A comparative analysis of components incorporated in conservation priority assessments: a case study based on South African species of terrestrial mammals

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Assessing the risk of extinction to species forms an essential part of regional conservation initiatives that facilitate the allocation of limited resources for conservation. The present study conducted conservation priority assessments for 221 South African terrestrial mammal species using existing data sources. These data sources included regional IUCN Red List assessments, regional geographic distributions, relative endemism, taxonomic distinctiveness, relative body mass and human density. These components were in turn subjected to two quantitative conservation priority assessment techniques in an attempt to determine regional conservation priorities for South African terrestrial mammals. The top 22 mammal species (i.e. the top 10% of assessed species) identified by both regional conservation priority assessment techniques to be of conservation priority, consistently identified 13 South African terrestrial mammal species to be of high conservation priority. Seven of the 13 species were from the order Afrosoricida, two species from the order Eulipotyphla, with one species each from the orders Chiroptera, Lagomorpha, Pholidota, and Rodentia. More importantly, 12 of the 13 mammal species were also listed as threatened in the 2004 *Red Data Book of South African Mammals*. These results suggest that the two conservation priority assessment techniques used in the present study may represent a practical and quantitative method for determining regional conservation priorities, and include measures that represent *vulnerability, conservation value,* and *threat.*

Key words: regional conservation priorities, terrestrial mammals, South Africa, vulnerability, conservation value, threat assessment.

INTRODUCTION

Halting species extinctions requires the identification and conservation of taxa and their habitats. As resources for conservation are limited, not all taxa and habitats can be conserved. It is therefore, necessary to identify species that are at the most risk of extinction (Master 1991; Mace 1995). There are various conservation assessment or prioritization techniques that have been used to identify such species (Freitag & van Jaarsveld 1997).

Conservation assessment or prioritization systems vary greatly in terms of the factors that are deemed important to include in the assessment and also how these factors are scored, weighted, and/or incorporated (Mehlman *et al.* 2004). On the one hand, incorporating as much information as possible in the assessment of a taxon's conservation priority increases the likelihood of a more accurate threat classification (Harcourt & Parks 2003; Knapp *et al.* 2003). On the other hand, incorporating multiple factors may complicate the prioritization process (Harcourt & Parks 2003; Knapp *et al.* 2003). Therefore, reaching a consensus on the conservation priority of a species may vary between assessment systems (Harris *et al.* 2000).

While there are various approaches for comprehensive conservation priority assessments, the scarcity of all-inclusive information has led to a number of alternative assessment techniques for the conservation prioritization of taxa (Polasky *et al.* 2001; Rodrigues & Gaston 2002). This includes the Regional Priority Score (RPS) approach that has been used to identify conservation priorities in

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Africa in general, and the southern African subregion in particular (Freitag & van Jaarsveld 1997; Mills *et al.* 2001; Reyers 2004; Keith *et al.* 2005). The RPS technique attempts to evaluate the regional conservation importance of taxa by assigning an RPS score to each taxon with reference to a taxon's *extinction risk, vulnerability,* and *conservation value* (Freitag & van Jaarsveld 1997). In an attempt to improve the accuracy of the regional priority assessment, Mills *et al.* (2001) subsequently introduced a quantitative measure of potential human interaction into the RPS computation as a measure of threat.

Given the critical need for up-to-date conservation priority assessments for taxa (Dunn *et al.* 1999), the RPS approach was revised in the present study in order to gain an insight into the implementation of conservation prioritization for South African terrestrial mammals at a national level. In particular, the RPS technique was revised to include three key concepts, namely: i) *vulnerability* (i.e. a species' susceptibility to threat); ii) *conservation value* of a species (often also referred to as *irreplaceability*); and iii) the intensity of the *threat* itself (Pressey *et al.* 1993; Noss *et al.* 2002; Harcourt & Parks 2003). The availability of recently up-dated mammal data (Bronner *et al.* 2003; Friedmann & Daly 2004; Keith 2004; Skinner & Chimimba 2005; Wilson & Reeder 2005), provided an ideal opportunity to undertake such a regional conservation priority assessment for South African terrestrial mammal species.

Traditionally, conservation priority assessments have focused on predictors of extinction risk for species (i.e. predictors of species' susceptibility to threat). In most cases, measures such as population size and temporal trends (Master 1991; Freitag & van Jaarsveld 1997; Dunn *et al.* 1999; Burgman 2002; Mehlman *et al.* 2004), vulnerability, and rarity are used (Gaston 1994; Gaston & Blackburn 1997; Kunin & Gaston 1997; Purvis *et al.* 2000; Manne & Pimm 2001).

The IUCN Red List assessment (IUCN 1994, 2001) is probably the most widely used method to identify taxa at risk of extinction and is based on ecological knowledge such as a taxon's geographic distribution, population size, and life history (IUCN 2001; Lamoreux *et al.* 2003; Rodrigues *et al.* 2006). The IUCN Red List Threatened categories namely, Critically Endangered (CR), Endangered (EN), and Vulnerable (VU) provide a quantitative framework to classify taxa according to their risk of extinction. By definition, taxa in these categories are considered at risk of becoming extinct unless conservation actions are taken. Consequently, the IUCN Red List categories extracted from the Red Data Book of the mammals of South Africa (Friedmann & Daly 2004), form part of one of the RPS concepts, namely, vulnerability expressed as Relative Vulnerability (RV). RV provides an estimate of vulnerability to extinction and is based on the regional IUCN Red List assessments. An additional component incorporated as part of the vulnerability concept is Regional Occupancy (RO) that attempts to estimate the regional extent of a taxon (Freitag & van Jaarsveld 1997).

However, conservation prioritization based on risk of vulnerability and extinction as sole indicators of a taxon's conservation priority is considered to be inadequate (Masters 1991; Mehlman *et al.* 2004). The conservation value (i.e. irreplaceability) of a taxon is also considered to be of critical importance when assessing conservation priorities (Pressey *et al.* 1993; Noss *et al.* 2002). The conservation value component as used in the current study attempts to measure how a taxon contributes to the overall biodiversity within a specific region of interest (Pressey *et al.* 1993; Noss *et al.* 2002).

The conservation value usually relates to a taxon's geographic distribution and its taxonomic uniqueness, such as endemism and phylogenetic distinctiveness (Keith *et al.* 2005). Endemic taxa are often considered to be of national conservation importance, while threatened endemic taxa are considered to be of an even higher conservation priority (Rebelo & Tansley 1993). A taxon's level of endemism to a specific region usually relates to the taxon's dependence on the region for its survival (Freitag & van Jaarsveld 1997). Consequently, endemism, one of the measures of conservation value as used in the RPS method (Keith *et al.* 2005), attempts to estimate the proportion of the taxon's geographic distributional range within the area under consideration.

Similarly, taxa that are phylogenetically distinct are usually considered to be of a higher conservation value than their close genetic relatives (Vane-Wright *et al.* 1991; Heard & Mooers 2000; Polasky *et al.* 2001). Modern phylogenetic analyses have allowed the ranking of taxa according to their degrees of phylogenetic diversity, highlighting the evolutionary history and genetic diversity of unique taxa (Freitag & van Jaarsveld 1997; Virolainen *et al.* 1999; Rodrigues & Gaston 2002).

Conservation priority assessments should also reflect the nature and intensity of the threat itself

(Reed 1992; Harcourt & Parks 2003). Including additional explicit criteria of threat may improve the process of assessing conservation priorities. In this regard, the effects of various anthropogenic demographic parameters on different flora and fauna have been extensively investigated (Kerr & Currie 1995; Liu *et al.* 2003). Generally, these studies suggest a relationship between human-induced activities and continental rates of habitat and taxon disappearance (Ceballos & Ehrlich 2002; Harcourt & Parks 2003; Luck *et al.* 2003).

In their assessment of geographic priorities for terrestrial carnivores in Africa, Mills *et al.* (2001) incorporated body size as a potential estimator of human threat. The rationale behind its inclusion was that large-bodied taxa are more likely to be negatively influenced by high human population densities (Entwistle & Stephenson 2000; Mills *et al.* 2001; Harcourt & Parks 2003). However, despite numerous documented relationships between body size, ecological, and taxonomic variables (see Gaston & Kunin 1997; Gittleman 1985; Jones *et al.* 2003), the effects of body size and characteristics of threat remain unclear (Arita *et al.* 1990; Dobson & Yu 1993; Dobson *et al.* 1997). Similarly, estimates of human population density throughout a taxon's distributional range have also been considered to be a good indicator of human threat, particularly to mammals at a global scale (Ceballos & Ehrlich 2000; Harcourt & Parks 2003). Because of the relevance of both body size and human population density as measures closely correlated to human threat, they may have to be included in regional priority assessments to allow an insight into the required conservation actions.

Given the above background, the aim of our study was threefold: 1) to assess the conservation priority of South African terrestrial mammals at a national scale using the RPS method incorporating components of vulnerability, conservation value, and susceptibility to threat; 2) to evaluate the effect of incorporating measures of threats (body mass and an index of human density) in our conservation priority analysis; and 3) provide an insight into the relationships between RPS components that may be important in determining the conservation priority ranking of a taxon with reference to extinction risk, conservation value, as well as measures of threat. To this end, we investigate and evaluate the relationships between the following six RPS components that are incorporated in the current regional conservation priority assessment: 1) relative vulnerability (RV); 2) relative occupancy (RO); 3) relative endemism (RE); 4) relative taxonomic distinctiveness (RTD); and the introduction of 5) relative body mass (RBM); and 6) relative human density (RHD) (Freitag & van Jaarsveld 1997; Mills *et al.* 2001; Keith *et al.* 2005).

MATERIALS & METHODS

The present study follows the recently published taxonomic framework of extant southern African terrestrial mammals by Bronner *et al.* (2003) as echoed by Skinner & Chimimba (2005) as well the recent taxonomic treatment of Wilson & Reeder 2005. The taxon list, excluding subspecies and sub-populations, was matched with the South African Red Data Book assessments for mammals (Friedmann & Daly 2004) as well as the available geographic distribution records of Freitag & van Jaarsveld (1995) and Keith (2004). All geographic distribution data were reduced to presence data in the form of quarter-degree squares (QDS), each of which represent an area of approximately 25 km × 25 km (or 625 km^2) (Freitag & van Jaarsveld 1995).

RPS components

As outlined below, six different RPS components were used to compute regional conservation priority scores for each South African terrestrial mammal species. These included the four traditional components defined and described by Freitag & van Jaarsveld (1997), as well as two additional components. These components were grouped into three subsets of data that were considered to reflect vulnerability, conservation value, and threat, and were calculated as follows:

Estimates of vulnerability

a) *Relative Vulnerability* (*RV*) – (based on the methodology defined and described by Mills *et al.* (2001)). The Red Data Book assessments for the mammals of South Africa (Friedmann & Daly 2004) were used to score categories of vulnerability as: 1.00: Critically Endangered (CR); 0.80: Endangered (EN); 0.70: Vulnerable (VU); 0.56: Near-Threatened (NT); 0.42: Data Deficient (DD); and 0.00: Either Least Concern (LC), Not Evaluated (NE) or Not Listed.

b) *Relative Occupancy* (*RO*) – Based on a taxon's geographic distribution data derived from museum records at QDS (Freitag & van Jaarsveld 1995, 1997; Keith 2004) and computed as:

$$\mathrm{RO} = \frac{1}{\begin{array}{c}\text{no. of quarter degree squares (QDS)}\\ \text{occupied in South Africa}\end{array}}\,.$$

Estimates of conservation value

a) *Relative Endemism* (*RE*) – (modified from Freitag & van Jaarsveld (1997)). The extent of occurrence, obtained from various sources (Haltenorth & Diller 1980; Skinner & Smithers 1990; Mills & Hes 1997; Boitani *et al.* 1999; Kingdon 2001; Skinner & Chimimba 2005) was categorized as follows: 1.00: endemic to South Africa only; 0.8: 75–99% geographic distribution in South Africa; 0.6: 50–74% geographic distribution in South Africa; 0.4: 25–49% geographic distribution in South Africa; and 0.2: 0–24% geographic distribution in South Africa.

b) *Relative Taxonomic Distinctiveness* (*RTD*) – Following Freitag & van Jaarsveld (1997) and computed as follows:

$$\mathrm{TD} = \frac{1}{\sqrt{\text{no. of regionally represented families} \times \text{no. of genera} \times \text{no. of species}}}\,.$$

TD attempts to reflect the taxonomic rarity of a taxon where taxa with fewer extant relatives are considered to be of a higher conservation value.

Estimates of threat

a) *Relative Body Mass* (*RBM*) – Based on average body weights (in grams) for each taxon obtained from Dorst & Dandelot (1972), Haltenorth & Diller (1980), Skinner & Smithers (1990), and Skinner & Chimimba (2005) and was computed as:

$$\mathrm{RBM} = \frac{\log\text{(body mass (g) (BM))}}{\log(\mathrm{BM}_{\max})}\,.$$

Body mass was log transformed and divided by the transformed maximum body mass of a South African terrestrial mammal species ($\mathrm{BM}_{\max}$) represented by the African elephant's (*Loxodonta africana* (Blumenbach, 1797)) $\mathrm{BM}_{\max}$ value of 14.74. RBM was incorporated in our current assessment as a potential estimator of human conflict following Mills *et al.* (2001).

b) *Relative Human Density* (*RHD*) – Included as an estimate of potential human interaction or 'threat' based on the rationale that the higher the human density within a taxon's geographic distributional range, the higher the level of interaction and threat to the taxon. Average human population per QDS was derived from magisterial human population data (Central Statistical Service 1998). Human density values for each taxon were calculated as follows:

$$\text{Human Density (HD)} = \frac{\sum\left(\begin{array}{c}\text{Averaged HD across a}\\ \text{taxon's distribution (QDS)}\end{array}\right)}{\text{No. of QDS the species occur in}}\,.$$

To obtain a relative human density value for each taxon across its known geographic range (in QDS), relative human density (RDH) per km^2 was calculated and standardized by dividing the human density of a taxon by the taxon scoring the highest human density value ($\mathrm{HD}_{\max}$), i.e.

$$\mathrm{RHD} = \frac{\mathrm{HD}}{\mathrm{HD}_{\max}}\,.$$

The large-eared free-tailed bat (*Otomops martiensseni* Matschie, 1897) scored the highest HD value among all mammals considered, with most of its geographic distribution falling within the Durban (KwaZulu-Natal Province) metropolitan and surrounding areas, which has an average HD value of 256 people/km^2. This HD value was treated as an outlier value (2.12) and was converted to 1.00 and not used as the $\mathrm{HD}_{\max}$ value. Instead, the second highest HD value (178 people/km^2) obtained for the Juliana's golden mole (*Neamblysomus julianae* Meester, 1972) was used as the $\mathrm{HD}_{\max}$.

RPS computations

Two RPS techniques for determining the relative conservation importance of 221 South African terrestrial mammals were used in the present study. The first approach (RPS_{01}) followed the RPS technique proposed by Freitag & van Jaarsveld (1997) as applied to a priority assessment at a regional scale. This method employs four components, namely, relative vulnerability (RV), relative occupancy (RO), relative endemism (RE), and taxonomic distinctiveness (RTD), which are subsequently used to rank taxa in order of their conservation importance and is computed as follows:

$$\mathrm{RPS}_{01} = \frac{\mathrm{RV} + \mathrm{RO} + \mathrm{RE} + \mathrm{RTD}}{4}\,.$$

The second RPS technique (RPS_{02}) (Keith *et al.* 2005) used in the present study was essentially based on the RPS_{01} structure, but included relative body mass (RBM) and relative human density (RHD) components that were incorporated in our analyses as indices of potential 'human impact' and was calculated as follows:

$$\mathrm{RPS}_{02} = \frac{\mathrm{RV} + \mathrm{RO} + \mathrm{RE} + \mathrm{RTD} + \mathrm{RBM} + \mathrm{RHD}}{6}\,.$$

Taxa scoring the top 10% RPS scores were considered to be of the highest conservation priority for each of the two regional RPS techniques used.

Statistical analyses

Mann Whitney *U*, Kruskal-Wallis analysis of variance (ANOVA) by ranks, Wilcoxon matched pair tests and Spearman's *R* correlation analysis (Sokal & Rohlf 1981; Zar, 1996) were used to test for statistically significant differences and correlations between the six RPS components. All statistical analyses were undertaken using Microsoft® Excel 2000 and algorithms in Statistica version 6.0 (StatSoft Inc. 2001).

RESULTS & DISCUSSION

RPS Components

The present study represents an empirical attempt to investigate the relationships between variables that may be important in determining conservation priority ranking of a taxon with reference to extinction risk, conservation value, as well as measures of threat. A total of 221 South African terrestrial mammal species representing 16 orders and 38 families were used to assess six RPS components and their resultant regional priority scores from two RPS techniques (RPS_{01} & RPS_{02}).

Similar to the analysis by Freitag & van Jaarsveld (1997), the RPS components in the present study were positively skewed (Fig. 1a–f) suggesting that high priority taxa are identifiable at the regional level when using any of the different RPS components and the two RPS (RPS_{01} & RPS_{02}) techniques. All RPS components were statistically significantly different from each other (Kruskal-Wallis $H_{5,1326} = 584.76$; $P < 0.001$). The statistically significant differences between these components suggest the importance of each and hence their usefulness in the consequential RPS calculations.

The RV scores for 127 South African terrestrial mammal species yielded values of 0.00 (i.e. those categorized as of Least Concern (LC)) (Fig. 1a), while 34 species were included in the threatened categories (i.e. either Critically Endangered, Endangered, or Vulnerable). Similar to analyses by Gelderblom *et al.* (1995), the majority of taxa in the threatened categories in the present study were from the orders Afrosoricida and Chiroptera.

The RO component in our analysis ranged from 0.008 to 0.28 (Fig. 1b), with van Zyl's golden mole (*Cryptochloris zyli* Shortridge & Carter, 1938), only recorded from one locality (i.e. one QDS) in the Northern Cape Province (Skinner & Chimimba 2005) having the highest RO value. Similarly, Freitag & van Jaarsveld (1997) found low RO values for most taxa, while the few geographically restricted taxa had high RO values. Freitag & van Jaarsveld (1995) noted that this may be a reflection of the limited available distributional data typical of most South African mammals, particularly the small mammals.

RE values for most species were *c.* 0.20, indicating that 0–24% of their geographic distributional ranges are within South Africa (Fig. 1c). Twenty-six species were classified as endemic to South Africa (i.e. with an RE = 1.00), with eight of these species being identified as threatened with extinction.

RTD scores for South African terrestrial mammals ranged from 0.007 to 1.00, with a low median value (0.029) (Fig. 1d). Members of three monotypic orders, namely, the Proboscidea (the African elephant, *L. africana*), the Tubulidentata (the aardvark, *Orycteropus afer* (Pallas, 1766)), and the Pholidota (the ground pangolin, *Manis temminckii* Smuts, 1832) scored RTD values of 1.00. Members of the orders Rodentia and the Chiroptera had relatively low RTD scores due to their large number of families, genera and species represented in South Africa (also see Freitag & van Jaarsveld 1997). The inclusion of the RTD in our analysis allowed for inter-specific differences to be reflected in the degree of distinctiveness of the species (Keith *et al.* 2005).

The RBM component (Fig. 1e) resulted in evenly distributed body mass categories. Similar to the study by Entwistle & Stephenson (2000), the present study found more than 60% of South African terrestrial mammals to be 'small' rodents, bats, chrysochlorids, elephant-shrews and shrews, weighing less than 7 kg.

The median RHD in the present study was 0.25 (Fig. 1f), with values ranging from 0.005–1.00. However, some species such as the large-eared free-tailed bat (*O. martiensseni*), the peak-saddle horseshoe bat (*Rhinolophus blasii* Peters, 1867), and the Damara woolly bat, (*Kerivoula argentata* Tomes, 1861) had high RHD values. It is possible that the high RHD values for these species may be a reflection of observer and/or collection bias by largely sampling in large metropolitan areas and coastal regions of the Western and Eastern Cape, and eastern KwaZulu-Natal Provinces of South Africa. Although some bats are considered to be expanding their geographic ranges by exploiting artificial roosting sites, such as roofs of buildings, road bridges/culverts, and abandoned mines (Taylor 2000; Fenton *et al.* 2002), they may also be inherently subjected to eradication through increased human interaction and pest control measures (Gelderblom *et al.* 1995; Taylor 2000; Fenton *et al.* 2002).

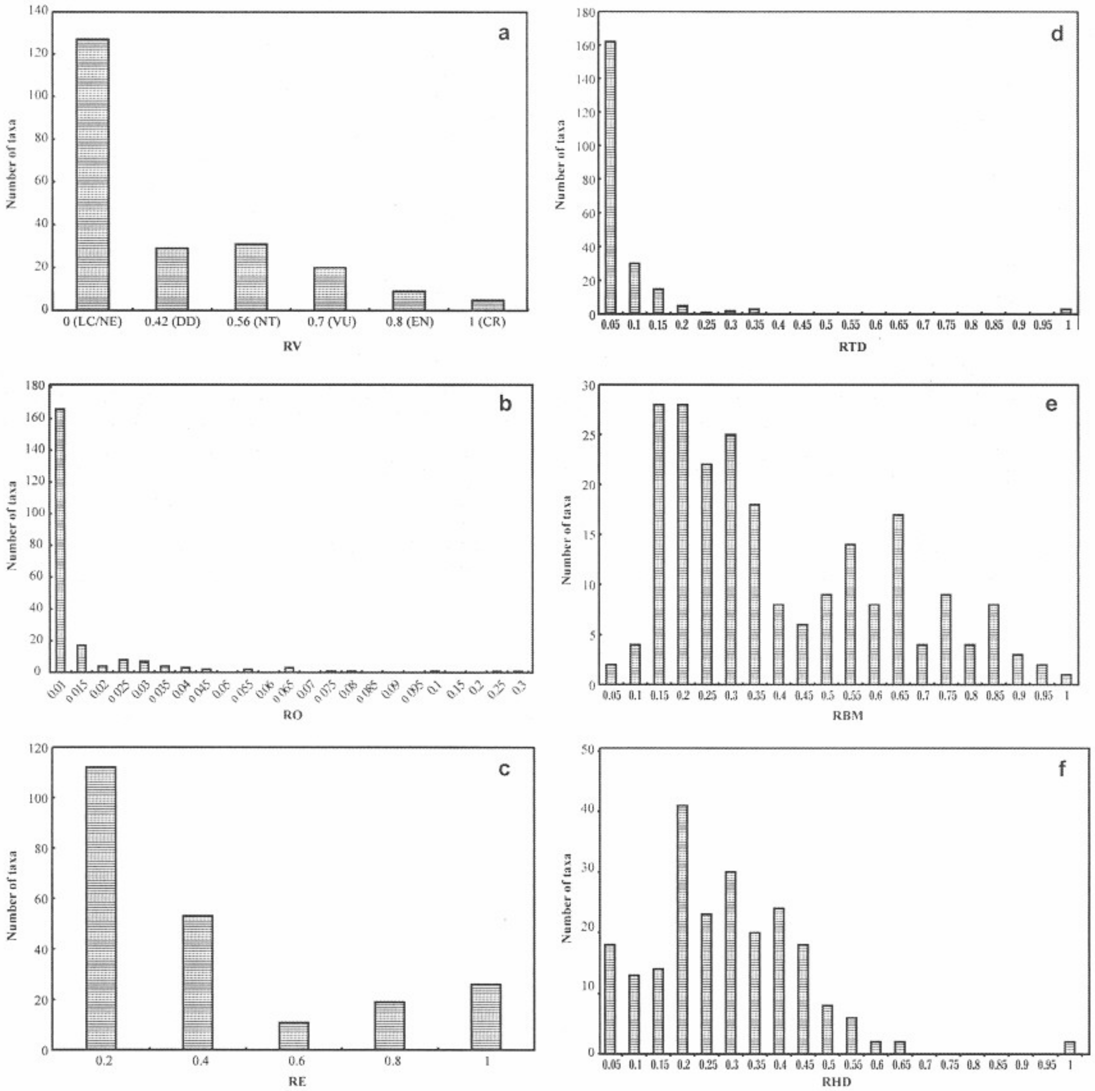

Fig. 1. The frequency distributions of component scores for (**a**) Relative Vulnerability (RV), (**b**) Relative Occupancy (RO), (**c**) Relative Endemism (RE), (**d**) Relative Taxonomic Distinctiveness (RTD), (**e**) Relative Body Mass (RBM), and (**f**) Relative Human Density (RHD) for 221 South African terrestrial mammals. See text for definitions of these components.

Pair-wise comparisons between the six RPS components indicated statistically significant correlations between some pairs of components (Table 1). The strongest positive correlation was found between RTD and RBM, as members from the speciose orders such as the Chiroptera (with low RTD values) can be regarded as small mammals (with low RBM values) and *vice versa* (Entwistle & Stephenson 2000). Similarly, a strong positive correlation was also shown to exist between RO and RV, while the strongest negative correlation was between RO and RBM (Table 1). It is possible that the negative relationship between RO and RBM may be due to the majority of large mammals such as large carnivores (see Gelderblom *et al.* 1995) being largely limited to the northern parts/borders of the country, often confined to protected areas and private game reserves. The five pair-wise comparisons between RPS components that were not statistically significantly correlated (Table 1), included pair-wise comparisons between: RE and RV; RTD and RV; RTD and RHD, as well as RHD and RBM.

Of particular relevance in our analysis is the

Table 1. *R*-values from Spearman's rank order correlation analyses of pairs of Regional Priority Score (RPS) components: RV = Relative Vulnerability; RO = Relative Occupancy; RTD = Relative Taxonomic Distinctiveness; RE = Relative Endemism; RBM = Relative Body Mass (RBM) and Relative Human Density (RHD). All values in bold indicate statistical significance at $P < 0.05$. Non-bold values denote non-statistically significant values.

	RV	RO	RE	RTD	RHD
RO	**0.50**	–			
RE	–0.01	0.04	–		
RTD	–0.04	**–0.15**	**–0.25**	–	
RHD	**0.19**	**0.14**	**–0.19**	–0.08	–
RBM	**–0.26**	**–0.32**	**–0.25**	**0.51**	–0.11

weak statistically significant negative correlation between RHD and RE. A study by Balmford *et al.* (2001) found that areas of high human population density (i.e. areas with high RHD values) also represent areas where the majority of taxa are geographically restricted (i.e. areas with high RE values). The available data show no major overlaps in geographic distributions for endemic South African terrestrial mammals, with various endemics occurring in areas of low human population density. Freitag & van Jaarsveld (1995) and Lennon *et al.* (2004) noted that regional patterns of species distributions are often dominated by the more widespread species that often conceal patterns in regional conservation analysis.

In addition, it is noted that our analysis may have been constrained by a lack of spatially explicit data for mammals, as it relied on geographic distributional data that were derived from museum records at quarter-degree grid square (QDS) resolution (Freitag & van Jaarsveld 1995, 1997). Such data may not be representative of a taxon's geographic distributions, as taxa may not be uniformly sampled and museum records may not be complete in coverage. It is possible that analyses based on QDS records may not be able to detect some fine-detail interactions between a taxon's geographic distribution and the environment (Rebelo & Tansley, 1993; Freitag & van Jaarsveld 1995; Lombard 1995). Such a constraint may limit the detection of associations between a taxon's geographic distribution and fine-scale factors such as topography, climate, and vegetation. Furthermore, the human density data were recorded at the municipal level, transformed to the QDS scale and subsequently weighted to density averages. The spatial as well as temporal differences between the data used may also contribute to the weaker relationships that were detected between the different components that were incorporated in the present study.

Nevertheless, despite the above outlined constraints, the respective components used in the present analysis and their relationship with each other allowed an insight into the contribution of each of the six RPS components. In general, most small mammals showed high RPS values, particularly with reference to endemism, vulnerability, and human density. Although the smaller mammals generally had low taxonomic distinctiveness and body mass values that coincided with the negative relationship between body mass and the other RPS components, these two variables were outweighed by the generally high values of the other RPS components used in the analysis.

RPS_{01} and RPS_{02} techniques

Although the RPS values derived from the two RPS techniques (RPS_{01} and RPS_{02}) used in the present investigation were strongly correlated (Spearman's $R_{220} = 0.79$, $P < 0.05$), there was considerable variation in RPS scores and rankings for South African terrestrial mammals. The *among*-technique RPS coefficients of variation (CV*) for the 22 top-ranked species (i.e. the top 10% of the assessed species) ranged between 1.38–34.40% (Table 2), with 10 species having CV*s of < 10% being among the 22 top-ranked species. This suggests that priority-setting techniques may be highly dependent on the components incorporated in an analysis and how they are scored, weighted, and integrated (Mehlman *et al.* 2004; Keith *et al.* 2005). The majority (>84.14%) of the 221 South African terrestrial mammals had RPS_{01} and RPS_{02} scores in the lower quartile of RPS scores. The distribution of RPS_{01} scores was heavily left-skewed (Fig. 2), while the distribution of the RPS_{02} scores was bell-shaped (Fig. 2), responding to either the incorporation of human density and/or body mass values or the interaction between variables.

The effect of the various RPS components on the derived RPS scores is evident in the conservation priority list of the top 10% of the 221 species assessed (i.e. the top 22 species). Apart from a few representatives of the orders Eulipotyphla and Chiroptera, members of the order Afrosoricida were dominant (45.45%) among the top 22 RPS_{01}-ranked South African terrestrial mammal species (Table 2; Fig. 3). Van Zyl's golden mole

Table 2. Regional Priority Score (RPS) rankings of the top 22 conservation priority South African terrestrial mammals (i.e. the top 10% of 221 species assessed) based on the two RPS techniques: RPS$_{01}$ (Freitag & van Jaarsveld 1997) and RPS$_{02}$ (highlighted in bold), as well as 34 Red Data Book of the mammals of South Africa (Friedmann & Daly 2004) not identified to be in the top 22 RPS conservation priority lists. Bold ranks of Rank$_{01}$ and Rank$_{02}$ indicate the top 22 taxa for each RPS technique. * = 13 species which were consistently identified, as conservation priority species by both RPS techniques. CV* = corrected coefficient of variation values calculated for the RPS scores. Abbreviations for Red Data Book assessments are outlined in Friedmann & Daly (2004).

Order	Taxon names	Red Data Book assessment	RPS$_{01}$	Rank$_{01}$	RPS$_{02}$	Rank$_{02}$	CV*
Chiroptera	***Cloeotis percivali* Thomas, 1901***	CR A2, a	0.38	**13**	0.33	**20**	9.40
Afrosoricida	***Cryptochloris wintoni* (Broom, 1907)***	CR B1ab(iii), B2ab(iii), D	0.56	**2**	0.38	**11**	31.58
Afrosoricida	***Cryptochloris zyli* Shortridge & Carter, 1938***	CR B1ab(iii)+2ab(iii); D	0.58	**1**	0.39	**9**	30.83
Afrosoricida	***Chrysospalax villosus* (A. Smith, 1833)***	CR C2a(i), D	0.51	**4**	0.48	**2**	5.40
Lagomorpha	***Bunolagus monticularis* (Thomas, 1903)***	CR C2a(i), E	0.54	**3**	0.44	**5**	15.43
Rodentia	***Mystromys albicaudatus* (A. Smith, 1834)***	EN A3c	0.41	**10**	0.37	**13**	6.71
Chiroptera	*Kerivoula argentata* Tomes, 1861	EN B1ab (iii) & 2ab (iii)	0.26	43	0.30	34	11.63
Afrosoricida	***Neamblysomus gunningi* (Broom, 1908)***	EN B1ab(i–iv) B2ab(i–iv)	0.47	**6**	0.45	**4**	4.32
Eulipotyphla	***Myosorex sclateri* Thomas & Schwann, 1905***	EN B1b(ii,iii), c(iv)+2b(ii,iii), c(iv)	0.47	**7**	0.41	**7**	10.52
Chiroptera	*Nycteris woodi* K. Andersen, 1914	EN B2 ab(v)	0.28	35	0.22	160	17.50
Chiroptera	*Rhinolophus swinnyi* Gough, 1908	EN C2a (i)	0.26	51	0.28	60	6.56
Ruminantia	***Ourebia ourebi* (Zimmermann, 1783)**	EN C2a(ii)	0.26	48	0.37	**14**	27.78
Macroscelidea	*Petrodromus tetradactylus* Peters, 1846	EN D	0.29	32	0.29	50	1.71
Carnivora	***Lycaon pictus* (Temminck, 1820)**	EN D	0.27	38	0.33	**21**	16.08
Primates	*Cercopithecus albogularis* (Sykes, 1831)	VU B1ab (ii,iii,iv)	0.25	60	0.32	23	21.04
Ruminantia	*Neotragus moschatus* (Von Dueben, 1846)	VU B1ab (ii,iii,iv,v)	0.24	66	0.29	47	14.15
Afrosoricida	*Calcochloris obtusirostris* (Peters, 1851)	VU B1ab(ii,iii),B2ab(ii,iii)	0.25	59	0.22	112	9.63
Hyracoidea	***Dendrohyrax arboreus* (A. Smith, 1827)**	VU B1ab(iii) + 2ab(iii), C1	0.31	26	0.39	**10**	17.01
Afrosoricida	***Neamblysomus julianae* Meester, 1972***	VU B2 ab (ii,iii)	0.44	**8**	0.50	**1**	9.95
Afrosoricida	***Chrysospalax trevelyani* (Günther, 1875)***	VU B2 ab (ii,iii, iv)	0.44	**9**	0.43	**6**	2.09
Eulipotyphla	***Crocidura maquassiensis* Roberts, 1946***	VU B2a,c(ii,iv)	0.33	**20**	0.34	**18**	1.38
Afrosoricida	***Eremitalpa granti* (Broom, 1907)**	VU B2ab (ii,iii,iv)	0.34	**19**	0.27	66	18.13
Rodentia	*Cricetomys gambianus* Waterhouse, 1840	VU C1	0.24	70	0.30	43	17.64
Pholidota	***Manis temminckii* Smuts, 1832***	VU C1	0.48	**5**	0.45	**3**	4.35
Ruminantia	***Hippotragus niger* (Harris, 1838)**	VU C1 + 2a(i)	0.23	75	0.36	**15**	34.40
Ruminantia	*Philantomba monticola* (Thunberg, 1789)	VU C1, C2a(i)	0.23	71	0.32	25	24.88
Carnivora	*Acinonyx jubatus* (Schreber, 1775)	VU D1	0.24	67	0.31	30	20.93
Ruminantia	*Hippotragus equinus* (Desmarest, 1804)	VU D1	0.23	74	0.32	27	24.99
Carnivora	*Panthera leo* (Linnaeus, 1758)	VU D1	0.24	69	0.32	24	24.33
Chiroptera	*Cistugo seabrai* Thomas, 1912	VU D2	0.23	72	0.18	157	18.99
Chiroptera	*Laephotis botswanae* Setzer, 1971	VU D2	0.24	68	0.20	138	15.16
Chiroptera	*Laephotis wintoni* Setzer, 1971	VU D2	0.29	33	0.26	73	8.45

Continued on p. 105

Table 2 (*continued*)

Order	Taxon names	Red Data Book assessment	RPS_{01}	$Rank_{01}$	RPS_{02}	$Rank_{02}$	CV*
Chiroptera	*Rhinolophus blasii* Peters, 1867	VU D2	0.23	76	0.27	63	13.59
Chiroptera	***Otomops martiensseni*** **(Matschie, 1897)**	VU D2	0.25	54	0.38	**12**	30.63
Chiroptera	***Cistugo lesueuri*** **(Roberts, 1919)**	NT	0.35	**18**	0.27	67	20.02
Eulipotyphla	***Myosorex longicaudatus*** **Meester & Dippenaar, 1978**	NT	0.40	**11**	0.31	32	21.25
Rodentia	***Bathyergus janetta*** **Thomas & Schwann, 1904**	NT	0.36	**16**	0.31	31	11.54
Chiroptera	***Rhinolophus capensis*** **Lichtenstein, 1823**	NT	0.39	**12**	0.32	29	17.81
Chiroptera	***Miniopterus fraterculus*** **Thomas & Schwann, 1906**	NT	0.35	**17**	0.32	26	6.45
Carnivora	***Parahyaena brunnea*** **(Thunberg, 1820)**	NT	0.27	39	0.33	**19**	17.30
Afrosoricida	***Chlorotalpa sclateri*** **(Broom, 1907)**	DD	0.32	**21**	0.27	65	11.79
Afrosoricida	***Chrysochloris asiatica*** **(Linnaeus, 1758)**	DD	0.36	**14**	0.29	46	17.73
Eulipotyphla	***Suncus lixus*** **(Thomas, 1898)**	DD	0.31	**22**	0.31	33	1.98
Eulipotyphla	***Myosorex cafer*** **(Sundevall, 1846)**	DD	0.31	25	0.33	**22**	3.71
Afrosoricida	***Amblysomus hottentotus*** **(A. Smith, 1829)***	DD	0.36	**15**	0.35	**17**	2.14
Tubulidentata	***Orycteropus afer*** **(Pallas, 1766)**	LC	0.30	31	0.35	**16**	13.16
Proboscidea	***Loxodonta africana*** **(Blumenbach, 1797)**	LC	0.30	30	0.40	**8**	22.59

(*C. zyli*) which scored the highest RPS_{01} score (0.58) was ranked 9th by the RPS_{02} technique (Table 2). Van Zyl's golden mole was initially only known from three specimens from one locality in the Northern Cape Province, South Africa (Skinner & Chimimba 2005). Information on this species, particularly with regard to its habitat, habits, and reproduction, is very limited. This species is threatened by the continued loss of habitat due to mining along the coast, and habitat alteration through human activities (Friedmann & Daly 2004).

The RPS_{02} technique also consistently ranked members from the order Afrosoricida to be of high conservation priority in South Africa, placing Juliana's golden mole (*N. julianae*) at the top of the conservation priority list for South Africa. This conservation prioritization is supported by the conservation priority assessment of Freitag & van Jaarsveld (1997), where Juliana's golden mole was given the highest priority score for mammals occurring in the former Transvaal Province. Similar to Van Zyl's golden mole, Juliana's golden mole is endemic to the Savanna biome, recorded only in three widely separated populations (Skinner & Chimimba 2005). Juliana's golden mole has specialized habitat requirements, with a Pretoria (Gauteng Province) population found mainly in sandy soils and rocky outcrops which are currently severely affected and threatened by intensive urbanization. The remaining two populations are also subjected to potential habitat alteration and degradation. In general, members of the order Afrosoricida are highly cryptic and rare with specialized habitat requirements, such that the available information is mainly derived from only a few specimens and few scattered localities (Skinner & Chimimba 2005).

The inclusion of body mass and human density in our analysis resulted in a number of species such as the African elephant, *L. africana* and the sable, *Hippotragus niger* (Harris, 1838) to be identified among the top 22 species considered to be of high conservation priority in South Africa. These species were not identified to be of high conservation priority in South Africa by the RPS_{01} technique which was only based on relative

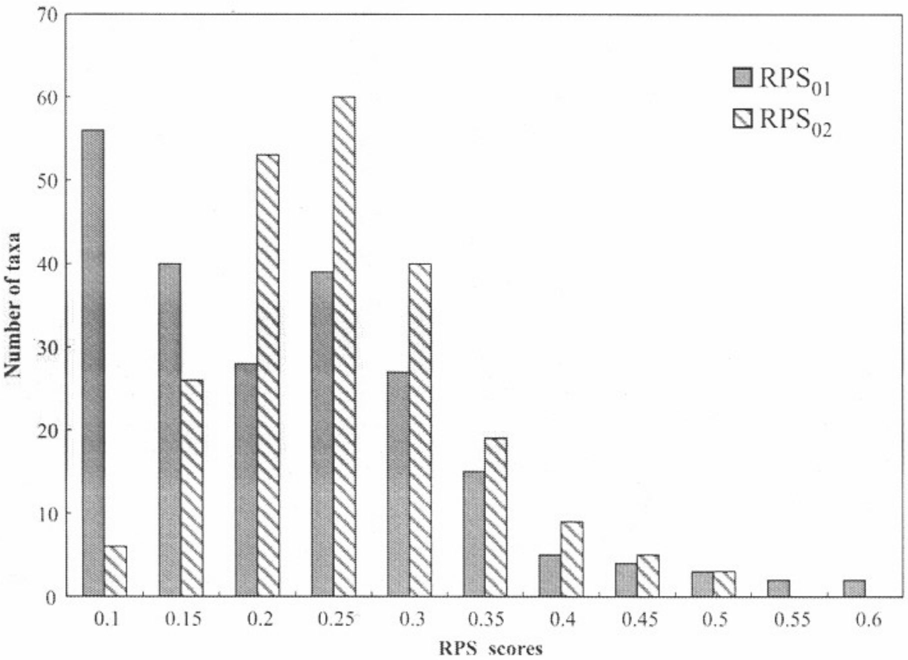

Fig. 2. Regional Priority Score (RPS) distributions for the two RPS techniques, RPS_{01} (Freitag & van Jaarsveld 1997) (grey shading) and RPS_{02} (Keith *et al.* 2005) (upward diagonally striped) for South African terrestrial mammals.

vulnerability (RV), relative occupancy (RO), relative endemism (RE), and relative taxonomic distinctiveness (RTD).

The Red Data Book of the mammals of South Africa (Friedmann & Daly 2004) provides regional IUCN Red List assessments derived from ecological knowledge such as geographic distribution, population size, and life history (IUCN 2001). Of the 57 South African mammal species identified by the Red Data Book of the mammals of South Africa to be either threatened or at the risk of extinction in the near future (Friedmann & Daly 2004), only 34 of these mammal species were included in the present analysis due to limited RPS assessment data such as the lack of geographic distributional data. All Critically Endangered (CR) and only five of the nine Endangered (EN) species and eight of the 20 Vulnerable (VU) species identified by Friedman & Daly (2004) were listed among the top 10% of the assessed species in the two RPS conservation priority lists. Chrysochlorids dominated both the top 22 conservation priority species lists identified by the RPS_{01} and RPS_{02} techniques, as well as the list of threatened species in the Red Data Book of the mammals of South Africa (see Table 2).

Various regional Data Deficient (DD) and Near-Threatened (NT) mammals (Friedman & Daly 2004) were, however, also included in priority lists based on either of the two RPS techniques. Of particular relevance is that the RPS_{02} technique identified two non-top-22 RPS_{01} Least Concern (LC) mammals, the African elephant (*L. africana*) and the aardvark (*O. afer*) to be of high conservation priority in South Africa. Although the African elephant has shown remarkable recovery in the southern African subregion, its populations are mainly contained and restricted to protected areas including private game farms (Skinner & Chimimba 2005). The increasing numbers within these protected areas require careful management of population sizes as elephants can have devastating effects on their habitats. In addition, throughout the remainder of the elephant's geographic distributional range, especially outside protected areas, elephants are facing increasing pressure from human-wildlife conflict and human encroachment (Hoare 1999; Skinner & Chimimba 2005). Similarly, the aardvark is exposed to various human-induced threats throughout its distributional range, and we require updated distributional and population data for more informed assessments and subsequent conservation actions (Friedmann & Daly 2004).

Of particular relevance in this study is that 13 species were consistently placed among the top 22 species that were identified to be of conservation

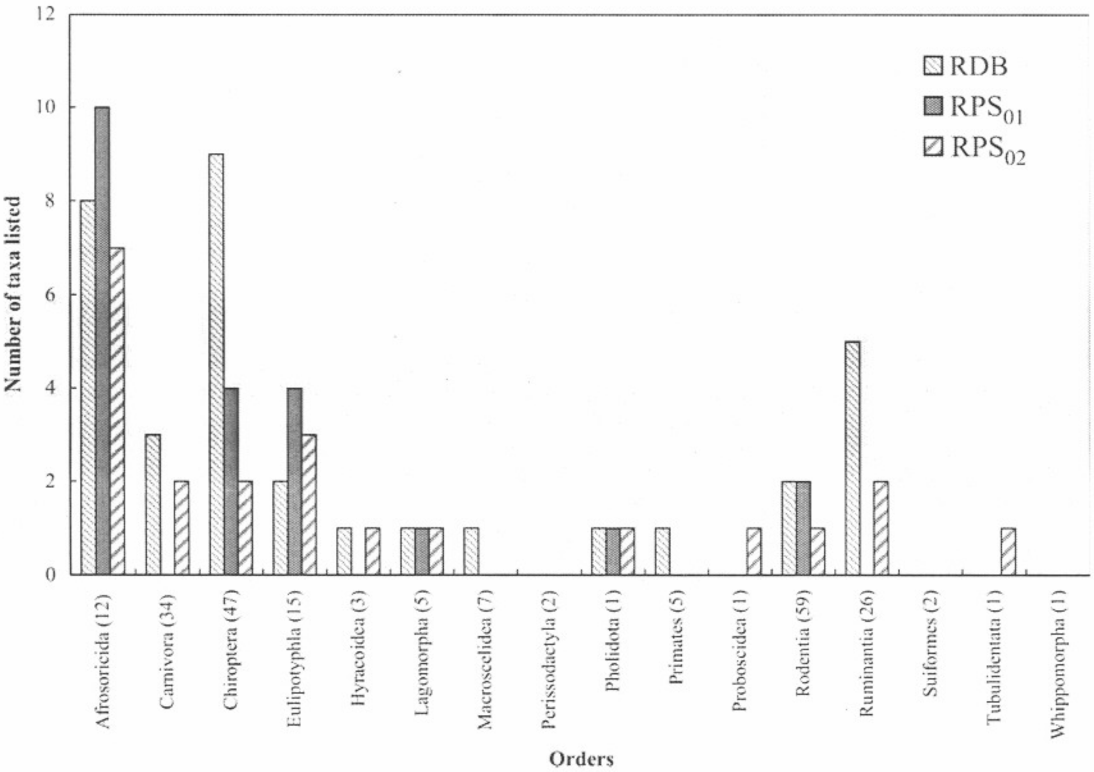

Fig. 3. Rankings per order of the 34 threatened Red Data Book of the mammals of South Africa included in the present study (Friedmann & Daly 2004) (upward diagonally striped), as well as the top 22 conservation priority South African terrestrial mammal species (i.e. the top 10% of 221 species assessed) based on two RPS techniques, RPS$_{01}$ (Freitag & van Jaarsveld 1997) (grey shading) and RPS$_{02}$ (Keith *et al.* 2005) (downward diagonally striped). Numbers in brackets represent the number of taxa per order as used in the present study.

priority in South Africa by both the RPS$_{01}$ and RPS$_{02}$ techniques (Table 2). Seven of these species were from the order Afrosoricida, two were from the order Eulipotyphla, and one species each from the orders Chiroptera, Lagomorpha, Pholidota, and Rodentia. Twelve of these 13 species were also identified as threatened by the Red Data Book of South African mammals (Friedmann & Daly 2004). However, the 13 species are not considered to be of high conservation priority based solely on their high susceptibility to extinction risk by the regional IUCN Red List assessment. Their RPS rankings in the present study were strengthened by the additional components that were incorporated and analysed such as conservation value and exposure to threat. The 13th RPS-ranked species in the present study, the Hottentot's golden mole, *Amblysomus hottentotus* (A. Smith, 1829) scored high in both RPS$_{01}$ and RPS$_{02}$ listings as it is an endemic taxon and had a relatively high RHD score, irrespective of its low RV value (i.e. being Data Deficient (DD) (*sensu* Red Data Book of the mammals of South Africa (Friedmann & Daly 2004)). This suggests that species with limited data can still be accorded a conservation priority while using alternative data sources as used in the RPS techniques in the present study (Harcourt & Parks 2003).

Ginsberg (2001) noted that conservation priority-setting exercises rarely assign carnivores the conservation priorities they deserve. In the present study, only the RPS$_{02}$ technique identified two carnivore species, the African wild dog, *Lycaon pictus* (Temminck, 1820) (EN D) and the brown hyaena, *Parahyaena brunnea* (Thunberg, 1820) (NT) as of high conservation priority in South Africa. Mills *et al.* (2001) identified the wild dog and the brown hyaena to be of the second and sixth highest conservation priority in Africa, respectively. In the present study, the cheetah, *Acinonyx jubatus* (Schreber, 1775) (VU D1) was ranked 67th by the RPS$_{01}$ technique and 30th by the RPS$_{02}$ technique.

The lion, *Panthera leo* (Linnaeus, 1758) (VU D1) was ranked 69th by the RPS_{01} technique and 24th by the RPS_{02} technique.

The low RPS and conservation priorities for these carnivores may be due to the majority of large carnivores mainly occurring in protected areas as well as the northern parts/borders of South Africa (Gelderblom *et al.* 1995) which led to most carnivores scoring low RO, RE & RHD values. This may have resulted in the low overall regional conservation priority rankings for carnivores in South Africa in the present conservation priority assessment. Mills *et al.* (2001) also found most carnivores to generally have low RE, RO, and RTD scores. However, irrespective of the overall low conservation priority of carnivores derived from the current analysis, the smaller less charismatic carnivores require more conservation focus and its associated funding. Nevertheless, the large charismatic carnivores still attract disproportionately greater research attention and more conservation funding (Amori & Gippoliti 2000; Polishchuk 2002), than for example, the smaller lesser known carnivores as well as the higher RPS-ranked chrysochlorids, shrews, bats and rodents.

The assessment of extinction risk, threat, and the setting of conservation priorities are all related processes but can also be treated as different processes. Despite published IUCN Red Lists being regularly available for a wide range of taxa (mostly at a global level), these categories do not reflect a conservation priority or provide a conservation status of a taxon (as it is often incorrectly referred to) (Gärdenfors *et al.* 1999; Ginsberg 1999, 2001; Harcourt & Parks 2003; Rodrigues *et al.* 2006; Tobias & Seddon 2002). The IUCN Red List categories and criteria reflect the extinction risk of a taxon (IUCN 2001), and offer an invaluable source of information, and should, therefore, precede the setting of conservation priorities (IUCN 2001). The availability of the recent Red Data Book assessments (Friedman & Daly 2004) and the availability of up-dated regional mammal data (Bronner *et al.* 2003; Skinner & Chimimba 2005) allowed for the next logical step of assessing conservation priorities for the mammals of South Africa. The results of the present study support that either of the two RPS techniques may offer a useful conservation priority assessment tool, and provided an insight into which species could be considered to be of conservation priority. We believe the RPS approaches towards attaining relevant regional conservation priorities that should not only rely on measures that assess vulnerability. The RPS approach is also considered to be capable in providing relevant conservation priorities when minimal data are available data (Keith *et al.* 2005).

We do not presume that the RPS components used in the present study are necessarily optimal, but rather serve to address the questions posed in our investigation. The RPS techniques as used in our study attempt to quantify the susceptibility of taxa to extinction (vulnerability), its conservation value, such as endemism and taxonomic distinctiveness, within a specific area such as South Africa (Vane Wright *et al.* 1991; Pressey *et al.* 1993). Although it was not always possible to include explicit measures of regional threat specific to each taxon, the use of body mass and human densities as surrogates for threat in the present study highlights their importance in determining conservation prioritization outcomes.

In conclusion, additional information, conservation focus and action is urgently required for the smaller, less charismatic, and lesser-known carnivores, chrysochlorids, shrews, elephant-shrews, rodents, and bats in South Africa that were identified to be of regional conservation priority in the current study. Internationally, chrysochlorids, shrews, elephant-shrews, bats, and rodents have been reported to be under-represented in conservation policies with several taxa from these orders having already become extinct (Ceballos & Brown 1995; Yu & Dobson 2000). Nevertheless, the larger mammals within the orders Carnivora, Perissodactyla, Proboscidea and Ruminantia still receive disproportionately greater research attention and more conservation funding (Amori & Gippoliti 2000; Polishchuk 2002), potentially to the disadvantage of smaller species. Our analyses suggest that the smaller, less charismatic species that were consistently identified to be of high conservation priority in South Africa require urgent attention.

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