range maps to test the effectiveness of the current reserve system in protecting small endemic mammal taxa in South Africa. She concluded that the existing reserve system does not adequately protect all the small mammals, and that this may have contributed towards the high proportion of threatened species within this group. In addition, Siegfried & Brown (1992) used a reserve selection algorithm to assess the effectiveness of the current reserve system in conserving biodiversity. They found that the existing arrangement of reserves, particularly in the north-eastern and eastern parts of the country, corresponds closely to an ideal configuration that would maximize the protection of resident, breeding, terrestrial mammalian species. However, they also showed that it does not adequately protect endemic mammal species.

Another way to assess the effectiveness of current reserves in protecting small mammals is to perform a gap analysis (Scott, Davis, Csuti, Noss, Butterfield, Groves, Anderson, Caicco, D'Erchia, Edwards, Ulliman & Wright 1993; Lombard, August & Siegfried 1992). In this study, gap analysis is used in a restricted sense to refer only to the taxa under investigation. We used a geographic information system (GIS) to identify hotspots, i.e. centres of total, endemic, or Red Data Book (RDB, Smithers 1986) species richness. These hotspots are then compared with the existing reserve system. Priority areas for conservation outside of the existing system are identified, and suggestions are made as to how the present system may be improved upon to include taxa at risk. Hotspots, however, do not usually represent all species within a taxon (Lombard 1995b). Thus, in addition to a gap analysis, we used a heuristic reserve selection algorithm to identify a more representative system of reserves.

The main difference between this study and recent work on the endemic mammals (Gelderblom 1993), and all South African terrestrial mammals (Siegfried & Brown 1992), is that point data, rather than range maps, are used. This allows one to identify important areas at a much finer scale. These areas can then be surveyed at minimal cost to verify the presence of species.

Target species

Endemic or threatened small mammals of the orders Rodentia, Macroscelidea, and Lagomorpha were selected for two reasons: (i) fairly reliable distribution data exist; and, (ii) the other small mammals i.e. orders Chiroptera and Insectivora, have been dealt with by Gelderblom, Bronner, Lombard & Taylor (1995).

Within the three orders under investigation, there are eight species of Macroscelidea, seven species of Lagomorpha (Skinner & Smithers 1990), and 73 species of Rodentia (De Graaff 1981) in southern Africa. In this paper, we examine two macroscelidids, two lagomorphs and 21 rodents. Of these, 16 are endemic to South Africa, two are southern African sub-region endemics, and seven are not endemic to South Africa or the sub-region. In terms of the RDB status, one species is listed as endangered (*Bunolagus monticularis*), two are vulnerable, five are rare, six are indeterminate, and 11 are not listed (see Table 1).

With 29 families, 443 genera, and about 2021 species (Wilson & Reeder 1993), rodents form the largest mammalian order. However, many questions regarding their taxonomy still remain unanswered (De Graaff 1981). Rodents are found in most types of habitat owing to their wide-ranging adaptations. They occur in all zoogeographic regions except the Antarctic and some oceanic islands (De Graaff 1981). The order Macroscelidea comprises the elephant shrews, with four genera represented by 15 living species distributed in Morocco, Algeria, and Africa south of the Sahara (Wilson & Reeder 1993). They are partly diurnal, and inhabit open plains, savannas, brushlands, or forests. The order Lagomorpha includes rabbits (Leporidae) and pikas (Ochotonidae) and comprises 13 genera, represented by 80 species (Wilson & Reeder 1993). They have a world-wide distribution, and occupy terrestrial habitats from the Arctic to the tropics.

Methods

Species distribution data

Digital data were received from the following Museum collections: South African Museum, Transvaal Museum, Durban Natural Science Museum, Natal Museum, and the National Museum in Bloemfontein. Analogue data were obtained from the Carnegie Museum of Natural History and the Smithsonian Institution in the USA. All data from museums were supplied in digital format at a quarter-degree square scale (QDS = 15' × 15'). QDS codes were those defined by the government printer for 1:50 000 maps (e.g. 3319AC). Once all data had been collated, they were screened for errors. Particular attention was paid to locality errors and possible mis-identification errors, especially with respect to earlier specimens. Corrected data were then formatted for GIS input. Data from the Smithsonian Institution and the Carnegie Museum were converted into digital format after confirming locality records in the gazetteer (Skead 1973). The data from museums were supplemented with information from the following literature sources: Dean (1978); Duthie, Skinner & Robinson (1989); Lynch (1983, 1989, 1994); Lynch & Watson (1992); Rautenbach (1982); Taylor, Richardson, Meester & Wingate (1994); and Bronner (1990).

Museum records were used for the following reasons: (i) museums provide the most convenient sources of data; (ii) the target taxa are not easily observed in the field; and, (iii) museum records are more reliable in terms of taxonomic identification, thus minimizing the potential for error. The size of the mapping unit used in mapping species can have significant consequences in prioritizing areas for conservation (Stoms 1994; Pressey & Logan 1994). Owing to the mixed scales of the data provided by museums (some data were point localities, and others were at a QDS scale), all data were converted to QDSs to facilitate analyses at one scale only.

The number of data points obtained from the various sources was as follows: Transvaal Museum — 1240 records; South African Museum — 295 records; Durban and Natal Museums — 157 records; Carnegie Museum and Smithsonian Institution — 129 records; National Museum in Bloemfontein — 115 records; and literature sources yielded 228

Table 1 List of species investigated

Species	[a]Endemic status	[b]Red Data Book status
Aethomys granti	SA	I
Bathyergus janetta	SA	R
Bathyergus suillus	SA	
Bunolagus monticularis	SA	E
Cricetomys gambianus		R
Dasymys incomtus		I
Dendromus nyikae		I
Elephantulus edwardii	SA	
Georychus capensis	SA	
Grammomys cometes		I
Graphiurus ocularis	SA	R
Myomyscus verreauxii	SA	
Mystromys albicaudatus	SA	V
Otomys karoensis[c]	SA	
Otomys laminatus	SA	
Otomys sloggetti	SA	
Otomys unisulcatus	SA	
Paraxerus palliatus		V
Parotomys brantsii	SA	
Petrodromus tetradactylus		R
Petromyscus collinus	SR	I
Pronolagus crassicaudatus	SA	
Steatomys parvus		I
Tatera afra	SA	
Zelotomys woosnami	SR	R

[a] SA = South African endemic; SR = southern African sub-region endemic

[b] E = Endangered; V = Vulnerable; R = Rare; I = Indeterminate

[c] Taylor, Meester & Kearney (1993)

records. All data points were combined into a final species presence-only dataset, at a QDS scale.

Analyses

Spatial analyses were performed using a GIS (PC ARC/INFO 3.4D+, Environmental Systems Research Institute, Redlands, California). The 'overlay' functions available in ARC/INFO are very useful for combining spatial data layers, e.g. species distributions, reserves, and biomes.

The QDS reserve database described by Lombard (1995a) was used for all analyses. The boundary reserve database (Lombard 1995a) was used only for graphic display in Figure 4. The biomes defined by Rutherford & Westfall (1986) were used for graphic display in Figures 1–3. These biomes were modified by G.N. Bronner, the only major change being the splitting of the savanna biome into arid and woodland savannas. The calculation of the biome specificity index in Table 5 is based on the modified biomes.

Maps of all species distributions were generated, and compared with the range maps in Skinner & Smithers (1990), De Graaff (1981), and regional texts, where available. This facilitated the identification of those records that fell outside of known ranges. These records were returned to the source museums for verification, and records that could not be verified were excluded from the analyses.

Hotspots

Four types of hotspots were identified: species richness, which refers to all the species considered here; endemic species richness, which refers to all species endemic to the greater South Africa; RDB species richness, which includes all those species listed in the Red Data Book (Smithers 1986); and hotspots of species that are both endemic and listed in the RDB. Hotspots were defined as the top 2% of all QDSs containing data.

Representative reserves

A heuristic reserve selection algorithm (Rebelo & Siegfried 1992) was applied to the species distribution database, in order to identify a set of reserves (QDSs) in which each species would be represented at least once. Here, the term 'representative reserve' is used rather than the more commonly used 'optimal reserve'. Underhill (1994) stated that heuristic reserve selection algorithms were suboptimal and suggested that linear programming techniques should be used to provide optimal solutions to reserve selection problems. However, Pressey, Possingham & Margules (in press) demonstrate that heuristic algorithms have practical advantages over linear programming and suboptimality is not necessarily undesirable for many real-world conservation problems.

Gap analysis

The hotspots of species richness, endemic species and RDB species were compared with existing reserves. This comparison was then repeated for representative reserves. This allowed the identification of areas that are important for the species under investigation, but are not protected. In addition, the species distribution data layer was compared with the existing reserves. This facilitated the identification of species that are currently not protected.

Biome specificity

Jacobs's modification of Ivlef's index (Jacobs 1974) was used to test the degree of specificity of each species within the modified biomes described previously. The value of the index ranges from −1, indicating avoidance, to +1, indicating endemism.

The index:

$$E_i = \frac{P_i - Q_i}{(P_i + Q_i) - 2P_iQ_i}$$

where $P_i = N_i / N_t$

$Q_i = A_i / A_t$

$N_i = \Sigma N_{i..j}$

$A_i = \Sigma A_{i..j}$

N_i is the abundance of the i^{th} species in habitat x (i.e. the number of records of species i in habitat x)

N_t is the total number of records for species i

A_i is the area of habitat x

A_t is the total area of all habitats.

Results

Hotspots

The areas of highest species richness are found in the south-western part of the country, within the fynbos and Succulent Karoo biomes (Figure 1). The region of convergence between the fynbos and Succulent Karoo is particularly important. The pattern of endemic species richness is very similar to that of total species richness, and the five endemic hotspots coincide with total species hotspots (thus no figure is presented). RDB richness is confined to the savanna biome, in Northern Transvaal and northern Kwazulu-Natal (Figure 2). Figure 3 shows the species richness of QDSs that contain species that are both endemic and have RDB status. The two QDSs with two species' records each are 3119BD and 3123CA, which both contain records for Grant's rock mouse (*Aethomys granti*) and the riverine rabbit (*Bunolagus monticularis*). The riverine rabbit, however, has not been seen in the area recently, and may no longer be present.

Table 2 and Figure 4 show the results of a comparison between species richness hotspots, RDB hotspots, and existing reserves. All of the five species richness hotspots fall within or near existing reserves, and all three of the RDB hotspots contain existing reserves.

Representative reserves

Ten QDSs were selected as representative reserves (RR) for the protection of all species under investigation (Figure 4). Five occur in the south-western part of the country, within the fynbos and Succulent Karoo biomes, with three in the north-eastern savannas, one in the alpine grasslands, and one in Kalahari Gemsbok National Park. All of these reserves fall within, or near, existing reserves (Table 2), with the exception of the most western reserve (QDS 2916BB), which is approximately 75 km south of Richtersveld National Park.

Figure 4 shows how the RR are situated in relation to hotspots. Only three of the ten RR overlap with hotspots, one is adjacent to a hotspot, and the remaining six are situated far from hotspots.

Species in reserves

Tables 3 and 4 show the possible occurrences of species within existing reserves. The occurrences are possible, as opposed to definite, owing to the QDS scale of the species distribution and the reserve databases. Although a species record and a reserve may fall in the same QDS, this does not guarantee that the species actually occurs in the reserve. For example, data in Table 3 indicate that the rat *Otomys sloggetti* may occur in 13 Natal Parks Board reserves, particularly the proclaimed components of the Natal Drakensberg Park. Rowe-Rowe & Meester (1982) observe that *O. slogetti* is confined to the alpine belt above the escarpment, and very little of this area falls within the reserve boundaries. The data shown in Tables 3 and 4 may thus provide an over-optimistic picture for some species.

It is evident from Table 3 that reserves managed by local authorities may contain 20 of the 25 target species, National Parks may contain 16 species, followed by reserves managed

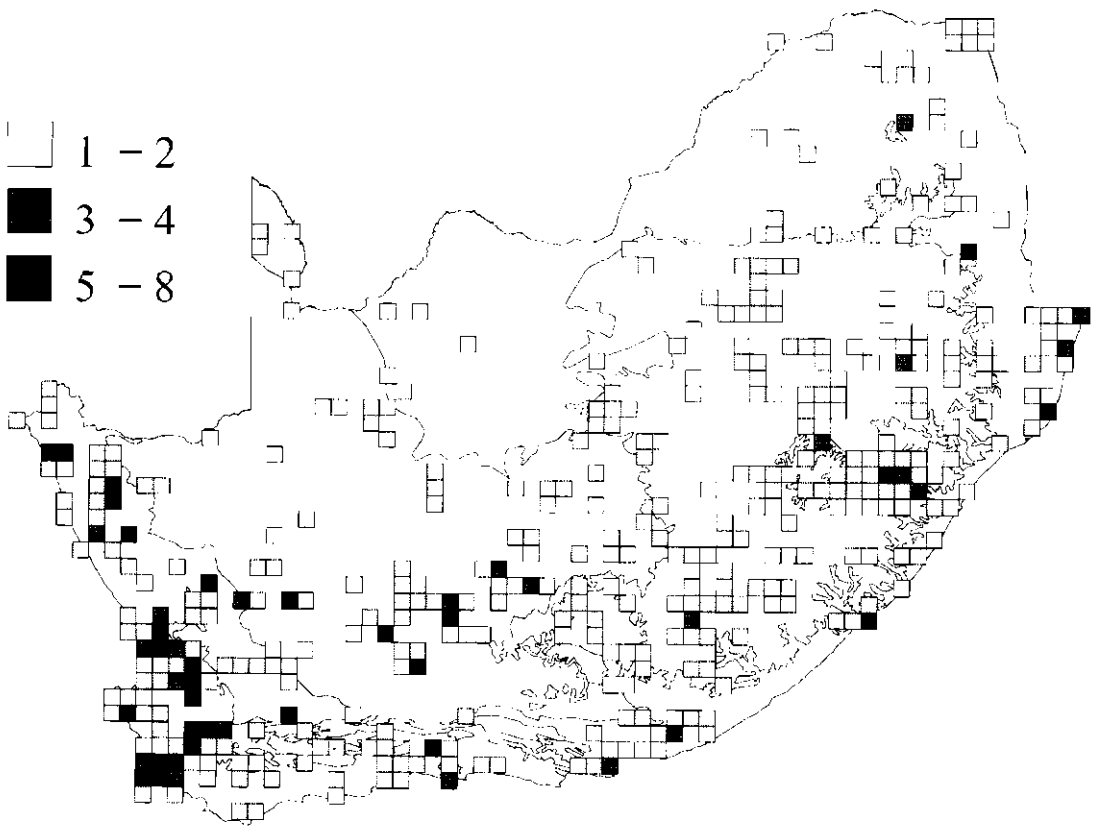

Figure 1 Patterns of species richness of endemic or threatened rodents, lagomorphs and macrosceledids in greater South Africa. Black squares are hotspots, and the key represents numbers of species.

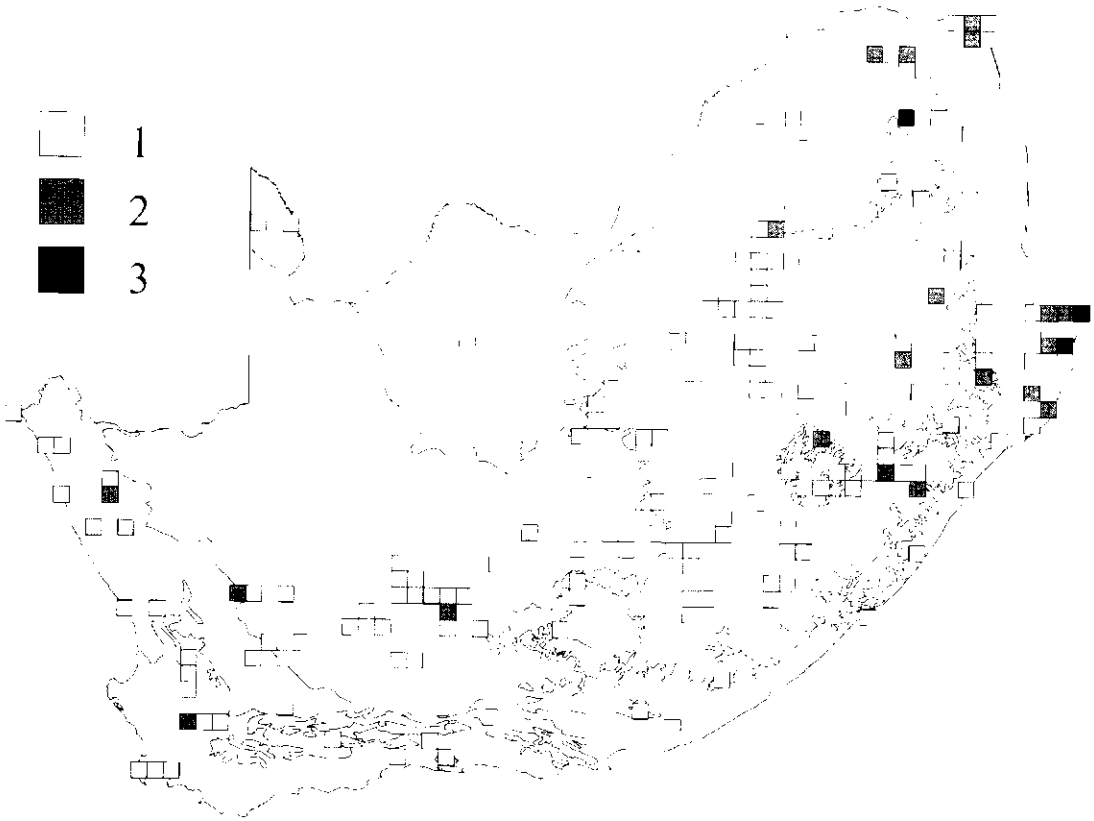

Figure 2 Patterns of species richness of rodents, lagomorphs and macroscelidids listed in the Red Data Book, in greater South Africa. Black squares are hotspots, and the key represents numbers of species.

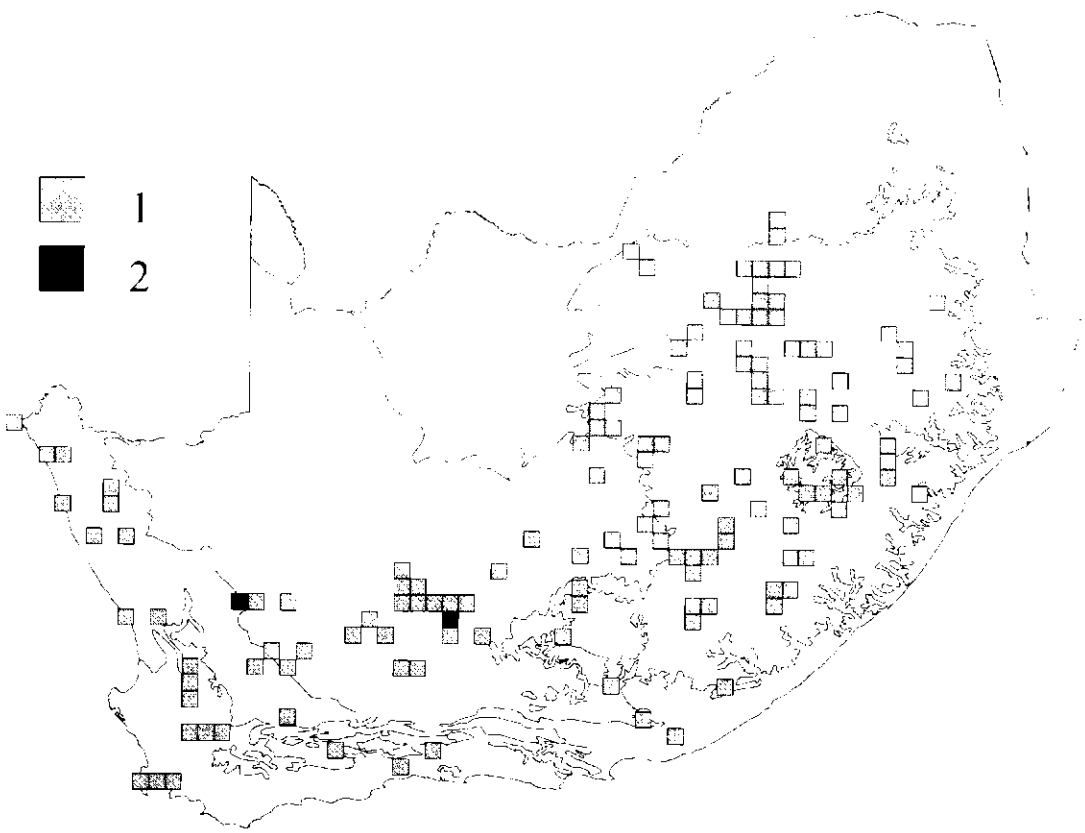

Figure 3 Distribution of rodents, lagomorphs and macroscelidids that are both endemic, and listed in the Red Data Book, in greater South Africa. The key represents numbers of species.

Table 2 Comparison of species richness hotspots (HS), Red Data Book hotspots (RDB HS), and representative reserves (RR), with existing reserves

HS	Existing reserve(s) within HS
3219AC	Cederberg Wilderness Area, *WCC, 64400 ha
3219CA	Cederberg Wilderness Area, WCC, 64400 ha
3319AC	Hawequas State Forest, WCC, 64634 ha
	Voëlvlei Tortoise Reserve, WCC, 130 ha
	Witzenberg State Forest, WCC, 1670 ha
3418AB	Cape of Good Hope Nature Reserve, LA, 7675 ha
	Table Mountain Nature Reserve, LA, 2904 ha
HS	**Nearest existing reserve(s) to HS**
3118DC	Cederberg Wilderness Area, WCC, 64400 ha (diagonally adjacent at 3218BB)
	Ramskop Nature Reserve, LA, 54 ha (diagonally adjacent at 3218BB)
RDB HS	**Existing reserve(s) within RDB HS**
2330CC	Fanie Botha Dam Nature Reserve, LA, 2850 ha
	Nmakgowa Forest (N. Transvaal), 1255 ha
	Wolkberg Wilderness Area, NTE, 22009 ha
2632DD	Maputaland Coastal Forest Reserve, KWA, 27185 ha
2732BC	Lake Sibaya Game Reserve, KWA, 940 ha
	Mabaso Tribal Game Reserve, KWA, 2337 ha
	Manguze Forest Reserve, KWA, 441 ha
	Maputaland Coastal Forest Reserve, KWA, 27185 ha
	St Lucia Marine Reserve, NAT, 44280 ha
RR	**Existing reserve(s) within RR**
2330CC	Fanie Botha Dam Nature Reserve, LA, 2850 ha
	Nmakgowa Forest (N. Transvaal), 1255 ha
	Wolkberg Wilderness Area, NTE, 22009 ha
2520CA	Kalahari Gemsbok National Park, NPB, 959103 ha
2632DD	Maputaland Coastal Forest Reserve, KWA, 27185 ha
2828DD	Royal Natal National Park, NAT, 8094 ha
	Stafford's Hill Bird Sanctuary, LA, 25 ha
3119BD	Akkerdam Nature Reserve, LA, 2301 ha
3219AC	Cederberg Wilderness Area, WCC, 64400 ha
RR	**Nearest existing reserve(s) to RR**
2530CA	Dingwell Military Area, NDF, 244 ha (adjacent at 2530AD)
	Nooitgedacht Dam Nature Reserve, ETC, 3370 ha (adjacent at 2530CC)
	Verloren Vallei Nature Reserve, ETC, 6022 ha (adjacent at 2530AC)
2916BB	Richtersveld National Park, NPB, 162445 ha (3 QDSs away at 2816BD & 2817CA)
2917DD	Goegap Nature Reserve, NCC, 14864 ha (adjacent at 2917DB)
3218DB	Cederberg Wilderness Area, WCC, 64400 ha (adjacent at 3219AC & 3219CA)
	Groot Winterhoek Wilderness Area, WCC, 19200 ha (adjacent at 3219CC)
	Kalabaskraal Nature Reserve, LA, 35 ha (adjacent at 3218DA)

* See footnote in Table 3 for explanation of reserve authority codes

by the National Defence Force, which may contain 15 species. Reserves of Western Cape Nature Conservation and Natal Parks Board, as well as the state forests, may contain between 13 and 10 species.

The total number of reserves in which a species could possibly occur is shown in the right hand column of Table 4 (this is the sum of all reserves for a particular species shown in Table 3). This number often exceeds the total number of records for a particular species, owing to the fact that the scale of a species record is a QDS, and any one QDS may contain several reserves.

Table 4 shows that all the records of four species may fall within existing reserves, however, two species have less than 20% of their records in reserves, *viz* the riverine rabbit (*Bunolagus monticularis*) and Brants' whistling rat (*Parotomys brantsii*). The Namaqua dune molerat (*Bathyergus janetta*) and the pygmy rock mouse (*Petromyscus collinus*) have no records in reserves. These four species all occur in the Succulent and Nama-Karoo. All other species have between 25–86% of their records in reserve-containing QDSs.

Biome specificity

Table 5 shows the results of the computation of the biome specificity index for each species within the six biomes defined by G.N. Bronner. The only species endemic to the fynbos is *Myomyscus verreauxii*, but *Bathyergus suillus, Elephantulus edwardii, Georychus capensis, Graphiurus ocularis, Otomys karoensis, Otomys larninatus* and *Tatera afra* have a strong preference for this biome ($E_i > 0{,}70$; Table 5).

Bathyergus janetta is endemic to the Succulent Karoo, and, although *Petromyscus collinus* is shown to be endemic to this biome (Table 5), this conclusion can not be based on the single data point available for this species (Table 4). *Otomys unisulcatus* and *Parotomys brantsii* show a strong preference for the Succulent Karoo ($E_i > 0{,}75$; Table 5). No species is endemic to the Nama-Karoo, but *Aethomys granti* and *Bunolagus monticularis* show a very strong preference for it ($E_i > 0{,}78$; Table 5). The grassland biome has no endemic species, but *Mystromys albicaudatus* and *Otomys sloggetti* show a strong preference for it ($E_i > 0{,}79$; Table 5). The arid savanna contains one endemic species, *Zelotomys woosnami*, and *Steatomys parvus* is endemic to the savanna woodlands. Three other species show a strong preference for savanna woodlands, *viz Cricetomys gambianus, Paraxerus palliatus* and *Petrodromus tetradactylus* ($E_i > 0{,}9$; Table 5).

Discussion

Spatial trends in endemism and RDB richness among the target taxa analysed here do not coincide. Endemism is concentrated in the fynbos, and to a lesser extent, the Karoo biomes of the south-west. Conversely, RDB richness is confined mainly to the savanna and adjacent grasslands along the Drakensberg escarpment in north-eastern South Africa, with hotspots in northern Kwazulu-Natal as well as the Tzaneen district of Northern Transvaal. Areas of high endemism in the fynbos and Karoo biomes are characterized by only intermediate RDB richness.

That endemism is concentrated in the south-western regions of South Africa has been noted also by range map studies on carnivores (Turpie & Crowe 1994), all endemic

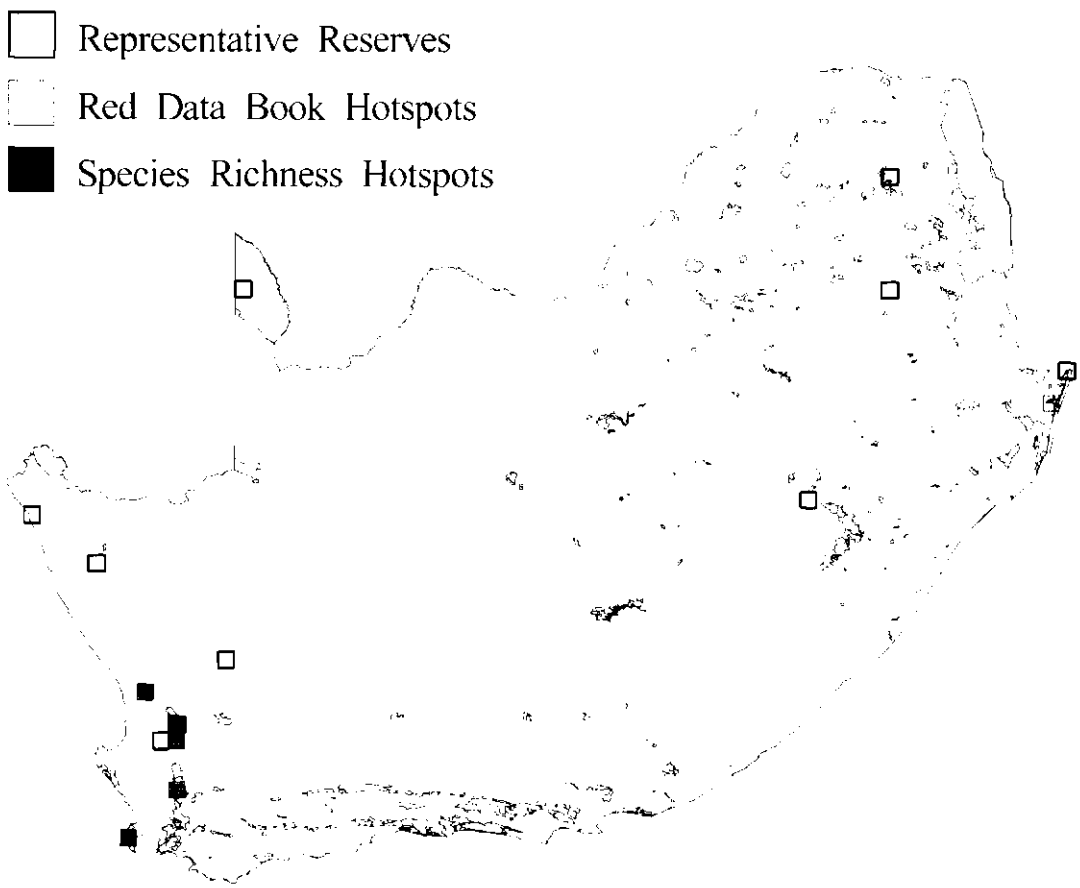

Figure 4 The coincidence of total species hotspots, Red Data Book species hotspots, and representative reserves.

mammals (Gelderblom & Bronner 1995), and South African mammals in general (Siegfried & Brown 1992). More accurate point-data analyses support these conclusions with respect to the Insectivora, Chiroptera, and Carnivora (Gelderblom *et al.* 1995). Current explanations for this phenomenon invoke the isolation of this region at the end of the African continent; the remarkable floristic diversity of the Cape Macchia floral kingdom (Cowling, Gibbs Russell, Hoffman & Hilton-Taylor 1989); and the existence of the Cape fold mountains, which may have facilitated speciation and acted as refugia during periods of climatic change (Coe & Skinner 1993; Sprugel 1991). Threatened-species hotspots coincide with areas of highest overall mammalian species richness in South Africa (Siegfried & Brown 1992). This, to a large degree, reflects the presence of tropical species whose ranges intrude only marginally into the northern savannas of South Africa. Termed the subtropical subtraction syndrome, this phenomenon is observed to a greater or lesser degree in all vertebrates, and is particularly evident in bats (Gelderblom *et al.* 1995). Examples of such species in the current study are *Petrodromus tetradactylus, Paraxerus palliatus* and *Cricetomys gambianus*, taxa that Smithers (1986) included in IUCN Vulnerable or Rare categories on account of their limited distributions in South Africa. Another four species (*Dasymys incomtus, Dendromus nyikae, Grammomys cometes* and *Steatomys parvus*) included in the Indeterminate category also have most of their range outside South Africa.

If only endemic species are considered, threatened species richness falls mainly outside of savanna, and the two hotspots coincide with areas of high endemism in the Nama-Karoo, and at the junction of the Nama- and Succulent Karoo biomes in the south-western parts of the country (Figure 3). The apparent disparity between patterns of endemism and RDB richness is, therefore, an artefact of a bias towards subtropical subtraction syndrome species in the Red Data Book. Indeed, of the 16 endemic species examined, only four are included in IUCN categories of threat (Smithers 1986). This is of concern, since South Africa is the most important centre of endemism in the southern African subregion (Gelderblom & Bronner 1995).

Priority areas for conservation

Hotspots are important areas for conservation, since they indicate areas where environmental conditions favour high species packing and richness (Lombard 1995a). In the present study, all five of the species richness and endemism hotspots in the south-western Cape fall in fynbos, and coincide with, or lie adjacent to, existing reserves. The extensive Cederberg Wilderness Area is an important reserve that includes two hotspots, and is adjacent to another one. Similarly, the three RDB hotspots fall in QDSs containing several reserves, and two (2632DD and 2732BC) fall in coastal forest and thornveld (Acocks 1988), protected by the Maputaland Coastal Forest Reserve, as well as several other reserves (Table 2). The other RDB hotspot at 2330CC includes two vegetation types (lowveld sour bushveld and NE mountain sourveld; Acocks 1988) that are protected by the large Wolkberg Wilderness Area (22009 ha), and two smaller reserves. In spatial

Table 3 The possible occurrence of species in existing reserves

	*Reserve authority																			
Species	CIS	ECC	ETC	KAN	KWA	LA	LNP	NAT	NBG	NCC	NDF	NPA	NHB	NTE	NWC	OFS	PWV	SF	SNT	TRA	WCC
Aethomys granti						3															1
Bathyergus janetta																					
Bathyergus suillus						21			2		7		3					5			27
Bunolagus monticularis													2								
Cricetomys gambianus						1					1			3				2			
Dasymys incomtus			3	3	3	6		26	2		2		5	8				9	1	1	4
Dendromus nyikae						1								2				1			
Elephantulus edwardii		1				11			1	1	2		5								28
Georychus capensis		2				27		1	3		4		4					12			22
Grammomys cometes						1		11			1		1					2			
Graphiurus ocularis						9				1	3		1								11
Myomyscus verreauxii						3							3					6			7
Mystromys albicaudatus	3	6				30	1	15	6		4	1	1		1	7	2	4			8
Otomys karoensis	1	7				14				1	4		2			1					13
Otomys laminatus			4	1	1	1		15			2							5	1	2	6
Otomys sloggetti						3	1	13					1								
Otomys unisulcatus	1	11				11				1	3		10		1	1					11
Paraxerus palliatus					6			9													
Parotomys brantsii						4				1	1		2								7
Petrodromus tetradactylus					7			10			1		3								
Petromyscus collinus																					
Pronolagus crassicaudatus			2	1	3	1		32	1		2	1				1		3	1	1	
Steatomys parvus					4			3													
Tatera afra						21			3		6		2					3			23
Zelotomys woosnami						1							2								

* CIS = Ciskei; DWA = Dept. Water Affairs & Forestry; ECC = Eastern Cape Nature Conservation; ETC = Eastern Transvaal Nature Conservation; KAN = KaNgwane; KWA = Kwazulu; LA = Local Authority; LNP = Lesotho National Parks; NAT = Natal Parks Board; NBG = National Botanical Garden; NCC = Northern Cape Nature Conservation; NDF National Defence Force; NPA = Natal Provincial Administration; NPB = National Parks Board; NTE =Northern Transvaal Environment & Tourism; NWC = North West Nature Conservation; OFS = OFS Nature Conservation; PWV = PWV Nature Conservation; SF = State Forest; SNT = Swaziland National Trust Commission; TRA = Transkei; WCC = Western Cape Nature Conservation. These codes refer to the authorities in charge of the reserves at the time the reserve database was compiled, ie. prior to the April 1994 elections and the resulting changes in authority names.

terms, therefore, hotspots of endemism and RDB richness among the taxa analysed appear to be adequately protected by the existing reserve system.

Conserving hotspots, however, does not ensure that all species, especially those that are rare or have restricted distributions, are adequately protected. Hotspots are often arbitrarily defined, and usually include only a percentage of the total species in an analysis (Lombard 1995b). For example, the distribution of the rare Namaqua dune molerat *B. janetta* does not coincide with any of the endemic or RDB hotspots identified here. To ensure that each species is protected at least once, it is necessary to consider not only hotspots, but also areas highlighted using other criteria, such as the iterative reserve selection algorithm we used to identify RR.

Of the four RR that occur in savanna and grasslands of north-eastern South Africa, two (2330CC and 2632DD) coincide with RDB hotspots, contain only non-endemic species and coincide with existing reserves, notably the Wolkberg Wildernesss Area and the Maputaland Coastal Forest Reserve. Another RR, at 2828DD, includes existing reserves that accommodate two endemic species, of which one (*Mystromys albicaudatus*) is listed in the Red Data Book. The configuration of the existing reserve system in north-eastern South Africa thus corresponds closely to an ideal arrangement that would maximize the protection of threatened taxa, especially species listed as a result of the subtropical subtraction syndrome. Siegfried & Brown (1992) reached a similar conclusion with reference to all mammalian species.

The other RR located in grassland of the Eastern Transvaal near Belfast (2530CA), however, contains two endemic species (*G. capensis* and *P. crassicaudatus*), and does not coincide with any existing reserves, although it is adjacent to two large reserves (Verloren Valei and Nooitgedacht Dam) that conserve the same highveld habitat (Acocks' veld type 57). Augmentation of the reserve system in this district is imperative to conserve the type locality of the molerat subspecies *G. c. yatesi*. We also recommend that management of the existing reserves in the Belfast district be adapted to ensure that the habitats of *G. c. yatesi* and *P. crassicaudatus* are optimally

Table 4 Possible overlap of species distributions with existing reserves

Species	No. of records	[a]No. of records in existing reserves	% of records in existing reserves	[b]Total No. of reserves
Aethomys granti	11	3	27	4
Bathyergus janetta	5	0	0	0
Bathyergus suillus	31	24	77	65
Bunolagus monticularis	17	2	12	2
Cricetomys gambianus	6	4	67	7
Dasymys incomtus	41	31	76	73
Dendromus nyikae	2	2	100	4
Elephantulus edwardii	39	24	62	49
Georychus capensis	31	23	74	75
Grammomys cometes	6	6	100	16
Graphiurus ocularis	15	10	67	25
Myomyscus verreauxii	6	6	100	19
Mystromys albicaudatus	92	38	41	89
Otomys karoensis	27	18	67	43
Otomys laminatus	19	16	84	38
Otomys sloggetti	40	10	25	18
Otomys unisulcatus	94	34	36	50
Paraxerus palliatus	7	6	86	15
Parotomys brantsii	58	11	19	15
Petrodromus tetradactylus	14	12	86	21
Petromyscus collinus	1	0	0	0
Pronolagus crassicaudatus	35	23	66	49
Steatomys parvus	4	3	75	7
Tatera afra	28	22	79	58
Zelotomys woosnami	3	3	100	3

[a] Number of records which fall in QDSs which contain existing reserves.

[b] Total number of reserves overlapping with the QDSs in [a].

sustained.

Of the six RR located in the drier western and south-western parts of South Africa, only one (3219AC) corresponds to an endemism hotspot, and another (3119BD) to a hotspot of endemic RDB richness. Three of the RR (2520CA, 3218DB and 3219AC) coincide with extensive reserves (>60000 ha). The RR located at 3119BD was chosen to protect two species: the riverine rabbit (*B. monticularis*) and Grant's rock mouse (*Aethomys granti.*). The small Akkerdam Nature Reserve (2301 ha) falls within this QDS, but the riverine rabbit is not present within the reserve, and its presence within the QDS needs confirmation. If the rabbit no longer occurs in this QDS, it can be replaced by the other endemic RDB hotspot, 3123CA, which also has locality data for both the riverine rabbit and Grant's rock mouse. As riverine rabbits have home ranges of 12–20 ha, and very specialized habitat requirements (Duthie 1989), it is imperative that any remaining suitable habitat within their present ranges be properly managed.

Neither of the other two western RR identified coincide with existing reserves. The RR at 2917DD, however, is adjacent to the Goegap Nature Reserve (Table 2), and contains three of the species examined here: *Graphiurus ocularis, Otomys unisulcatus* and *Petromyscus collinus*. It may also contain *Bathyergus janetta* (J. Jarvis, pers. comm). *Petromyscus collinus* occurs widely in Namibia, but is represented in Little Namaqualand by the endemic subspecies *P. c. barbouri*, which does not occur in any existing reserve. We thus recommend that intensive surveys be carried out at Goegap to establish if this taxon occurs there, and if so, that management be adapted to maximally protect its preferred lithophilic habitat. If this species does not occur at Goegap, the augmentation of this reserve with suitable areas in the QDS 2917DD must be considered a conservation priority. Perhaps the most urgent priority, in terms of supplementing the existing reserve system, is to conserve the RR located at 2916BB. There are currently no reserves in this QDS, which contains three endemic species (*Parotomys brantsii, Otomys unisulcatus,* and *Bathyergus janetta).* Two of these three endemics may be relatively well protected by the existing reserve system (Table 4), but the Namaqua molerat *B. janetta* is not (although it may occur in the Goegap Nature Reserve). De Graaff (1974) also concluded that *B. janetta* was not found in any of South Africa's National Parks. This species has a very restricted distribution limited to the northern Namaqualand coastal plain, and is not known to occur in the mountainous Richtersveld National Park, which is the nearest existing reserve. Establishment of a reserve on the Namaqualand coastal plain will ensure that this species is protected; and will also enhance the protection status of Brant's whistling rat (which has only 19% of existing records within reserves; Table 4), as well as two golden mole species not adequately protected at present (Gelderblom *et al.* 1995).

It must be noted that all RR should be surveyed for the presence of viable populations of the species thay are chosen to represent, before any decisions are made regarding reserve proclamation or management.

Priority taxa of conservation concern

Endemic species

Of the 16 endemic species considered, nine have at least 62% of their records falling in reserve-containing QDSs. These species are probably not at risk, providing their habitats are being suitably managed. Included in this group is the spectacled dormouse *Graphiurus ocularis*, which Smithers (1986) afforded rare status. Considering its wide distribution, common occurrence in reserves, and the lack of evidence showing any decline in numbers or range, we recommend that the status of this taxon be changed to Out of Danger.

Although the Cape molerat *Georychus capensis* may occur in as many as 75 reserves, most of these are located in the southern parts of the country where the nominotypical subspecies occurs. The subspecies *G. c. yatesi*, however, is restricted to the eastern Transvaal highveld, and occurs in only one municipal reserve (Ermelo district). As this taxon differs substantially from nominotypical *G. capensis* allozymically, and also in mtDNA sequence (Honeycutt, Edwards, Nelson & Nevo 1987; Nevo, Ben-Shlomo, Beiles, Jarvis & Hickman 1987), it must be considered a unique genotype worthy of at least Rare status.

A further five species (*Aethomys granti, Otomys sloggetti, O. unisulcatus, Mystromys albicaudatus* and *Parotomys*

Table 5 Biome specificity of species, as incidated by the index E_i (– 1 indicates avoidance, + 1 indicates endemism, see methods for details)

Biome	Species	No. of records	E_i
Fynbos	*Aethomys granti*	1	0,22
Fynbos	*Bathyergus suillus*	26	0,98
Fynbos	*Dasymys incomtus*	2	–0,11
Fynbos	*Elephantulus edwardii*	17	0,85
Fynbos	*Georychus capensis*	22	0,95
Fynbos	*Graphiurus ocularis*	8	0,89
Fynbos	*Myomyscus verreauxii*	6	1,00
Fynbos	*Mystromys albicaudatus*	3	–0,31
Fynbos	*Otomys karoensis*	13	0,87
Fynbos	*Otomys laminatus*	5	0,70
Fynbos	*Otomys unisulcatus*	12	0,39
Fynbos	*Parotomys brantsii*	3	–0,08
Fynbos	*Tatera afra*	22	0,97
Succulent Karoo	*Aethomys granti*	2	0,49
Succulent Karoo	*Bathyergus janetta*	5	1,00
Succulent Karoo	*Bathyergus suillus*	5	0,43
Succulent Karoo	*Bunolagus monticularis*	3	0,47
Succulent Karoo	*Elephantulus edwardii*	11	0,67
Succulent Karoo	*Georychus capensis*	2	–0,05
Succulent Karoo	*Graphiurus ocularis*	4	0,65
Succulent Karoo	*Mystromys albicaudatus*	2	–0,55
Succulent Karoo	*Otomys karoensis*	1	–0,33
Succulent Karoo	*Otomys unisulcatus*	33	0,75
Succulent Karoo	*Parotomys brantsii*	23	0,79
Succulent Karoo	*Petromyscus collinus*	1	1,00
Succulent Karoo	*Tatera afra*	6	0,56
Nama-Karoo	*Aethomys granti*	8	0,78
Nama-Karoo	*Bunolagus monticularis*	14	0,87
Nama-Karoo	*Elephantulus edwardii*	8	–0,13
Nama-Karoo	*Graphiurus ocularis*	3	–0,14
Nama-Karoo	*Mystromys albicaudatus*	9	–0,51
Nama-Karoo	*Otomys karoensis*	1	–0,79
Nama-Karoo	*Otomys sloggetti*	3	–0,61
Nama-Karoo	*Otomys unisulcatus*	36	0,30
Nama-Karoo	*Parotomys brantsii*	22	0,29
Nama-Karoo	*Pronolagus crassicaudatus*	1	–0,84
Grassland	*Cricetomys gambianus*	1	–0,33
Grassland	*Dasymys incomtus*	16	0,23
Grassland	*Dendromus nyikae*	1	0,43
Grassland	*Elephantulus edwardii*	2	–0,76
Grassland	*Georychus capensis*	4	–0,46
Grassland	*Grammomys cometes*	3	0,43
Grassland	*Mystromys albicaudatus*	71	0,79
Grassland	*Otomys karoensis*	10	0,19
Grassland	*Otomys laminatus*	9	0,39
Grassland	*Otomys sloggetti*	37	0,94
Grassland	*Otomys unisulcatus*	4	–0,80
Grassland	*Paraxerus palliatus*	1	–0,41
Grassland	*Parotomys brantsii*	1	–0,92
Grassland	*Petrodromus tetradactylus*	2	–0,41
Grassland	*Pronolagus crassicaudatus*	23	0,66
Arid savanna	*Mystromys albicaudatus*	2	–0,74
Arid savanna	*Otomys unisulcatus*	2	–0,74
Arid savanna	*Parotomys brantsii*	9	0,11
Arid savanna	*Zelotomys woosnami*	3	1,00
Savanna woodland	*Cricetomys gambianus*	5	0,90
Savanna woodland	*Dasymys incomtus*	23	0,66
Savanna woodland	*Dendromus nyikae*	1	0,59
Savanna woodland	*Elephantulus edwardii*	1	–0,82
Savanna woodland	*Georychus capensis*	3	–0,42
Savanna woodland	*Grammomys cometes*	3	0,59
Savanna woodland	*Mystromys albicaudatus*	5	–0,64
Savanna woodland	*Otomys karoensis*	2	–0,53
Savanna woodland	*Otomys laminatus*	5	0,16
Savanna woodland	*Otomys unisulcatus*	7	–0,53
Savanna woodland	*Paraxerus palliatu*	6	0,92
Savanna woodland	*Petrodromus tetradactylus*	12	0,92
Savanna woodland	*Pronolagus crassicaudatus*	11	0,28
Savanna woodland	*Steatomys parvus*	4	1,00

brantsii) may have < 50% of their records within reserves. Of these, however, only *Aethomys granti* occurs in less than 10 reserve-containing QDSs, and is worthy of special concern. This species has a limited distribution in the southern-central parts of South Africa, and shows a strong preference for Nama-Karoo (Table 5), which is under-represented in the existing reserve system (Siegfried & Brown 1992). It thus satisfies the criteria pertaining to the Rare RDB category (Smithers 1986: p. 6). The white-tailed mouse *Mystromys albicaudatus*, which Smithers (1986) included in the Vulnerable category on the grounds of habitat loss to agricultural development, may occur in 38 reserve-containing QDSs. This suggests that its preferred habitats, at least in the savanna region, are adequately conserved, and thus that this taxon deserves no more than Rare status.

The endemic molerat *Bathyergus janetta* occurs only on the Namaqualand coastal plain, an area not adequately protected by current reserves. Since its range is very restricted, and its habitat is being degraded by diamond mining operations, we recommend that its RDB status be elevated from Rare to Vulnerable.

The riverine rabbit *Bunolagus monticularis* may occur in only two reserves, and has specialized habitat requirements. Since its habitat outside reserves has been badly degraded, we concur with Smithers (1986) that it should be afforded Endangered status.

Finally, we recommend that the endemic subspecies *Petro-*

myscus collinus barbouri, which is not protected by the existing reserve system, but may be more widespread than current data indicate, should be afforded Rare status.

Non-endemics

Given that the nine non-endemic species examined here occur at the extremes of their ranges in South Africa, the RDB hotspots in the north-eastern savanna and grassland may not serve as areas for protecting them optimally. Centres of high species richness that occur near the centre of a vegetation type are more effective for conservation, since they are more likely to coincide with areas in which the ranges of many species overlap (Gelderblom *et al.* 1995).

Although the species is the most practical, measurable unit of biological diversity, biodiversity embraces many different levels, from genes to species to ecosystems (Hockey, Lombard & Siegfried 1994). Affording subtropical subtraction zone species RDB protection status might thus be justified if it can be demonstrated that local populations represent distinct subspecies characterized by unique genotypes or phenotypes not protected outside South Africa.

Unfortunately, the statuses of some local taxa are too dubious to assess whether they fulfil this criterion. This applies particularly to the dendromurines, which are in need of revision (De Graaff 1981). Thus, the local subspecies *Dendromus nyikae longicaudatus* and *Steatomys parvus tongensis* must remain in the Indeterminate category until their taxonomy has been clarified. Although *Steatomys parvus tongensis* ranges into southern Mozambique, the status of local populations, and the extent of suitable habitat remaining after the civil war that has ravaged this country's environment, need to be established before its protection status can be objectively assessed.

Of the murine non-endemics, *Grammomys cometes cometes* and *Dasymys incomtus incomtus* are widespread outside southern Africa. However, recent studies have shown that both display karyotypic variation, and may include a complex of distinct taxa (Gordon 1991; Taylor *et al.* 1994). Although both may live in close proximity to man, providing their preferred habitats (indigenous forests and wetlands, respectively) are not degraded, their provisional relegation to the Indeterminate category is warranted. The same treatment might be applied to *Dasymys incomtus capensis*. However, this subspecies is separated from *D. i. incomtus* by a wide hiatus in the eastern Cape, and has a restricted range in the south-western Cape. As it is known from only two, widely-separated populations, only one of which is protected (3319AC; Table 2); and is at risk from desiccation and drainage of wetlands (Davis 1962), we recommend that the status of *D. i. capensis* should be elevated from Indeterminate to Rare.

The giant rat is represented in South Africa by only one subspecies, *Cricetomys gambianus ansorgei*, which is restricted to forests and tropical woodlands in the northern Transvaal and northern Kwazulu-Natal. Although its range within South Africa is small, the local populations occur largely within proclaimed reserves, and the subspecies has a wide extralimital distribution extending to Angola and Kenya. Evidence suggests that their numbers may have increased in recent years, since giant rats flourish in orchards and vegetable gardens adjacent to their forest habitat. There is not, therefore, any reason to believe that *C. g. ansorgei* is at risk, or that local populations represent phenotypes or genotypes not protected elsewhere. We thus recommend that its Red Data Book status be changed to Out of Danger.

The status of the two *Paraxerus palliatus* subspecies in South Africa is also uncertain. These subspecies are represented by relict populations in forests that were once probably connected by a larger forest that extended northwards to join up with the habitat of *P. p. sponsus*. Whether or not these relict populations represent distinct phenotypes or genotypes is unclear, since too many subspecies are recognized (Meester, Rautenbach, Dippenaar & Baker 1986). It is unlikely that *P. p. tongensis* and *P. p. ornatus* in Zululand represent different species, as suggested by Viljoen (1980). Although the known demes are small and isolated, there is no evidence suggesting a decline in their numbers, and both occur in existing reserves that are managed specifically to protect their habitat. There is, therefore, no reason to believe that the causal factors that have led to the contraction of their range are still operating. Following the definition of Smithers (1986: p. 6), we recommend that their Red Data Book status be changed from Vulnerable to Rare.

The four-toed elephant shrew is represented by two subspecies in South Africa, *P. t. beirae* and *P. t. warreni*. These taxa have very restricted ranges within the country, which fall mainly within reserves. Both subspecies extend into southern Mozambique, but the possibility exists that populations there may have been severely impacted by disturbances associated with the protracted civil war in this region. Until such time as it is demonstrated that these subspecies are adequately protected in Mozambique, we recommend that their Red Data Book status be maintained as Rare.

Woosnam's desert rat *Zelotomys woosnami* is known in South Africa exclusively from reserves, particularly Kalahari Gemsbok National Park. This species does not, therefore, appear to be at risk, although it does have a very restricted distribution. We consequently recommend that its status be changed to Out of Danger.

Acknowledgments

We thank Ms D.R. Drinkrow for the data from the South African Museum, Dr P. Taylor for data from the Durban and Natal Museums, and J.P. Eksteen for data from the National Museum in Bloemfontein. Thanks are also due to Dr D. Schlitter (Carnegie Museum) and Dr M. Carleton (Smithsonian Institution) for providing their data. The biome data were supplied by the National Botanical Institute. We thank Dr T. Rebelo of the National Botanical Institute for the use of the reserve selection algorithm. The QDS reserve database was compiled by J. Hurford of the FitzPatrick Institute and updated by J. Harrison of the Avian Demography Unit, UCT. Financial support was provided by the Foundation for Research Development and the Department of Environmental Affairs and Tourism. This study was undertaken by D.N. Mugo in partial fulfillment of the requirements of the M.Sc. in Conservation Biology, FitzPatrick Institute, 1994. The Kenya Wildlife Service is thanked for allowing D.N. Mugo study leave and the World Bank is thanked for further financial support.

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