Conservation assessment of South African mammals

by

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Abstract

Clearly established conservation priorities are urgently required for taxa and ecosystems in critical need of conservation. This helps to identify and document taxa most in need of conservation attention, and provides an index of the state of degeneration of biodiversity. Including as much relevant information as possible in a prioritisation assessment will deliver the most accurate classification, yet these variables should not overly complicate the prioritisation process. Conservation assessments depend not just on the taxon's susceptibility to threat (i.e. risk of extinction, or Red List assessments), but also the conservation value, irreplaceability and nature and intensity of the threats. Research into the value and applicability of conservation prioritisation tools at a regional scale, allowed for the assessment of the extinction risk as well as subsequent priority ranking of South African mammals.

At the outset research was directed towards investigating South African mammals in accordance with their respective regional and global World Conservation Union (IUCN) Red List and Red Data Book assessments. The regional Red List assessment drastically improved local knowledge of the current extinction risk of various mammals, and identified 57 marine and terrestrial mammals to be highly threatened.

Up to date regional extinction risk assessments, allowed for the investigation of whether a human activity threat index derived from six human activity variables across South Africa could be used to highlight mammals threatened with extinction while also being exposed to high human activity. Evidence indicated various threatened and lower risk mammals were exposed to high human activity throughout their range, pointing to high potential threat and future increase in extinction risk.

For relevant prioritisation to take place, components of vulnerability (IUCN Red List assessments, and occupancy data), irreplaceability (endemism and taxonomic distinctiveness), and threat measures (body mass and human density in a taxa distributional range) was introduced into relational priority assessment which allowed for a simplified approach in determining conservation priorities for taxa under various region-specific conditions. The use of different sets of information clearly affected the priority rankings.

South African Chiroptera and Carnivora was used as a case study to addresses whether a simple measure of taxonomic diversity can be used as a proxy for different measures of phylogenetic diversity in determining regional conservation priority of taxa, when such information is limited. Evidence does suggest that the utilisation of the simple taxonomic diversity measure may provide the appropriate information on evolutionary diversity.

Two theoretical concepts were proposed to address some potential shortcomings in the conservation prioritisation arena. The Orange List method offers a system to identify "species [or taxa] of high national importance or of high conservation value" (South African National Environmental Management: Biodiversity Act 2004). In turn the Green Data List essentially represents a radical shift in the traditional approach to the management of both threatened and invasive taxa.

Throughout this thesis, evidence do point to smaller mammals being of high conservation concern in South Africa, with the members from the Orders Rodentia, Chiroptera and Insectivora being constantly identified as high conservation priority. Apart from contributing to our current understanding of the conservation importance/priority of South Africa mammals, this current thesis has resulted in a robust understanding of various assessment techniques.

Key words: Regional conservation prioritisation, IUCN Red List, Red Data Book, vulnerability, irreplaceability, threat assessments, taxonomic distinctiveness, phylogenetic diversity, Orange List, Green Data List

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Disclaimer

This thesis consists of a series of chapters that have been prepared for submission to, or publication in, a range of scientific journals. As a result styles may vary between chapters in the thesis and overlap may occur to secure publication.

In accordance with the 2001 IUCN Red List categories and criteria, the term "taxon" (pl. taxa) is used in this study to represent species, sub-species or sub-populations.

CHAPTER 1

General Introduction

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General Introduction

Identifying and targeting species and ecosystems in critical need of conservation action requires clearly established priorities, particularly in the context of increasing financial and logistical constraints (Master 1991; Mace 1995; Stein et al. 1995; Dunn et al. 1999). Prioritisation of conservation action for species and ecosystems has become standard practise in the field of conservation biology (Mehlman et al. 2004). In many cases, the prioritisation process serves two basic purposes. First, it helps to identify and document species most in need of conservation attention, and second, it provides an index of the state of degradation of biodiversity. Although related, the identification of species conservation priorities and the assessment of species extinction risk (Fitter & Fitter 1987) are two different and confounded processes (Rodríquez & Rojas-Suárez 1996). The category of threat simply provides an assessment of the extinction risk under certain conditions, whereas a system for assessing priorities for action will include numerous other conservation action-related factors such as costs, logistics, chances of success, and other biological characteristics (IUCN 2003a). However, conservation prioritisation has mainly focused on taxa that are rare and threatened with extinction (Master 1991; Freitag & van Jaarsveld 1997; Dunn et al. 1999).

Conservationists argue that the earth is embarking on a mass extinction phase similar in magnitude to those that occurred during the Permian and Cretaceous Periods (Smith et al. 1993). Approximately 680 vertebrates have been recorded as extinct since the early 1600s (Smith et al. 1993; Magin et al. 1994; IUCN 2003a), while approximately 3500 (6%) of extant vertebrates are listed as threatened (IUCN 2003a). Of these vertebrates, mammals are considered to represent a highly threatened Class with approximately 23.6% deemed threatened with extinction in the near future (IUCN 2003a). Currently, 24 of the 26 mammalian Orders of the world include threatened taxa. The highest proportions of globally threatened mammals are in the Orders Proboscidea (100%), Perrisodactyla (70.6%), Hyracoidea (42.9%), Primates (38.6%), and Insectivora (35.0%) (IUCN 2003a). While these numbers are indeed alarming, there are still many other Orders of vertebrates, invertebrates, and plants that have a much higher proportion of threatened taxa, such as the Order Hymenoptera (94%) of the Class Insecta (IUCN 2003a).

Red Data Books and Red Lists

The growth of public awareness in the problem of the decline and possible extinction of taxa originated in the early 1960s with the development of The World Conservation Union (IUCN) Red Data Book concept pioneered by Sir Peter Scott (Magin et al. 1994). The first ever threatened categories used in the Red Data Book and Lists were published in 1966 and assessed mammals on a global basis (Smithers 1986; Gärdenfors 2001). Since then the Red List classification scheme has been universally accepted to the extent that it has been applied across a wide taxonomic spectrum (Colyvan et al. 1999).

However the pre - 1994 categories were qualitative, subjective, and simple with regard to data requirements (Todd & Burgman 1998). The 1994 IUCN Red List categories and criteria (version 2.3) marked a shift from the qualitative Red Data Book categories to a more quantitative Red List approach developed by the IUCN (IUCN 1994, 2001). More recently, the Red List categories and criteria were reviewed and some modifications were introduced (IUCN 2001). The Red List approach assesses each taxon's threat status by using one to eight threat categories determined by a review of its conservation status throughout the taxon's distributional range (Figure 1). Three of these categories include Critically Endangered (CR), Endangered (EN), and Vulnerable (VU), which are collectively known as the Threatened category. These categories broadly reflect the different levels of the risk of extinction (IUCN 1994) based on a variety of criteria. The quantitative risk assessment criteria are based on five sets of decision rules comprising one or more attributes connected by logical "*and/or*" statements (Keith et al. 2000). The attributes addressed include: 1) rates of decline (rule A); 2) distribution/range size in conjunction with fragmentation, meta-population structure, continuing decline, and extreme fluctuations (rule B); 3) population size in conjunction with continuing decline (rule C); 4) population size only (rule D); and 5) probability of extinction (rule E) (IUCN 2001).

Regional Assessments

The 1994 and 2001 IUCN Red List categories and their definitions were primarily developed for global scale assessments. However, regional and local conservation agencies require regional threat assessments in order to provide baseline data to allow comprehensive decisions to be made with regard to relevant conservation and management programmes. Consequently, a protocol has recently been

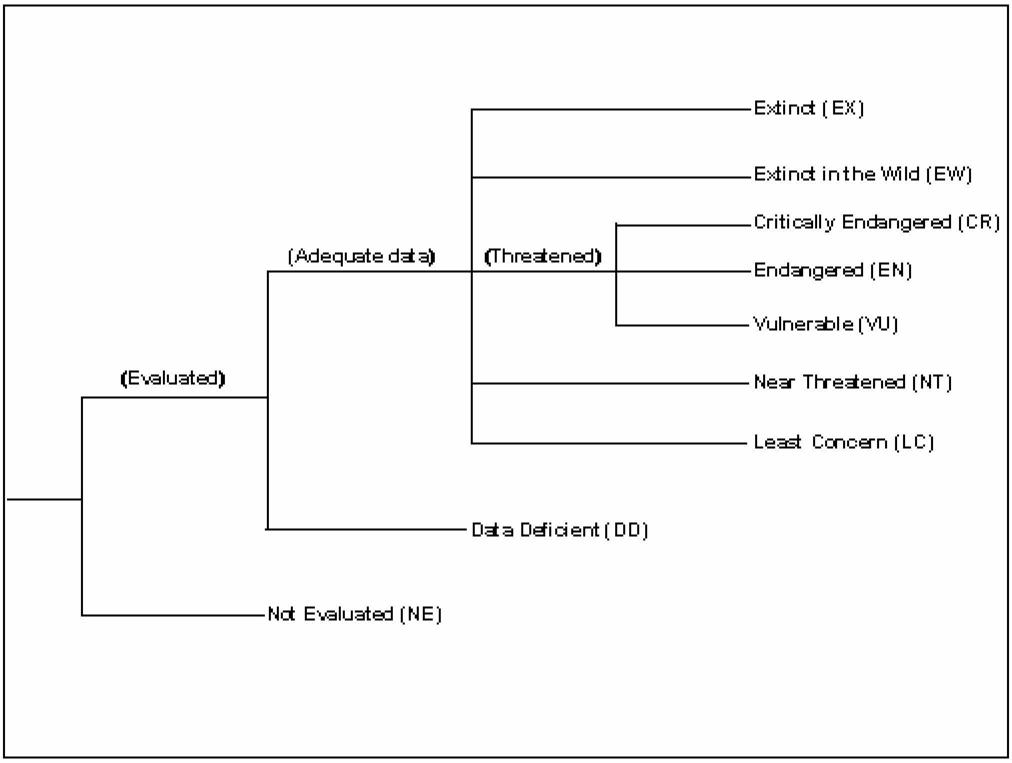

Figure 1. Structure of the 2001 IUCN Red List criteria.

released ("*Guidelines for application of IUCN Red Data List criteria at regional levels*") for determining how the global Red List categories and criteria may be applied on a regional scale (IUCN 2003b).

The Red List categories, therefore, provide a widely used method for high-lighting taxa under high risk of extinction at both the global and regional scales. These Red List assessments are based on considerable ecological knowledge defined by strict sets of criteria that are supported by decision rules based on thresholds of parameters such as distributional ranges, population sizes, and life histories (IUCN 2001; Lamoreux et al. 2003). Consequently, the IUCN Red List assessments have played an increasingly prominent role in guiding conservation activities, and are regularly included in conservation prioritisations or assessments (IUCN 2003a; Mehlman et al. 2004).

South African Mammal Red Data Book

In the 1970s, the IUCN Red Data Book concept was first applied at a national level in South Africa by Meester (1976), and subsequently, Skinner et al. (1977), and focussed on small and large mammals, respectively. Subsequently, these were followed by a Red Data Book by Smithers (1986) who implemented the then IUCN categories of threat which used broad definitions for five threatened categories, of which only two, namely, Vulnerable (V) and Endangered (E), directly indicated the likelihood of extinction (Statterfield 1996). However, these IUCN threat categories are considered to be subjective and may not accurately reflect the actual risks of extinction (Mace & Lande 1991).

Since the 1994 inception of the new IUCN Red List Categories and Criteria, the IUCN has assessed over 4500 mammalian taxa based on the Red List categories and criteria on a global scale. This process provides a global assessment of mammalian taxa that occur in the country under consideration. For South Africa, 110 marine and terrestrial mammals have thus far been assigned some IUCN Red List categories based on the relevant criteria at a global scale (IUCN 2003a).

More recently (2002), the South African non-governmental organization (NGO), the Endangered Wildlife Trust (EWT) initiated a workshop based on the Conservation Assessment and Management Plan (CAMP) approach (Friedmann & Daly 2004) to assess 295 South African mammals according to the latest IUCN categories and criteria at a national level (Friedmann & Daly 2004). This assessment high-lighted the conservation status of 57 mammalian taxa that are highly threatened with extinction at either the Critically Endangered (CR), Endangered (EN), or Vulnerable (VU) categories (Friedmann & Daly 2004).

Conservation Assessment

The availability of three different Red List and Red Book assessments that span nearly 18 years, as well as two generations of IUCN assessment categories and criteria allows for the analysis of South African mammalian taxa that have been high-lighted as threatened with extinction. The global and regional information provides an opportunity to undertake an objective evaluation of the threats facing a taxon at both a national and/or a global scale (Gärdenfors 2001). Such an evaluation can also facilitate the inclusion of region-specific threat levels into conservation prioritisation exercises but also with reference to global assessments (Master 1991; Mace 1995; Hilton-Taylor et al. 2000). The likelihood of assigning different threat categories to taxa when using regional and global assessments has rarely been examined (Gärdenfors 2001). Consequently, South Africa, with Red List assessments at both the global and regional scales, offers an ideal opportunity to explore the implications of different scale assessments for identifying taxa at risk of extinction.

Additional Measures of Conservation Prioritisation

Conservation prioritisation based on risk of extinction as the sole indicator of a taxon's conservation priority is considered to be inadequate (Masters 1991; Mehlman et al. 2004). Various other components, such as endemism, ecological specialization, phylogenetic diversity, and a series of threat variables are also considered to be important in determining vulnerability to extinction and subsequently, in conservation prioritisation exercises (Burke & Humphrey 1987; Lande 1993; Dobson, Yu & Smith 1995; Cardillo & Bromham 2001). By incorporating as much information as possible in the assessment of a taxon's conservation priority, the likelihood of a more accurate classification may be increased (Harcourt & Parks 2003; Knapp et al. 2003), so long as the variables used do not overly complicate the prioritisation process (Harcourt & Parks 2003; Knapp et al. 2003).

Conservation assessments do not only rely on a taxon's susceptibility to threat (i.e., risk of extinction or Red List assessments), but also on the nature and intensity of the threat itself (Reed 1992; Harcourt & Parks 2003). It is possible that the inclusion of additional explicit criteria of threat may improve the process of assessing threat. A variety of anthropogenic demographic components and their effect on different flora and fauna, and their disposition to become extinct, have been extensively investigated (Kerr & Currie 1995; Thompson & Jones 1999; Liu et al. 2003). Generally, these studies suggest a relationship between continental rates of habitat, taxon disappearance, and human-induced activities (Ceballos & Ehrlich 2002; Harcourt & Parks 2003, Luck et al. 2003).

Consequently, the present investigation attempts to address questions on the relationship between anthropogenic variables and measures of mammalian richness and their potential use in the assessment of threats to terrestrial mammals across their distributional ranges in South Africa. The study focuses on terrestrial mammals because of the relatively general lack of information on marine mammals. The use of regional IUCN Red List assessments (Friedmann & Daly 2004) which provide an assessment of extinction risks of taxa, in conjunction with various measures of anthropogenic impact, may allow for more informed decisions on the conservation of South African mammals at a national scale (Hannah et al. 1994; Sisk et al. 1994; Harcourt & Parks 2003).

The conservation value of a taxon in conservation priority planning is also considered to be of critical importance. Conservation values are usually equated to a taxon's geographic distribution and taxonomic uniqueness, such as endemism and phylogenetic distinctiveness. While there are a variety of approaches for determining the conservation value of a taxon (Vane-Wright, Humphries, & Williams 1991; Crozier 1992; Faith 1992; Heard & Mooers 2000), the scarcity of comprehensive information has led to a search for alternative measures for identifying unique taxa (Polasky et al. 2001; Rodrigues & Gaston 2002). Consequently, in order to gain an insight into the implementation of conservation prioritisation of South African mammal taxa, a modified Regional Priority Score (RPS) (Freitag & van Jaarsveld 1997; Mills et al. 2001; Reyers 2004) approach for identifying conservation priorities was reviewed in the current study.

Freitag and van Jaarsveld (1997) proposed RPS as a taxon-specific priority scoring technique for conservation priority-setting for at a regional scale. They suggested a method where regional taxa were scored in order of regional conservation importance according to a number of different but complementary rarity, vulnerability, and irreplaceability criteria (Freitag & van Jaarsveld 1997). Their priority scores consisted of the following four components: 1) Relative Vulnerability (RV) which equates to estimates of vulnerability to extinction based on Red Data Book or Red List assessments; 2) Regional Occupancy (RO) measures which estimates the regional extent of taxa 3) Relative Endemism

(RE) measures which equates to the proportion of the taxon's distributional range falling within the area under consideration; and 4) Relative Taxonomic Distinctiveness (RTD) which represent simple measures of taxonomic diversity. These four components have since been used to rank taxa in order of regional conservation importance (Freitag, van Jaarsveld & Biggs 1997; Reyers 2004).

Apart from the four components included by Freitag and van Jaarsveld (1997) in their regional analysis, the present investigation also incorporates additional information in the national RPS assessment for South African terrestrial mammals. Available information on vulnerability (i.e., extinction, probability and occupancy), irreplaceability value (i.e., endemism and taxonomic distinctiveness), as well as additional measures such as human interaction (which include human density and body size) that are considered to measure some form of threat were used in the present study.

Phylogenetically distinct taxa are generally considered to be of a higher conservation value than those with close genetic relatives. However, the general lack of all-inclusive and wide-ranging phylogenies has led to a search for alternative measures for identifying distinct species (Polasky et al. 2001). With the availability of comprehensive ordinal phylogenies (for example Primata (Purvis 1995), Chiroptera (Jones et al. 2002), Carnivora (Bininda-Emonds, Gittleman & Purvis 1999), Insectivora (Greyner & Purvis 2003), and the Lagomorpha (Stoner et al. 2003)), the present investigation attempts to address questions of whether measures of "simple" taxon's richness could function as a proxy in the absence of more comprehensive measures of phylogenetic diversity in regional conservation prioritisation exercises. To this end, the recently published phylogenies of members of two extant Orders, namely, the Chiroptera (Jones et al. 2002) and the Carnivora (Bininda-Emonds et al. 1999) allowed for such an assessment.

Conservation Prioritisation

The philosophy of conservation biology, which initially focused almost exclusively on the prioritisation and conservation of species, has also changed (Pressey et al. 1993; Lombard 1995; Entwistle et al. 2000; Margules & Pressey 2000; Ginsberg 2001). The conservation of single taxa was usually justified through the use of flagship and umbrella taxa approaches which were in turn extrapolated to the broader protection of ecosystems and sympatric taxa (Simberloff 1998; Leader-

Williams & Dublin 2000). The subsequent shift in focus towards 'systems' and 'biodiversity' have reinforced area selection procedures for conservation purposes (Freitag et al. 1997). Selecting areas of high endemism (hot spots) (Mittermeier et al. 1998), complementarity, as well as iterative conservation value-based and representation algorithms (Pressey et al. 1993; Freitag et al. 1997) came to the fore-front in area prioritisation and conservation processes.

Current systematic conservation planning incorporates explicit goals, quantitative targets, prioritisation of various biodiversity features of high significance as well as using rigorous criteria (Margules & Pressey 2000; van Jaarsveld et al. 2003). To this end, various systematic conservation-planning techniques, such as C-Plan software (New South Wales National Parks & Wildlife Service 2001) and Marxan software (Ball & Possingham 2000) have been developed, and are being widely used and implemented by decision-makers to review the consequences of land-use decisions across planning regions.

Some of the better known conservation planning projects in South Africa, includes projects on the National Biodiversity Strategy Action Plan (NBSAP), the Cape Action Plan for the Environment (CAPE), the Succulent Karoo Ecosystem Plan (SKEP), and the Sub-tropical Thicket Ecosystem Planning (STEP) (Balmford 2003; Cowling et al 2003; Driver et al. 2003; Rouget et al 2004). In its use and implementation, systematic conservation assessment relies on six essential steps (see Margules & Pressey 2000; Driver et al 2003), the first of which involves "*the identification or prioritisation of species, vegetation type, future land use pressures or other measures to use as surrogates for overall biodiversity*" (Driver et al. 2003). This step is the most relevant to the current study as it relies on the selection of threatened and priority taxa.

Equally, at a national level, the selection of threatened and priority taxa contribute to the requirements of Part 2 of Chapter 5 under "*Threatened or Protected Ecosystems and Species – Protection of threatened or protected species"* in the new South African National Environmental Management: Biodiversity Act 2004. Provisions of this part of the Act requires the listing of: "*(a) critically endangered species, being any indigenous species facing an extremely high risk of extinction in the wild in the immediate future; (b) endangered species, being any indigenous species facing a high risk of extinction in the wild in the near future, although they are not a critically endangered species; (c) vulnerable species, being any indigenous species facing an extremely high risk of extinction in the* *wild in the medium-term future, although they are not a critically endangered species or an endangered species; and (d), protected species, being any species which are of such high conservation value or national importance that they require national protection, although they are not listed in terms of paragraph (a), (b) or (c).*"

Even though the terminology used by the Act is similar to that used by the IUCN Red List threatened categories, it is no way nearly as comprehensive in assessing and highlighting the extinction risk and threat to taxa as the Red List process (IUCN 2001; Chapter 2). Of particular relevance is that the IUCN Red Listing process could facilitate and high-light taxa that would be listed under parts *a*— *c* of the Act. In order to assist in the identification of protected species of high national importance or of high conservation value as outlined in part *d* above, an Orange List approach (Victor & Keith 2004) was adopted in the present investigation. The Orange List approach attempts to accommodate taxa that would have been categorised as Rare (R), Insufficiently Known (K), and Indeterminate (I) in the pre-1994 IUCN Red List system of determining threat status, but excluded under the current Red List categories and criteria (IUCN 1994, 2001).

The rationale behind the Orange List approach was neither to address the problems of priority-setting for conservation purposes nor to replace the functionality of the Red Listing process. It rather intended to provide lists from which conservationists and decision-makers could prioritise what to conserve according to all factors that need to be considered in biological conservation exercises, such as financial feasibility, practicality, and urgency (Master 1991; Mace 1995).

Similarly, a Green Data Species List (Keith & van Jaarsveld 2002) concept was developed because capacity constraints, such as financial and logistical support, and uncertainties faced by national regulatory, enforcement, and border control agencies because of increasing management and active enforcement of escalating numbers of conservation-related instruments. These instruments include the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), IUCN Red Data Lists, and the pending invasive species regulations. It may, therefore, be imperative to support calls for a radical shift in the traditional approaches to the management of threatened species such as Red Data and/or CITES listings, and the maintenance of the integrity of biological systems such as the control of potentially invasive species. This should perhaps include the establishment of Green Data Species Lists as proposed by Imboden (1987) which may represent a reciprocal list of taxa that are not threatened (i.e., not Red Listed), not affected by trade (i.e., not CITES listed), or pose little threat of invasion according to importing authorities.

Aims of Study

In order to facilitate and improve regional conservation practice for South African mammals, a better understanding of various conservation assessment techniques may be imperative. This may allow an insight into the value and applicability of various conservation assessment tools for prioritising mammals at a regional scale. By incorporating relevant source data into various well-established conservation and priority setting techniques, this may in turn offer an opportunity to explore the conservation priorities of South African mammals.

Objectives of Study:

To this end, the present investigation, therefore, includes the following four objectives:

1. To explore the implications of different scale assessments for high-lighting South African mammal taxa at risk of extinction by using regional and global Red List and Red Data Book assessments;

2. To assess whether various measures of human-induced activities can function as proxies of threat to South African mammals that could in turn be used in conservation priority-setting exercises;

3. To assess whether relevant priorities for conservation can be determined for South African mammals based on measures of vulnerability, irreplaceability, and threat; and

4. To assess if a simple measure of taxonomic distinctiveness can be an effective surrogate for measures of phylogenetic diversity in the absence of comprehensive phylogenies, and to evaluate whether the inclusion of measures of more comprehensive phylogenetic diversity can alter the conservation priorities of South African mammals.

Key Research Questions and Study Outline:

In order to achieve the objectives in the present study, the following key research questions followed by the relevant study outline were addressed:

> **Key Research Question I:** Do the quantitative Red List categories and criteria provide an insight to into the risk of threats faced by South African mammals at a regional scale?;

> **Key Research Question II:** Do regional Red List assessments for South African mammals differ from those based on global Red List assessments?

These two key research questions are addressed in the first part of this study (Chapter 2) and are directed towards investigating and comparing South African mammals according to their respective regional and global World Conservation Union (IUCN) Red List and Red Data Book assessments. This included the use of the 1986 regional Red Data Book assessments (Smithers 1986), 2003 global IUCN Red List assessments of species occurring within the borders of South Africa (IUCN 2003a) as well as the latest regional Red List assessment (Friedman & Daly 2004). This part of the study allowed an investigation of the nature and extent of the qualitative and quantitative IUCN assessments over an 18-year period from 1986 to 2004 (Smithers 1986; IUCN 2003a; Friedman & Daly 2004).

> **Key Research Question III:** Can different measures of human-induced activities provide relevant information on threat to allow for more inclusive priority assessment for South African mammals to be made?

This key research question is addressed in Chapter 3 and is directed at assessing the relationship between six human activity variables (see section: Data utilized in study) and the recent regional Red List assessment (Friedmann & Daly 2004). In addition, the relationship between anthropogenic variables and measures of mammalian richness, and their potential use in the assessment of threats to South African mammals are investigated. This part of the study focuses on terrestrial South African mammals because of the general lack of quantifiable spatial data for marine mammals. Although both natural and anthropogenic threats may be important in assessing a taxon's risk of extinction (Kerr & Currie 1995), only limited threat data have been included in previous quantitative risk assessments.

Key Research Question IV: Would the inclusion of measures of vulnerability, irreplaceability, and threat in conservation priority assessment techniques allow for a simplified, region-specific conservation priority-setting for South African mammals?

This key research question is addressed in Chapter 4 and is directed towards assessing the conservation priorities allocated to a range of South African terrestrial mammals when measures considered to be related to vulnerability (IUCN Red List assessments and occupancy data), irreplaceability (endemism and taxonomic distinctiveness), and threat (body mass and human density) are included in the analysis. An additional focus is also directed at assessing the effect of including body mass and a human density index in a priority exercise.

Key Research Question V: Can a simple measure of taxonomic distinctiveness act as potential surrogates for measures of phylogenetic diversity in the conservation assessment of South African mammals?

This key research question is addressed in Chapter 5 and is directed at assessing whether a simple measure of taxonomic diversity can be used as a proxy for measures of phylogenetic diversity in high-lighting taxa of regional conservation priority. In this part of the study, members of the Orders Chiroptera and Carnivora from South Africa are used as a case study because of the availability of their published phylogenies and their representation of a large proportion of South African terrestrial mammals.

Key Research Question VI: Do current conservation assessment techniques adequately incorporate relevant information for an inclusive conservation assessment of South African mammals?

This research question is addressed in Chapters 6 and 7 and is directed at the different facets and limitations of current conservation prioritisation processes. Conforming to the demands of the new South African Biodiversity Act of 2004, as well as the inherent short-comings of many conservation assessment techniques, two conceptual frameworks are proposed to circumvent potential limitations.

Data Utilised in Study

Mammal taxonomy

Broadly, the entire study is based on extant South African mammals and following the Friedman and Daly (2004) taxonomy established in 2002, the taxonomic framework of Wilson and Reeder (1993) and augmented by that of Taylor (2000) for the Order Chiroptera. For taxa with taxonomic discrepancies between authorities, taxon specialists working on the specific problematic groups were consulted (see Friedmann & Daly 2004). While this study acknowledges the recently published taxonomic framework of Bronner et al. (2003), this study follows the taxonomy used by the recent regional Red List assessment by Friedmann and Daly (2004) (based on the taxonomy used by the Conservation Assessment and Management Plan for the Mammals of South Africa (Friedmann et al. 2002)) in order to facilitate comparisons between the present study and previous work.

Red Data Book, Red List, and distribution data.

The regional Red Data Book (RRDB) assessments were extracted from Smithers (1986) and Mugo et al. (1995), while the global IUCN Red List assessments (GRL) included information from the 2003 global Red List assessment (IUCN 2003a). The recent regional Red List assessment (RRL) by Friedman and Daly (2004) was included in all relevant regional Red List assessments throughout the study. Subsequent analyses (Chapters 3 – 5) focused on terrestrial taxa for which relevant spatial distributional, biological and threat data were available. Mammal distributional data were obtained from distributional presence records from various natural museums in South Africa and electronic range maps (Freitag & van Jaarsveld 1995; Keith 2004). All spatial data were generalised to a common resolution at the quarter degree square (QDS) level representing an area of 25 x 25 km (or 625km^2) (Freitag & van Jaarsveld 1995).

Regional Priority components

Components used in Chapters 4 and 5 included: 1) Relative Vulnerability (RV) based on the regional IUCN Red List assessment of Friedmann and Daly (2004); 2) Relative Occupancy (RO) based on presence data from natural history museum distributional records (Freitag & van Jaarsveld, 1995; Keith 2004); 3) Relative Endemism (RE) based on the level of endemism following Freitag and van Jaarsveld

(1997); 4) Relative Taxonomic Distinctiveness (RTD) following methodology as proposed by Freitag and van Jaarsveld (1997); 5) Relative Body Mass (RBM) based on average body weights (in grams) for each species; and 6) Relative Human Density based on the average human population per QDS derived from magisterial human population data (Central Statistical Service 1998). To facilitate analysis in Chapter 5, information on phylogenetic diversity was were extracted from comprehensive ordinal phylogenies for bats (Jones et al. 2002) and carnivores (Bininda-Emonds et al. 1999), while taxonomic distinctiveness values were calculated as described by Freitag and van Jaarsveld (1997). More precise methodologies and other sources of data are outlined in the relevant chapters.

Anthropogenic Data

Six anthropogenic variables were used in Chapter 2. These included: 1) human population density; 2) human change; 3) poverty; 4) affluence; 5) urbanization; and 6) land transformation and degradation. The main sources for information on human population density, human change, poverty, and affluence included magisterial district data (Central Statistical Service 1995, 1998), while all land-cover and transformation data were collated from the National Land-Cover database (Fairbanks & Thompson 1996). These data were also converted to a spatial scale at the QDS level in order to conform to mammal distributional data.

Rationale of Study

It is anticipated that the utilization of a wide range of approaches of assessing/prioritising mammals as adopted in the present study may extend our understanding of the methods that are most comprehensive in identifying priority species. It is also anticipated that the approaches adopted in the present study may also further our understanding towards the development of a more encompassing list of priority mammals for South Africa to allow for relevant conservation decisions to be made. Of particular importance is that the approaches used in the present study may not only be relevant for South African mammals, but may also be applied to other regions worldwide, as well as to a wide range of other taxonomic groups within both the animal and plant kingdoms.

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CHAPTER 2

Regional IUCN Red List assessments for South African terrestrial and marine mammals: An overview

For submission to: *Biological Conservation*

Abstract

This paper investigates and compares South African mammals according to their various regional and global World Conservation Union (IUCN) Red List and Red Data Book listings. Recently, the extinction risk of 295 extant marine and terrestrial mammal taxa was evaluated at a regional scale using the latest IUCN Red List categories and criteria. This risk assessment was compared with the risk status in the 2003 global Red List assessment and the 1986 South African Mammals Red Data Book. For the first time in the South African history of regional Red List or Red Data Book assessments, 42 marine mammals were assessed, with the majority being identified as Data Deficient. The regional Red List assessment listed 57 marine and terrestrial mammals as threatened (Critically Endangered, Endangered or Vulnerable), the majority belonging to the Order Insectivora. The regional Red List assessment identified more South African taxa to be threatened than was the case with the global Red List assessment. A large proportion of mammals were identified as regionally Data Deficient, and thus do not have sufficient information to allow for an adequate IUCN Red List assessment at the regional scale. A strong reliance on IUCN Red List category B (distribution/range size in conjunction with severe fragmentation, population structure, continuing decline and extreme fluctuations) and D (taxa with restricted area, or with a small number of breeding individuals) were evident in the regional Red List assessment. It is essential to recognize that the regional Red List assessment can only be considered as provisional and those regional assessments are imperative to allow for the monitoring of changing extinction risk in South African mammals.

Keywords: IUCN Red List, Read Data Book, regional assessments, terrestrial/marine mammals, South Africa

1. Introduction

Growing awareness about the possible extinction of certain taxa is largely attributed to the development of the World Conservation Union's (IUCN) Red List and/or Red Data Book (RDB) concept (Magin et al., 1994). The IUCN Red List was conceptualised by Sir Peter Scott in 1963 and has evolved significantly over the years (Ferrar, 1991; Magin et al., 1994). Red Lists and RDBs are in simple terms, methods for identifying declining taxa, which will allow conservation scientists to establish the nature and extent of such declines introduce conservation actions, research, and the monitoring of such taxa (Ferrar, 1991; Sutherland, 2001; Possingham et al., 2002; Lamoreux et al., 2003).

Red Lists and RDBs contribute to basic research and to the general knowledge of taxa by providing consolidated information, reflecting the probability of decline or loss of a taxon through extinction. The identification of taxa under threat of extinction has proven to be helpful by drawing public focus to these taxa, as well as their declining habitats (Ferrar, 1991; Possingham et al., 2002). The compilation of Red Lists and RDBs are an essential component of modern conservation practice (Sutherland, 2001).

Before 1994, the more subjective Red Data book threatened species categories, used by the IUCN, had been in place, for almost 30 years (IUCN, 1994). The strengths of these pre-1994 Red Data Book categories were their simplicity, modest data requirements and wide acceptance (Todd and Burgman, 1998). These categories were, however, largely qualitative and subjective, and as a result, depended almost exclusively on expert opinion. Consequently, categorisations made by different authorities, from different areas and across RDBs, were inconsistent and did not accurately reflect the actual extinction risks (Mace and Lande, 1991; Master, 1991; Todd and Burgman, 1998).

In 1989, the IUCN Species Survival Commission steering committee started to develop a more objective and quantitative approach that provided the conservation community with a useful methodology for assessing the risk of extinction of species. The 1994 IUCN Red List categories and criteria (version 2.3) marked a shift from qualitative to a more quantitative system (IUCN, 1994, 2001). These Red List categories and criteria were recently reviewed and some modifications were introduced (IUCN, 2001). The categories and criteria (IUCN, 1994, 2001) consider five different aspects of a taxon's life history traits, including information on population and distribution sizes and trends. A taxon, therefore, qualifies for any of the nine IUCN Red List categories (see IUCN, 2001 for definitions) if it meets any one of the five specified threat criteria (Criteria A-E). These then are used to ascertain the possible threat of extinction to that particular taxon (IUCN, 2001), instead of the traditional “conservation status or assessment” (Smithers, 1986; Proudlove, 2004).

In addition, the 1994 and 2001 IUCN Red List categories and criteria were designed for global assessments of taxa rather than for use in units defined by either regional or national boundaries (IUCN, 2001). Moreover, a global-scale assessment of threat is impractical for regional and local conservation agencies that require extinction risk and threat data at a regional scale to formulate management goals (Gärdenfors, 1996; Freitag and van Jaarsveld, 1997; Gärdenfors et al., 2001). One limitation of applying the global system at a regional scale is that estimating extinction risk in a portion of a taxon’s range may be different from the assessment of extinction risk at a global level (Gärdenfors et al., 1999, 2001). This can be expected to impact on the regional threat and conservation category assigned to a taxon for conservation purposes.

Consequently, regional threat assessments are required to provide baseline data that regional and local conservation agencies need to incorporate into their conservation and management programmes**.** It is considered that regional Red Lists would provide a more objective evaluation of the threats facing a taxon at either a national or regional scale (Gärdenfors, 2001). It can also facilitate the inclusion of threat levels into national conservation planning (Master, 1991; Mace, 1995). However, the likelihood of assigning different threat categories to taxa when using regional and/or global assessments has rarely been examined (Gärdenfors, 2001). South Africa, having had Red List assessments at both global and regional scales, offers the ideal opportunity to explore the implications of different scale assessments for highlighting taxa at risk of extinction.

The publication of the first set of national Red Data Books for South African mammals commenced in the 1970s and stemmed from global initiatives (Meester, 1976; Skinner, Fairall and Bothma, 1977; Smithers, 1986; Lamoreux et al., 2003). Smithers (1986) produced the last RDB for South African terrestrial mammals in 1986 and provided assessments on the “conservation status as defined by the International Union for the Conservation of Nature and Natural Resources” (Smithers, 1986). The RDB categories of threat, used by Smithers (1986) provided broad definitions for five threatened categories, of which only two directly indicated the likelihood of extinction (Mace and Lande, 1991; Statterfield, 1996).

No regional South African RDB or Red List assessment for large groups of mammals has been undertaken, since Smithers' (1986) Red Data Book for terrestrial mammals except for some qualitative re-evaluations by Mugo et al., (1995). This prompted the revision and development of an up-dated Regional Red List of all extant South African mammals (RRL; Friedmann and Daly, 2004). This process was conducted according to current IUCN Red List categories and criteria (version 3.1; IUCN, 2001), and also included the first regional assessment for South African marine mammals.

In this paper, we review the three existing IUCN RDB, regional and global Red List threat assessments of South Africa's mammals. We examine the nature and extent of the differences between qualitative and quantitative assessments across the 18-year period from 1986 to 2004, as well as differences between the regional and global assessments. In particular, we focused on whether changes in assessment criteria, changes in our current knowledge of taxa, or actual changes in the extinction likelihood of species were the dominant driving force of change over this period (McIntyre, 1992).

2. Methods

The regional RDB (RRDB) assessments by Smithers (1986) and Mugo et al., (1995), global assessments included in the 2003 global Red List (GRL), and the recent regional Red List (RRL) by Friedman and Daly (2004) were used as source material in the present study. Taxonomy is based on that of the recent regional Red List (Friedmann and Daly, 2004).

*2.1. South African Red Data Book (1986/95) (*hereafter *RRDB)*

A revised list of Red Data Book listed mammals were obtained from the South African Red Data Book of terrestrial mammals (Smithers, 1986) and re-assessments by Mugo et al., (1995) (the latter focused on rodents, lagomorphs and macroscelids). These two assessments were based on the perceived subjective pre-1994 RDB categories (see Smithers, 1986). The five categories identified and fully defined by Smithers (1986) were: Endangered (E), Vulnerable (V), Rare (R) Indeterminate (I), and Out of Danger.

2.2. Global Red List (2003)

Information on the global 2003 IUCN Red Listing (from now on GRL) for South African mammals was extracted from the IUCN Red List website (IUCN, 2003). The IUCN (2001) Red List categories are fully defined therein, including the "threatened" categories: Critically Endangered (CR), Endangered (EN), and Vulnerable (VU). Additional categories, that can be defined as "non-threatened" categories included: Near Threatened (NT), Data Deficient (DD), Least Concern (LC), and Not Evaluated (NE) (IUCN, 2001). The IUCN (2001) categories also included the Extinct (EX) and Extinct in the Wild (EW) classifications. The IUCN Red List assessment uses five different criteria (A-E) that are derived from a wide set of attributes. These include: rates of population decline (criteria A), changes in distribution/range sizes in conjunction with severe fragmentation, population structure, continuing decline and extreme fluctuations (criteria B), population size in conjunction with continuing decline (criteria C), population size (criteria D), and probability of extinction (criteria E) (IUCN, 1994, 2001).

2.3. South African Regional Red List (2004)

Information for the regional IUCN Red List (hereafter referred to as RRL) assessment was obtained from the regional Red List for South African mammals (Friedmann and Daly, 2004). All extant terrestrial and marine mammals were assessed at a regional level according to the IUCN Red List categories and criteria in version 3.1 of IUCN (2001). Red List assessments were undertaken for all extant taxa within South African borders, excluding Lesotho and Swaziland, but included mammals from the sub-Antarctic Prince Edward Islands.

2.4. Analysis

Comparisons between the respective RRDB (1986/95), RRL (2004) and GRL (2003) assessments focused on different taxa assessments, categories and criteria at specific taxon, Family, and Order levels relating to the risk of extinction in the near future. The various criteria that were assigned to each taxon were explored for both the RRL and GRL assessments. The interpretation of results dealing with comparisons among taxa, between lists from different areas or lists from different time eras should be approached with caution (Possingham et al., 2002). To allow for comparisons among taxa, lists and across time, "metrics [information] from threatened taxa lists should be scaled to account for the number of taxa that were assessed, and for the number for which there was sufficient data to make an assessment" (Possingham et al., 2002). For the current study, the proportion of threatened taxa per RRDB (1986/95), RRL (2004), GRL (2003), threat category per specific Order, as well as the proportions of all taxa assessed were derived and presented.

In accordance with the 2001 IUCN Red List categories and criteria, the term "taxon" (pl. taxa) is used in this study to represent species, sub-species or sub-populations (IUCN, 2001).

3. Results

3.1. RRDB assessment (1986/95)

Eighty one extant listed taxa (species and subspecies) were extracted from the RRDB (Smithers, 1986; Mugo et al., 1995) and corresponded with the mammal taxonomy used in the more recent RRL (2004) assessment, allowing for a revised list of RRDB assessed mammals (Appendix 1). From the derived RDB listing, three mammal taxa were listed to be Endangered (E), 12 Vulnerable (V), 28 Rare (R), five Out of Danger (O), and 33 Indeterminate (I) (taxa counts adapted from Smithers 1986) were listed in accordance with the 1986 RRDB categories (Table 1; Appendix 1). If one accepts Endangered (E) and Vulnerable (V) as being "threatened" (see Rebelo and Tansley, 1993), 15 taxa from the 243 recognised taxa were threatened (6.17%). The three taxa listed as Endangered were the African wild dog (*Lycaon pictus*), the riverine rabbit (*Bunolagus monticularis*), and the roan antelope (*Hippotragus equines*). In general, the majority of the 81 listed taxa in the RRDB were recorded as Rare (40.74%) or Indeterminate (34.57%). Most of the taxa ranked as Rare, were either found in the Order Carnivora, Artiodactyla, or Rodentia. Mainly the smaller mammals, e.g. the Chiroptera (100%) and Insectivora (78%) contributed most taxa to the Indeterminate (I) category (Table 1).

3.2. GRL assessment (2003)

The GRL listed 271 mammals (24 of the 295 taxa in the 2004 RRL were not evaluated in this global list) known to occur in South Africa, with 43 taxa (15.87%) classified as globally threatened (threatened includes: Critically Endangered (CR), Endangered (EN), and Vulnerable (VU)). These threatened taxa were

Table 1. Summary outline of the updated regional Red Data Book (RRDB) assessments per Order of the 81 taxa of the Red Data Book assessments for terrestrial taxa occurring in South Africa (Smithers, 1986; Mugo et al., 1995). RDB categories Endangered (E), Vulnerable (V) Rare (R), Out of Danger (O) and Indeterminate (I). Number of taxa in parenthesis in RRDB column are according to the published assessments by Smithers (1986). The three extinct taxa were not included in current analysis.

Order	**E**	**V**	**R**	**O**	**I**	**Total**
Artiodactyla	1	3	6	0	0	10
Carnivora	1	2	9	1	0	13
Chiroptera	0	0	0	0	17	17
Hyracoidea	0	0	1	0	0	1
Insectivora	0	2	2	0	14	18
Lagomorpha	1	0	0	0	0	1
Macroscelidae	0	0	1	0	0	1
Perissodactyla	0	2	0	0	0	2
Pholidota	0	1	0	0	0	1
Primates	0	0	2	0	0	2
Proboscidea	0	0	0	1	0	1
Rodentia	0	1	7	3	2	13
Tubulidentata	0	1	0	0	0	1
Grand Total	3 (3)	12 (14)	28 (25)	5 (2)	33 (45)	81 (89)

Table 2. Summary outline per Order of the 295 taxa of the global IUCN Red List (GRL) assessments for taxa occurring in South Africa (IUCN, 2003). IUCN Red List categories ranged between that of IUCN Red List version 2.4 and 3.1. The following abbreviations are used within the table: Critically Endangered (CR); Endangered (EN); and Vulnerable (VU), Near Threatened (NT) (also including Lower Risk/near threatened (LR/nt)), Data Deficient (DD), Lower Risk/conservation dependant (CD) and Least Concern (LC) (also including the old Lower Risk/least concern (LR/lc) category) and Not Evaluated (NE).

Orders	**CR**	**EN**	**VU**	**Threatened Total**	**NT**	**DD**	**CD**	**LC**	**NE**	**Total**
Artiodactyla	0	0	1	1	0	0	25	7	0	33
Carnivora	0	1	4	5	1	0	1	28	3	38
Cetacea	0	3	2	5	0	16	13	4	4	42
Chiroptera	0	0	4	4	10	0	0	33	3	50
Hyracoidea	0	0	1	1	0	0	0	2	0	3
Insectivora	3	1	9	13	0	0	0	13	7	33
Lagomorpha	0	1	0	1	0	0	0	6	0	7
Macroscelidae	0	0	3	3	0	0	0	4	0	7
Perissodactyla	1	2	1	4	1	0	0	1	0	6
Pholidota	0	0	0	0	1	0	0	0	0	1
Primates	0	0	0	0	0	0	0	6	1	7
Proboscidea	0	1	0	1	0	0	0	0	0	1
Rodentia	0	1	4	5	5	2	0	48	6	66
Tubulidentata	0	0	0	0	0	0	0	1	0	1
Grand Total	4	10	29	43	18	18	39	153	24	295

categorised mainly within the Vulnerable (VU) category (29 taxa, Table 2) (IUCN, 2003). Ten taxa were listed as Endangered (EN) including some of the following taxa: Visagie's golden mole (*Chrysochloris visagiei*), van Zyl's golden mole (*Cryptochloris zyli*), Juliana's golden mole (*Neamblysomus julianae*), and the south-central black rhino (*Diceros bicornis minor*). Eighteen taxa were listed as Near Threatened (NT) and another 18 as Data Deficient (DD). Thirty-nine taxa retained the old 1994 Low Risk conservation dependant (LR/cd) category. Twenty-four taxa (subspecies and newly described taxa) were not evaluated (NE) at the global level (Table 2, Appendix 1).

Taxa from the Orders Perissodactyla, Insectivora, and Macroscelidae were found to have the highest proportion of threatened taxa per Order with 66.67%, 39.39% and 42.87% threatened taxa, respectively. Similarly, the Order Chiroptera had the highest proportion (20%) of taxa considered to be Near Threatened (NT) at a global scale. Of all South African marine mammals, the Order Cetacea contained the highest proportion of globally Data Deficient (DD) taxa listed (Table 2).

The highest number of threatened taxa as a proportion of the assessed taxa in the GRL list were of the Order Insectivora, with 13 insectivore taxa (32.23%) being identified as threatened, nine as Vulnerable (VU), one as Endangered (EN), and three Critically Endangered (CR) (Table 2).

3.3. RRL assessment (2004)

The Regional Red List assessed 295 taxa, identifying 57 (19.32%) threatened mammals (CR = 10, EN = 18 and VU = 29) (Table 3). Thirty-eight (12.88%) mammals were identified as regionally Near Threatened, as well as 53 taxa (17.9%) being listed as Data Deficient. For more detail of taxa assessments see Appendix 1.

The highest proportion of threatened taxa per Order, were recorded within the Pholidota (100%), Perissodactyla (66.67%), and the Primates (42.86%). However, in terms of the absolute number of taxa assessed, the highest proportion of threatened taxa was found within the Orders Insectivora and Chiroptera. The Order Chiroptera also contained the highest number of Near Threatened taxa in absolute numbers in the regional assessment. The Cetacea had the highest proportion of Data Deficient taxa. Twenty three (54.76%) of the 42 taxa assessed in the Order Cetacea were assessed as DD. The Orders Insectivora and Macroscelidae also had a large proportion of taxa listed as Data Deficient. Overall, 14 Insectivora (42.42% of the Insectivora assessed) were threatened, five were regarded as CR and all belong to the Family Chrysochloridae.

3.4. Comparisons across assessments

3.4.1 Comparisons of RRDB and Red Lists (RRL and GRL)

Table 4a correspond to comparisons of the variation found between RRDB (1986) taxa with regard to RRL (2004) placement. The three RRDB (1986) Endangered (E) taxa were still listed in the threatened RRL (2004) categories (Table 4a; Appendix 1). Of the 12 Vulnerable (V) RRDB taxa, eight remained in a threatened RRL criterion, with two taxa being identified as RRL Near Threatened (the honey badger, (*Mellivora capensis*), and the Namaqua dune mole-rat (*Bathyergus janetta*)). Two Vulnerable RRDB taxa, the aardvark (*Orycteropus afer*), and the African wild cat, (*Felis silvestris*), were both classified as RRL Least Concern (LC). Of the 28 Rare (R) RRDB taxa, various taxa were classified in the RRL as Endangered or Vulnerable (Table 4a; Appendix 1). The Rare RRDB Meller's mongoose (*Rhynchogale melleri*), African weasel (*Poecilogale albinucha*), and Selous' mongoose (*Paracynictis selousi*), were listed as Data Deficient by the RRL. Of the 33 Indeterminate (I) RRDB taxa, five were still deemed regionally Data Deficient, and additional 22 Data Deficient assessed terrestrial taxa and 23 Data Deficient marine RRL taxa, were identified, which were not previously assessed by the RRDB (Table 4a; Appendix 1). In addition, three of the Out of Danger (O) RRDB taxa were listed as Least Concern taxa in the RRL, whereas two were classified as threatened by the GRL (African elephant, (*Loxodonta Africana*) (EN A1b) and spectacled dormouse (*Graphiurus ocularis*) (VU A1cd) (Appendix 1)). The cheetah (*Acinonyx jubatus*), was regarded in the RRDB to be Out of Danger (O), and yet both the GRL and RRL listed it as threatened (VU C2a(i) and VU D1, respectively).

Table 3. Summary outline per Order of the 295 taxa with regional Red List (RRL) categorisation. IUCN Red List categories correspond to that of IUCN Red List version 3.1 (Friedmann and Daly, 2004). The following abbreviations are used within the table Critically Endangered (CR); Endangered (EN); and Vulnerable (VU), Near Threatened (NT), Data Deficient (DD), and Least Concern (LC).

Order	CR	EN	VU	Threatened Total	NT	DD	LC	Total
Artiodactyla	0	2	5	7	1	0	25	33
Carnivora	0	2	2	4	7	3	24	38
Cetacea	0	2	4	6	1	23	12	42
Chiroptera	2	2	6	10	18	3	19	50
Hyracoidea	0	0	1	1	0	0	2	3
Insectivora	5	4	5	14	4	14	1	33
Lagomorpha	1	0	0	1	0	0	6	7
Macroscelidae	0	1	0	1	0	2	4	7
Perissodactyla	1	1	2	4	0	0	2	6
Pholidota	0	0	1	1	0	0	0	1
Primates	0	1	2	3	0	0	4	7
Proboscidea	0	0	0	0	0	0	1	1
Rodentia	1	3	1	5	7	8	46	66
Tubulidentata	0	0	0	0	0	0	1	1
Grand Total	10	18	29	57	38	53	147	295

Table 4a. Comparisons of the variation found between RRDB (1986) taxa with regard to RRL (2004) placement. RDB categories Endangered (E), Vulnerable (V) Rare (R), Out of Danger (O) and Indeterminate (I). Critically Endangered (CR); Endangered (EN); and Vulnerable (VU), Near Threatened (NT), Data Deficient (DD), and Least Concern (LC).

Categories	**RRDB 1986**	**E**	**V**	**R**	**I**	**O**
RRL 2004						
CR		1	1	1	4	-
EN		1	1	5	4	-
VU		1	6	6	7	2
NT		-	2	4	12	-
DD		-		3	5	-
LC		-	2	9	1	3

Table 4b. Comparisons of the GRL (2003) taxa with regard to RRL (2004) placement. The following abbreviations are used within the table: Critically Endangered (CR); Endangered (EN); and Vulnerable (VU), Near Threatened (NT) (also including Lower Risk/near threatened (LR/nt)), Data Deficient (DD), Lower Risk/conservation dependant (CD), Least Concern (LC) (also including the old Lower Risk/least concern (LR/lc) category) and Not Evaluated (NE).

Categories	**GRL 2003**	**CR**	**EN**	**VU**	**NT**	**DD**	**LC**	**CD**	**NE**
RRL 2004									
CR		2	1	3	1	-	1		2
EN		-	3	3	-	-	3	2	7
VU		2	2	8	5	2	6	3	1
NT		-		6	5	1	19	2	5
DD		-	2	2	1	14	22	5	7
LC		-	2	7	6	1	102	27	2

3.4.2. Comparison of GRL and RRL

Ninety-eight taxa were assigned a higher RRL category than their allocated GRL category, with 33 of these 98 taxa being classified as threatened (VU, EN, or CR) at the regional scale and either near threatened (NT), Least Concern (LC), Not Evaluated (NE), or Low Risk Conservation Dependant (LR/cd) at a global scale (Table 4b, Appendix 1). Thirty-one GRL taxa dropped in category when compared with the RRL, with 19 globally threatened taxa not deemed to be threatened regionally. This shift was in most cases the result of up to date regional information being incorporated in the regional assessments, and as well as stable population trends for a number of taxa within the borders of South Africa (see Friedmann and Daly 2004 for more detail). Four taxa were awarded a regional Data Deficient (DD) category shifting from a GRL threatened category, and 34 regionally DD taxa were placed in the GRL not threatened categories (LC, NE, LR/cd) with 14 taxa remaining DD.

Taxa that made the largest shift between categories were in many cases new taxa, not previously assessed (GRL - NE), and were classified as RRL CR (Ongoye red squirrel, (*Paraxerus palliatus ornatus*) and the Pretoria sub-population of the Juliana's golden mole, (*Neamblysomus julianae*) (Table 4b, Appendix 1)). Seven GRL NE taxa were identified as RRL EN, one NE taxon being regionally VU, five NE taxa being identified NT and seven NE taxa being categorized as DD (Table 4b; Appendix 1). The GRL taxa that made the largest shift between categories, from EN (both cases) to RRL LC, were the Barbour's rock mouse (*Petromyscus barbouri*) and the African elephant (*Loxodonta africana*).

3.5. Use of IUCN criteria in assessments

No comparison with the RRDB assessment was feasible as this approach does not employ quantitative data and criteria for determining threat status.

Of the criteria used by the GRL, criterion B was used most often (19 times – 44.18%), with criterion A being implemented second most (13 times – 30.23%) (Table 5). Criterion A refers to a marked reduction in population size. Criterion B is used to qualify taxa with a restricted distribution (either extent of occurrence or area of occupancy), which are showing a decline, becoming fragmented or showing marked fluctuations in abundance (Mace and Balmford, 2000; IUCN, 2001).

Table 5. Summary of the various criteria from the global 2002 IUCN Red List (GRL) and the regional Red List (RRL) applied for the 295 mammal Red List assessments. Criterion A refers to a marked reduction in population size. Criterion B is used to qualify taxa with restricted distribution (either extent of occurrence or area of occupancy) showing decline, fragmented or marked fluctuations in abundance (Mace and Balmford 2000; IUCN, 2001). Criterion C covers taxa showing a continuing decline in fragmented, fluctuating or isolated populations (IUCN, 2001). Criterion D include taxa with restricted area, or else if the number of breeding individuals is very small. Criteria E require evidence from qualitative assessments (e.g. Population Viability Analysis PVA) (Mace and Balmford, 2000). For a proper outline of criteria, consult IUCN (2001) or http://www.redlist.org

IUCN Red List Criteria	**GRL**	**RRL**
A	13	4
A, B	0	1
A, C	0	1
A, D	3	0
B	19	18
B, C	0	2
B, D	0	2
C	5	8
C, D	0	1
D	3	20

4. Discussion

4.1. Red Data Book and Red List comparisons

4.1.1. Regional assessments

The incorporation of the new quantitative Red Listing criteria of the IUCN increased the number of threatened mammal taxa in South Africa from nearly 7% (RRDB 1986/95) to nearly 20% of all mammals deemed to be threatened with extinction (RRL 2004). The RRDB categories (Smithers, 1986) provided broad definitions, of which only two categories directly indicated the likelihood of extinction (E and V; Mace and Lande, 1991; Statterfield, 1996). For the most part, these categories have been considered to be subjective, and as a result, categorisations do not accurately reflect the actual extinction risks (Mace and Lande, 1991). The application of the new Red List criteria presented not only threat categories, criteria and sub-criteria describing the t risk of going extinct, but also allowed the inclusion of more relevant population size and trends, and geographic range data. These categories and criteria (IUCN, 1994; 2001) are supported by decision rules related to range, population size and population history (Todd and Burgman 1998; Burgman et al., 1999; IUCN, 2001), which provides an explicit and objective framework for the classification of taxa according to their extinction risk as opposed to the traditional RRDB categories (Statterfield, 1996; IUCN/SSC, 1999). The relative objectivity of the new listing criteria (IUCN 1994; IUCN 2001) makes them an excellent tool for observing changes in the "threat of extinction" over time and for providing a more systematic, transparent, and informative approach to the threat listing of taxa (IUCN/SSC 1999; IUCN, 2001) while, most importantly, still providing some room for uncertainty (Todd and Burgman, 1998; Akçakaya et al., 2000; Gärdenfors, 2001; Lamoreux et al., 2003).

4.1.2. Global and regional assessments

Comparing the RRL with GRL assessments demonstrated that from a regional perspective, more taxa are deemed threatened (19.37%) than estimated by the GRL (15.87%). Evidence from the current study match general findings that regional Red List assessments can expect a higher percentage of threatened taxa than global Red List assessments (Gärdenfors et al., 2001). The reason for this may be that smaller countries have smaller populations (fewer locations) and the probability of local extinction is generally higher in smaller populations (Gärdenfors et al., 1999).

Similarly, the number of regional NT and DD listed taxa increased noticeably at the regional assessment level in comparison with the GRL NT and DD listed taxa, indicating that various taxa were either bordering on being classified as threatened (i.e. NT) or that too little information was available at a regional scale for an appropriate assessment. The IUCN (2001) states that "…a taxon is Data Deficient when there is inadequate information to make a direct, or indirect, assessment of its risk…" and should usually be applied as a last resort. If this is the case, the 52 Data Deficient taxa identified in the South African RRL (29 of which are terrestrial), urgently require research to gain an insight into these DD listed taxa's life history traits for consistent and authentic Red List assessment in future, both at the regional and global scale.

Studies are urgently required especially on the smaller, less charismatic and lesser-known carnivores, rodents, several bats, and most importantly, almost all cetaceans. It is has been reported that there is severe conservation bias towards larger more charismatic taxa, which are usually awarded the majority of resources for research and conservation (Polishchuk 2002). In general, even the basic life history and habitat requirements of the smaller taxa are unknown due to their scarcity and cryptic nature (Meester, 1976; Ceballos and Brown, 1995; Entwistle and Stephenson, 2000, Mickleburgh, 2000), which hinders quantitative data-intensive threat assessments such as the IUCN Red List assessments (Mace, 1995; Mickleburgh, 2000; Keith and van Jaarsveld, 2002). It is troublesome that at a regional scale, general population and life history data are very limited for most South African mammals (large number of DD taxa), even for the more charismatic "well known" mammals such as the cheetah. Furthermore, what is even more disconcerting is that Possingham et al. (2002) noted that South Africa's Red Lists are some of the most complete among African countries, further illuminating the potential shortfall of suitable data from neighbouring African countries, as regional information usually feeds into global IUCN Red List assessments (Rodriquez et al., 2000; Hilton-Taylor et al., 2000; Gärdenfors et al., 2001).

4.1.3. Extinction risk trends and patterns

With the recent RRL threat assessments being the first South African mammal assessment using the latest Red List categories and criteria, information on the regional trends in risk of extinction will only become apparent after the next proposed regional Red List assessment in *c.*2009. A likely stabilisation of the IUCN Red List categories and criteria (Garnett et al., 2003) will allow for a more appropriate comparison of categories and criteria over time, to permit insight into changes in extinction probability of many taxa (Avery et al., 1995; Garnett et al., 2003). It is also important to monitor taxa that make large shifts across Red List categories between regional Red List assessments (e.g. assessment shifts between the RRDB and RRL assessments). Taxa of concern for the current study are the cheetah, the African wildcat, the aardvark and the black-footed cat, which all made large shifts between the regional RRDB and RRL assessments. Rather than a change in extinction risk, these changes are most likely due to either an increase in knowledge and probably most likely the result of changes in the assessment criteria (Possingham et al., 2002; Garnett et al., 2003). Several taxa (e.g. Barbour's rock mouse (*Petromyscus barbouri*), Cape rock elephant shrew (*Elephantulus edwardii*), and Smith's rock elephant shrew (*Elephantulus rupestris*)) dropped from the GRL threatened categories to LC in RRL mainly due to the increase of relevant and up-to-date information, allowing for a decrease in suspected risk assessment (Friedmann and Daily 2004). However, it is cautioned that such changes as witnessed here, can also likely be the result of either the inconsistent use of inferences or the incorrect implementation of assessment criteria leading to erroneous threat assessments (for example, the RRDB assessments for the giant rat (*Cricetomys gambianus*) and the cheetah's "Out of Danger") (Stattersfield, 1996; Hilton-Taylor et al., 2000; Keith et al., 2004).

Likewise variation of assessments between regional and global assessments have also been linked to changes and differences in taxonomy (Garnet et al., 2003), but in the current study, this does not seem to be the case. This large flux is most likely due to the different scales at which the assessments were undertaken, which is definitely expected (Gärdenfors et al., 1999). However, in considering the various regional criteria employed in assessing South African mammals, there were a large number of regional Data Deficient taxa, whereas for the global list the same taxa were placed in a relevant threat category. This was also the case with endemic taxa attaining different assessments between the two assessments. Hilton-Taylor et al. (2000) points to the above-mentioned discrepancy being a case of inconsistent use of the IUCN Red List by the regional assessors, even though the same information and sources should be used, especially in the case of endemic mammals. Stattersfield (1996), however, indicated that the IUCN (2001) categories and criteria rely heavily on inference when there is limited data available (Gärdenfors 2001). This could also point towards the different perceptions, availability or relevance of data used by assessors (Keith et al., 2004). Overall, it does seem that the regional vs. global changes in threat assessments in this case is most likely not actual changes in extinction likelihood, but more importantly, the information that is available or used in threat assessments that has produced the current regional Red List categories and criteria for South African mammals. It is anticipated that more exact trend information with regard to the mammal's extinction likelihood will become more apparent after another regional Red List assessment.

Through the consideration of which criteria were used in different spatial or temporal Red List assessments, allows for an indication of the information drawn upon to make assessments, either due to the information being relevant for the specific assessment of a taxon, or that it is the only information available to make a correct assessment. The majority of the South African RRL assessments implemented criterion B which usually indicates that the taxon's restricted distribution (either extent of occurrence or area of occupancy), is showing a decline, becoming fragmented, or showing marked fluctuations in abundance (Mace and Balmford, 2000; IUCN, 2001). Criterion B's use is most likely, in the current study, not a function of the definitions used but rather the availability and reliance on existing knowledge of the historical distribution and range size, and the lack of reliable population trend data (McIntyre, 1992; Golding, 2004; Keith et al., 2004). Historical geographic distribution is often available for many taxa. Similarly, the RRL also pointed to criterion D, being implemented on numerous occasions (Table 5). Criterion D relies on information regarding small populations of range-restricted taxa. Very few assessments relied on information relating to declines of populations (Categories A and C) and support findings from an earlier study on plants by Golding (2004). In addition, Mace and Kershaw (1997) indicated that some criteria are more relevant for certain taxa and it will frequently be impossible to assess some taxa by criteria for which data are simply routinely unavailable, yet such shortfalls calls for continued research to provide pertinent information to make Red List re-assessments useful is necessary and has to continue to produce relevant new knowledge (Smithers, 1986)..

Another lapse of 18 years between Red List threat assessments (RRDB (Smithers 1986) and RRL (Friedmann and Daly, 2004)) cannot be appropriate for the future, if the state of South African mammals is to be monitored through the use of the IUCN Red List categories and criteria (Garnet et al., 2003). It is, therefore, imperative that the current RRL assessment should be the first of regular Red List threat re-assessments using the latest and most up-to-date IUCN Red List categories and criteria (Ferrar, 1991; IUCN, 2001).

Of the 251 terrestrial mammals in South Africa, 36 were classified as endemic, of which 17 (47.22%) were threatened (Friedmann and Daly, 2004). It would appear from the RRL assessment that a large proportion of the South African mammal endemics are threatened. Endemic taxa are often considered as of national conservation priorities, while threatened endemic taxa are considered as having an even higher priority (Rebelo and Tansley, 1993), accentuating the conservation importance of these 17 taxa within a national conservation framework (Danell and Aava-Olsson, 2002). In addition, the majority of endemic mammals are mainly small (Gelderblom and Bronner 1995), predominantly Insectivores (14 of 36 endemics; Ceballos and Brown ,1995; Friedmann and Daly, 2004). The Order Insectivora was highlighted in the regional assessment as having the most threatened taxa (42.42%) within the specific Order, and yet very few of the Insectivora were assessed by either the RRDB or the GRL. This study confirms the importance of taxa belonging to the Chrysochloridae (Gelderblom et al., 1995), especially the more cryptic and newly described taxa (44% of Chrysochloridae taxa were assessed for the first time during the recent South African Mammal RRL). The taxa from the Family Chrysocloridae display high levels of speciation and unique ecological characteristics and requirements (Gelderblom et al., 1995; Danell and Aava-Olsson, 2002), making them more vulnerable to habitat-specific threats.

Threatened species lists are designed primarily to provide an easily comprehensible estimate of extinction risk (Possingham et al., 2002), and there is no doubt that threatened species lists fulfil important requirements such as a guide to conservation planning e.g. reserve planning (see Freitag et al., 1997; Possingham et al., 2002; Lamoreux et al., 2003). Possingham et al. (2002) noted that Red Lists have limitations, and the current global and regional Red List should not be regarded as either a conservation priority setting exercise, as a yardstick to influence Environmental Impact Assessments, or as a component that influences resource allocation for the conservation of certain taxa (Ferrar, 1991; Freitag et al., 1997; Possingham et al., 2002; Victor and Keith, 2004). The IUCN Red Lists are often used as a “powerful tool for estimating the current conservation status of all taxa” (Proudlove, 2004). It is ineffective for conservation planners to use Red List for this, as IUCN Red List status simply provides an assessment of extinction risk under a set of conditions (IUCN, 2001). The Red List assessments form only part of a large suit of information (e.g. costs, logistics and legal frameworks for conservation) required to establish conservation priorities (Master, 1991; Gärdenfors et al., 2001; Harcourt and Parks, 2003, Possingham et al., 2002), which are urgently required for South African mammals.

It has become clear that if regional conservation actions and priority setting should occur, that the regional Red List threat assessment should not be used in isolation, and that the global IUCN Red List threat assessments and regional endemism should always be brought into consideration when attempting to set conservation goals and actions (Harcourt and Parks, 2003, McKee et al., 2003). With the availability of all the above mentioned information, emanating from Red List assessments such as these, the stage is set to allow for the implementation of a so called Conservation Cube. According to the IUCN (1994) and Gärdenfors (1996), any regional assessment should always be accompanied by the taxon's global threat assessment. In similar fashion, when undertaking a regional assessment, it is important to include an indication of the proportion of the international/continental population found within the country of assessment (IUCN, 1994; Gärdenfors, 1996). Failure to consider regional taxa in their larger context can often lead to short-sighted management (Hunter and Hutchinson, 1994). An indication of a species conservation requirements can be provided by combining the three measures or axes of conservation priority, with the first considering regional threat, the second a wider geographical (global) threat assessment, and the third measuring the proportion of the taxon's global distribution falling within the region of interest (as an indication of the region's importance to the global conservation of the species). One can picture this process as forming the three axes of a national conservation cube (Avery et al., 1995; Warren et al., 1997; Palmer et al., 1997). Taxa can be sorted according to their general "location" within this "conservation cube", by putting national conservation priorities into the context of international conservation priorities (Avery et al., 1995; Warren et al., 1997). The Conservation Cube allows the sorting of the taxa according to a combination of their regional and global threat listing as well as varying regional endemism (Avery et al., 1995). The Conservation Cube allows for a useful guide to assign regional assessments in an international framework, which in turn can inform regional prioritisation exercises. In using the Conservation Cube, taxa are awarded a further dimension of conservation priority. Instead of considering three separate and unique threat assessments and endemism values in isolation, which provides invaluable information all the same, the Conservation Cube provides the user a unique means of viewing priority taxa in a unique combination which can further elucidate a taxon's importance in terms of regional and global conservation. The implementation of such a Conservation Cube for South African mammals will be investigated in the near future.

5. Conclusion

The application of the IUCN Red List categories and criteria (IUCN, 1994; 2001) to the regionally extant mammal taxa found within the borders of South Africa has improved local knowledge of the current risk of various mammals becoming extinct in the near future. Moreover, it has also provided an opportunity to evaluate South African marine mammals at a regional scale for the first time since the conception of the quantitative threat assessment criteria (e.g. IUCN Red Lists). This will allow a better reflection of objective and quantitative evaluations of threat for the purpose of incorporating threat levels into national conservation planning (Master, 1991; Mace, 1995; Possingham et al., 2002). In addition, the up-dated regional list and its resulting up-dated data will be available for up-dating the global RL. It is anticipated that the new regional IUCN Red List threat assessment (Friedmann and Daly, 2004) will be used to inform, influence, and assist regional and provincial conservation priority setting actions for South African terrestrial and marine mammals.

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CHAPTER 3

Incorporating measures of anthropogenic threat in regional conservation assessments: A case study based on South African mammals

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Abstract

Informed conservation decisions can only be made after assessing current threats to biodiversity. The inclusion of human demographic data as one potential measures of biodiversity threat is known to improve our understanding of threats. The present study examines six possible human threat variables and their impacts on mammal priority assessments in South Africa. These variables which were also combined into a "Combined Human Threat" (CHT) measure for each of the assessed taxa incorporated: 1) average human density; 2) human population growth rate changes; 3) a poverty index; 4) per capita income expressed as Gross Geographic Product (GGP)/capita; 5) infrastructure, with reference to the degree of urbanisation and road cover; and 6) percentage land area transformed and degraded. The potential influence of the six anthropogenic variables were evaluated with reference to three measures of mammalian richness, namely: 1) overall mammalian richness; 2) endemic mammal richness; and 3) threatened mammal richness. There were varying, but weak statistically significant correlations between the human threat variables and the three measures of mammalian richness. There was little variance found across the three measures of mammalian richness in the manner they were predicted by the anthropogenic variables, suggesting that the potential mammal richness and human-threat variables may be responding to a common driver such as primary productivity. However, this analysis highlighted various mammals that were also categorized as threatened in the 2004 regional IUCN Red List, as well as being under considerable threat due to human activities. Moreover, a number of other mammalian taxa, mostly within the Orders Rodentia and Chiroptera, not necessarily threatened, emerged as mammals vulnerable to human threat. In addition, our results revealed 16 Data Deficient (DD) mammals which experienced higher than average combined human threat values than all Threatened mammals from South Africa. It is therefore possible that these mammals may be under higher risk than indicated in the 2004 regional IUCN Red List, or that these mammals are well adapted to human dominated landscapes.

Key words: Anthropogenic activities, extinction threat, IUCN South Africa mammals

Introduction

Human actions threaten biological diversity at a global scale, and these sources of threat include taxon-specific threats such as exploitation, introduced taxa as well as various forms of ecosystem degradation e.g. land transformation, pollution etc. (World Resources Institute 2000). These threats disrupt and alter ecosystem structure and function (Sisk et al. 1994) and eventually leading to species' extinctions (Kerr & Currie 1995). Informed species conservation decisions can only be made after assessing the current state and threats faced by species in order to identify priority species for conservation. This forms only a part of a multi-faceted approach that can be used to set conservation priorities (Hannah et al. 1994; Sisk et al. 1994). Various studies have focused on assessing the state of species populations and a wide range of techniques such as IUCN Red List Criteria and Categories (IUCN 2001) have been developed and are routinely used for this purpose. However, it is only recently that human impacts have been incorporated into species threat status assessments (Mills et al. 2001; Harcourt & Parks 2003).

Various human activities, their effects on animal and plant taxa and the associated extinction vulnerabilities have been investigated (Kerr & Currie 1995; Thompson & Jones 1999; Cincotta et al. 2000; Ceballos & Ehrlich 2002; Harcourt & Parks 2003; Liu et al. 2003). Overall, these studies strongly suggest correlations between continental rates of habitat change and local species disappearances with levels of human activity (Cincotta et al. 2000; Balmford et al. 2001; Ceballos & Ehrlich 2002; Harcourt & Parks 2003, Luck et al. 2003; van Rensburg et al. 2004a).

It is critical to understand the relationship between human activity and biodiversity condition at national scales, as this allows the identification of local threatening processes and priority areas, and more specifically, specific taxa at risk of extinction (Chown et al. 2003; Liu et al. 2003). Species richness has been successfully used as a biodiversity surrogate in such assessments. These data are available and relatively easy to compile, and are often useful for prioritising areas of conservation importance (Fjeldså 2000). However, the relationship between human activities, mammal richness, and threats to species richness at a national level remain largely unclear. South Africa has several spatially explicit datasets of human demographic data (Central Statistical Service 1995; 1998; Fairbanks et al. 2001; Harcourt & Parks 2003), and a national assessment of human activity and species threat status can use such data.

Six human activity related variables (for which data are readily available) human population density, human population change, a poverty index; affluence measure (expressed as Gross Geographic Product (GGP)/capita), infrastructure and land transformation and degradation are widely acknowledged as threats to plant and vertebrate taxa in the study area and elsewhere (Macdonald 1991; James 1994; Kerr & Currie 1995; Cincotta et al. 2000; Ceballos & Ehrlich 2002; Harcourt & Parks 2003, Luck et al. 2003). While it is acknowledged that human activities are complex, and not entirely encapsulated in these six variables, these variables will allow for improved insight into the relationship between human activity and mammal species threat in South Africa.

Due to the strong correlations between human density, population growth, poverty, and environmental degradation, these factors are mostly reinforced by additional influences such as household dynamics, urbanization, technology, and political stability (World Resources Institute 2000; Liu et al. 2003; Rouget et al. 2003). It has however been demonstrated that as human populations grow, this results in declining agricultural productivity/capita, and this in turn, increases levels of rural poverty (Upkolo 1994). Consequently, rural populations migrate to urban areas (Upkolo 1994; World Resources Institute 2000) resulting an urban sprawls that generally lead to the complete transformation of relatively large urban fringes (Macdonald 1991; Cincotta et al. 2000; Liu et al. 2003). The combined forces of population demographics therefore, exert tremendous pressures on ecological systems in especially Africa and other developing areas of the world (Ukpolo 1994; Hanks 2000; Rouget et al. 2003; van Jaarsveld et al. 2005).

Human population density is considered a relatively good indicator of threat in the assessment of risk of species extinctions (Thompson & Jones 1999; Harcourt & Parks 2003) because vertebrate population declines are mostly concentrated in areas with either high human densities or with high human impact such as agricultural areas (Burgess et al. 2002; Ceballos & Ehrlich 2002; Araújo 2003).

In many countries, increasing poverty is closely related to high population density, which in turn exerts tremendous local pressure on biodiversity (Lucas & Synge 1981; James 1994). Consequently, poverty-stricken communities are forced to rely on surrounding resources for survival, which often leads to environmental degradation (James 1994). In addition, the relationship between per capita income (GNP) and environmental degradation has been shown to be complex (Naidoo & Adamowicz 2000). Per capita

GDP has also been shown to be closely correlated with the proportion of threatened mammals (Kerr & Currie 1995; Naidoo & Adamowicz 2001). Naidoo and Adamowicz (2001) reports that high GNP usually triggers excessive land conversion and resource exploitation, which increases the number of threatened taxa.

Changes in land-use and cover are important drivers in the broader context of global environmental change. The impact of anthropogenic land use and the loss of species is often directly related to the proportion of the area either degraded, transformed and/or fragmented (Pfab & Victor 2002; Melles et al. 2003; Theobald 2003). Theobald (2003) found areas with more than 15% development to be highly fragmented and, therefore, impact negatively on species and resulting in local extinctions. Similarly, road networks have been implicated to have disproportionate effects on species, their construction and maintenance significantly altering and fragmenting natural habitats and landscapes (Macdonald 1991; Reyers 2004).

Both natural and anthropogenic factors are important in determining a taxon's risk of extinction (Kerr & Currie 1995) and consequential its priority for conservation. The use of regional IUCN Red List (RL) assessments (Friedmann & Daly 2004) which provide an assessment of species extinction risks, in conjunction with measures of anthropogenic impacts, may allow for more informed decisions about the conservation priority of South African mammals (Hannah et al. 1994; Sisk et al. 1994; Harcourt & Parks 2003). The current study is aimed at investigating the relationship mammal richness measures (including endemic and threatened mammal richness) and measures of anthropogenic threat to assess the conservation status of South African mammals across the country.

Methods

South African Mammal data

Regional IUCN Red List assessment information (Friedmann & Daly 2004) for 249 currently recognized extant South African terrestrial mammals was included in the current study in addition to their respective distribution information. Two types of distribution data were used for analysis: presence records and extent of occurrence range maps (Freitag & van Jaarsveld 1995; Keith 2004). These data sets were based upon presence data (Frietag & van Jaarsveld 1995; updated for Friedmann & Daly 2004), and the extent of occurrence data (range maps; Keith 2004) that can be regarded as the potential distribution of species. The use of presence data in conjunction with distribution range maps have been proven to be the most effective way of mapping mammal biodiversity in South Africa, circumventing potential data bias of large mammals being restricted to conservation areas as well as additional data constraints (Freitag & van Jaarsveld 1995; Gelderblom & Bronner 1995). All distribution data were generalised to a common resolution of the quarter degree squares (QDS – an area of ~ 625km^2).

Three measures of mammalian richness were derived from the distribution data. First, a measure of overall mammal richness (OMR) for South Africa was collated at the QDS level. The second included a literature-derived measure (Skinner & Smithers 1990; Siegfried & Brown 1992; Friedmann & Daly 2004) of South African endemic mammal richness (EMR). The third included a measure of South African threatened mammal richness (TMR) based on all mammals highlighted as "Threatened" by Friedmann & Daly (2004) (categorised as Vulnerable (VU), Endangered (EN), or Critical Endangered (CR)). As suggested by Rebelo & Tansley (1993), both EMR and TMR were standardized and corrected for total mammal richness in order to derive a standardized EMR and TMR at a QDS scale.

South African anthropogenic data

Six anthropogenic variables were used in the present study including: 1) human population density, 2) human population growth rate change 3) a poverty index; 4) affluence measure 5) infrastructure, and 6) the degree of land transformation and degradation. Human population density, human change, poverty, and affluence data were derived from magisterial district data (Central Statistical Service 1995, 1998), while all land-cover and transformation data were collated from the National Land-Cover database (Fairbanks & Thompson 1996). In order to standardize with the mammal distributional data, data were converted to a spatial scale at the QDS level using ESRI ArcView GIS 3.2. Consequently, most human demographic and impact data represent weighed averages/QDS.

The 1996 South African population census data (Central Statistical Service 1998) were used to estimate the weighted average population density per QDS (Human Density - HD). HD was denoted as the average number of people/km^2 within each QDS. The average percentage increase/decrease of human population per QDS (human growth rate change - HC) over the period 1996 to 2001 (Central Statistical Service 1998; Rouget et al. 2004) was used as a direct proxy for the impact of human population growth on the environment.

A poverty index (Economic Poverty (EP)) was estimated as the proportion of people per municipality earning less than R200 per month (Central Statistical Service 1998). A United Nations Development Programme South Africa (2003) report for South Africa indicated that people earning less than R354 per month could be regarded as earning below the poverty line. The census data uses broad categories of which "less than R200/month" together with the "no income" category was regarded as earning below the poverty level. This allowed the computation of a weighted average of the proportion of people per QDS earning less than R200/month.

A measure of Economic Affluence (EA) denoted as the weighted average GGP/capita income per QDS, was based on Gross Geographic Product (GGP) obtained for all South African magisterial districts (Central Statistical Service 1995). GGP represents "the remuneration received by the production factors – land, labour capital and entrepreneurship for their participation in production within a defined area" (Central Statistical Service 1995). The Central Statistical Service (1995) provides 1994 estimates of GGP and remuneration of employees by magisterial district in South African Rand (R). This GGP data represents the finest-scale data available and was incorporated in the current analysis rather than GNP data as previously used by Kerr & Currie (1995).

Current infrastructure data were extracted from the National Land-Cover database (NLC) (Fairbanks & Thompson 1996). One of the land-cover variables included in the current study was the percentage of QDS' covered by road and urbanised areas (Land — cover – Roads and Urban (LRU). A buffered road network for South Africa was obtained from Reyers et al. (2001) representing various buffered road types in South Africa. The extent of the urban area was extracted from all types of "Urban/built-up land" land cover type (= land cover type 24-30; Fairbanks & Tompson 1996) in the NLC database.

An additional land-cover variable, the degree of Land — cover – Transformed and Degraded (LTD) was also extracted from the NLC database. Fairbanks et al. (2001) grouped 31 land-cover classes in

South Africa into three categories, namely, Natural, Transformed, and Degraded land-cover types. The area transformed and degraded in each QDS was calculated to represent a measure of LTD.

Statistical Analysis

By collating the six measures of human impact on the environment used in the present study, a Combined Human Threat (CHT) measure was derived for each QDS in South Africa. Initially, the QDS data for South Africa were ranked according to each of the six separate anthropogenic measures. Subsequently, an averaged CHT rank score for each mammal species was based on the average human impact measure ranks throughout the species' QDS range. All six anthropogenic variables were ranked and weighted equally in calculating CHT. The relationship between CHT and mammal distribution in South Africa was assessed in order to derive an average CHT rank for each of the 249 mammals with reference to their respective QDS distributional ranges.

All three measures of richness (OMR, EMR and TMR) and the six-anthropogenic variables (HD, HC, EP, EA, LRY LTD, and CHT) were log-transformed for statistical analyses. Kruskal-Wallis Analysis of Variance (ANOVA) by Ranks and Spearman's *R* Rank order correlations (Zar 1996) were used to test for statistical differences and correlations, respectively, between measures of mammal richness and CHT and the six anthropogenic variables. Independent Generalized Linear Models (GLZ; McCullagh & Nelder 1989) were used to assess the relationship between each of the three measures of mammal richness and the six anthropogenic variables.

Because the measures of mammal richness were in the form of counts, a Poisson distribution with a logarithmic link function was used in the GLZ (Maggini, Guisan & Cherix, 2002). A goodness of fit test (a deviance statistic), which explains the proportion of deviance for each model in the GLZ (McCullagh & Nelder 1989) was independently used to assess the relationship between: 1) the three measures of mammal richness, namely, OMR, EMR, and TMR; 2) the six anthropogenic variables, namely, HD, HC, EP, EA, LTD, and CHT; 3) mammal species, IUCN Red List categories, human pressures, and threat. All statistical analyses were based on analytical sub-routines in STATISTICA version. 6 (StatSoft 2001).

Results

South African mammal richness

The three measures of mammal richness, namely, OMR, EMR, and TMR were all significantly different from each other (Kruskall Wallis $H_{3,\ 5871}$ = 12491; P < 0.001). OMR was significantly correlated with EMR (Spearman's R = 0.36; n = 1955; P < 0.05), with the regression model explaining approximately 67.83% (Pearson ^{2} = 503.74; d.f. = 1955; P < 0.001) of the total variance. Similarly, OMR and TMR were strongly and significantly correlated (Spearman's R = 0.64; n = 1955; P < 0.05), with the regression model explaining approximately 56.56% (Pearson ^{2} = 658.62; d.f. = 1955; P < 0.01) of total variance. The relatively strong correlations suggest a strong influence of OMR in explaining endemic and threatened mammal counts in South Africa.

Anthropogenic measures

Areas of high combined human threat (CHT) were generally found throughout the Western Cape, areas of the Eastern Cape, Free State North West Province and Gauteng (Figure 1). HD and HC were high in the large metropolitan areas such as those in the Western Cape, Gauteng, and KwaZulu-Natal Provinces (Figure 2a-c). Gauteng Province shows the highest average anthropogenic variables except for EP and EA. KwaZulu-Natal Province presented the highest EP, North-West Province the highest EA, with Northern Cape Province yielding very low EA values throughout the province. While areas with high LRU are in Gauteng, areas with high LTD are evident in the Western Cape, Eastern Cape, North-West, and Free State Provinces (Figure 2a-c).

CHT ranking and the six anthropogenic variables were all strongly significantly different from each other (Kruskall Wallis $H_{6,\ 11601}$ = 7307.40; P < 0.001), with varying negative and positive correlations between them (Table 1). Larger Spearman's R-values indicate a strong dependence of the respective variables on one another. In most cases, EA was negatively correlated with other anthropogenic variables (Table 1), suggesting a weak dependence between EA and the other anthropogenic variables. EP and HC were the only variables that were not correlated.

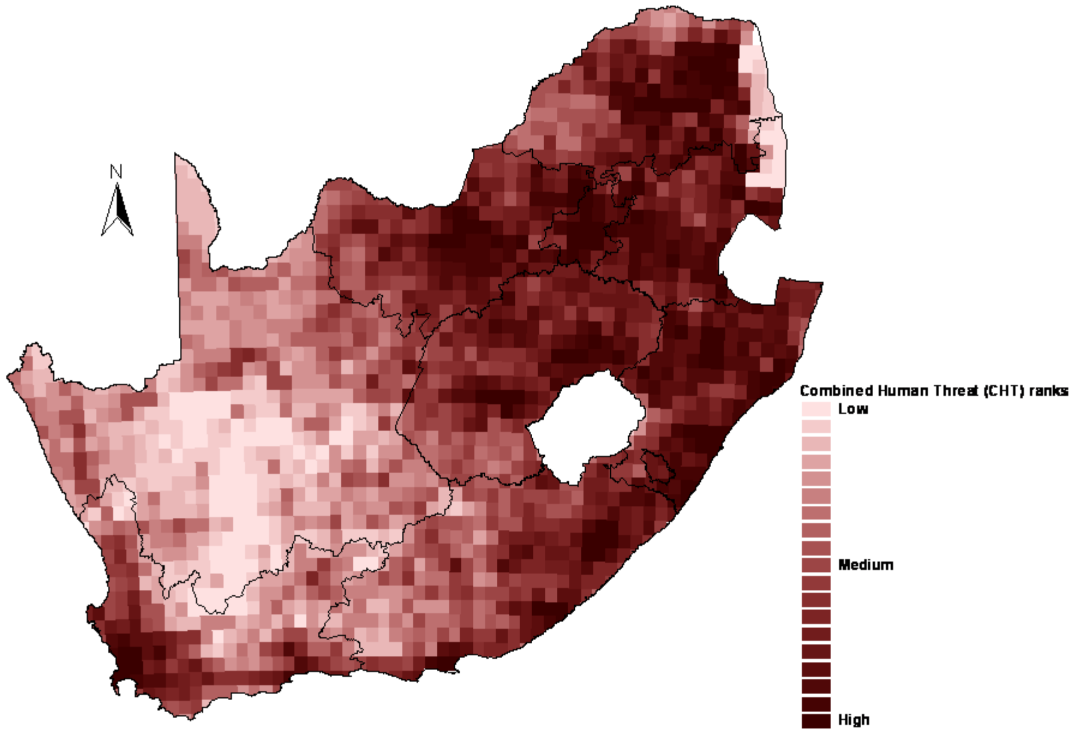

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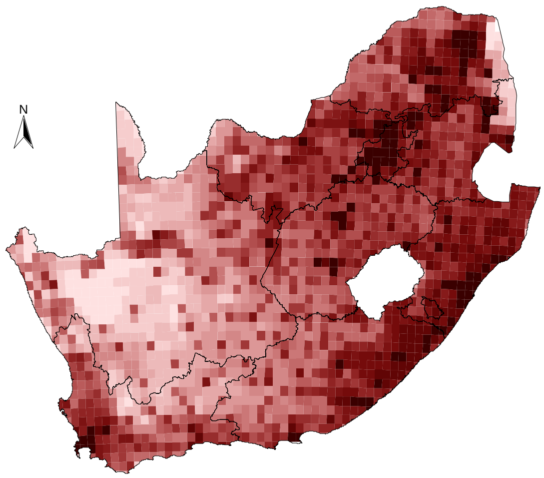
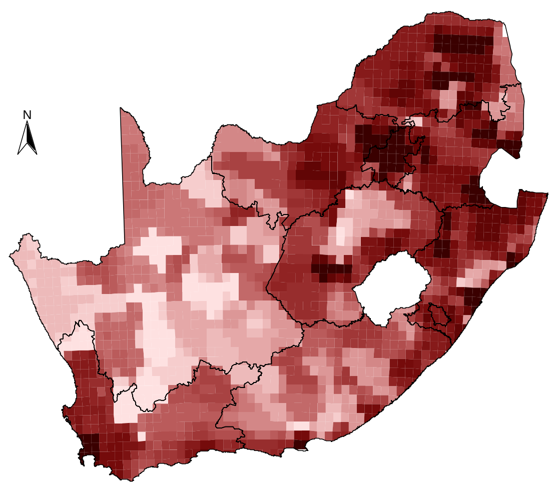
Figure 1. Spatial representation of the combined human threat (CHT) ranked QDS across the South African landscape, based on six anthropogenic measures, human density, human population rate change, poverty, affluence, infrastructure and area transformed or degraded.

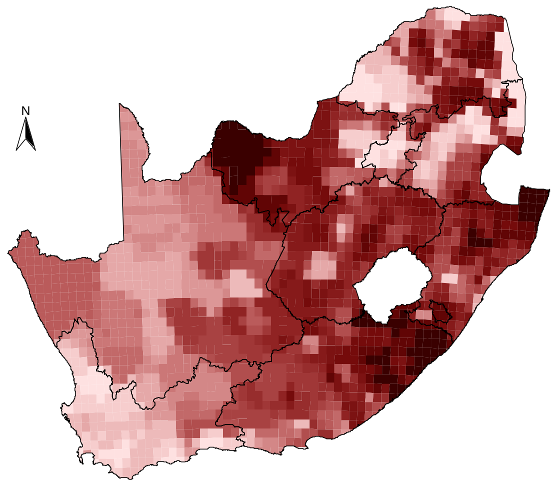


HD

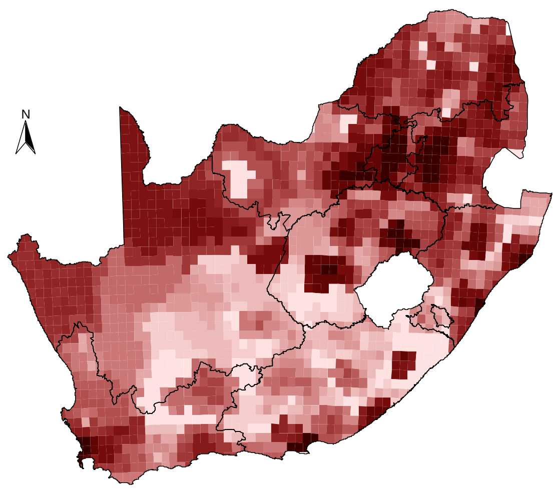


HC

Figure 2a. Spatial representation of 1) human population density (HD), 2) human growth rate change (HC), which were used in combination of the other anthropogenic ranks to calculate a human threat measure (CHT). High impacts are in darker colours and light impacts in light shades.

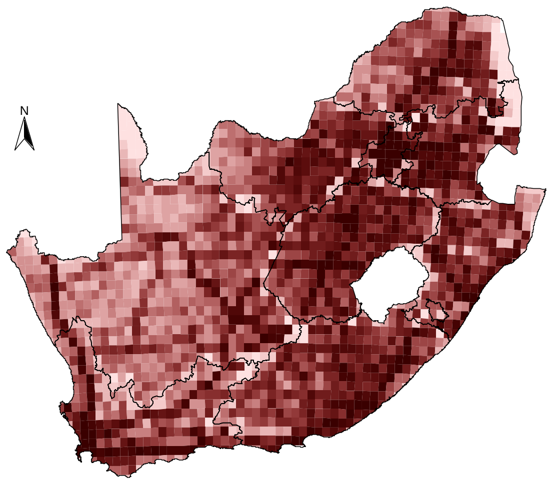


EP

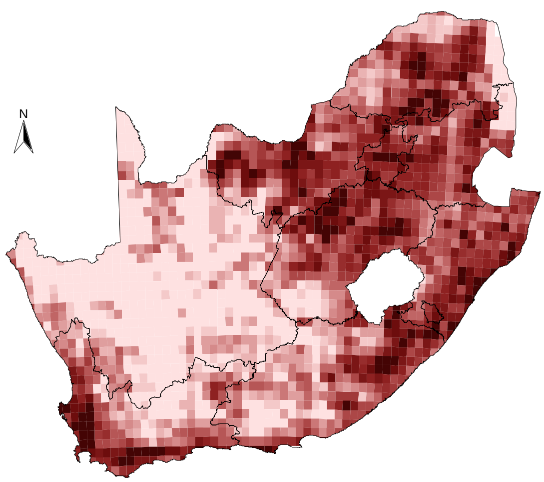


EA

Figure 2b. Spatial representation of 3) poverty index (economic poverty (EP); 4) measure of economic affluence (EA) denoted as the weighted average GGP/capita (EA) which were used in combination of the other anthropogenic ranks to calculate a human threat measure (CHT). High impacts are in darker colours and light impacts in light shades.



LRU



LTD

Figure 2c. Spatial representation of 5) infrastructure (road and urbanised areas (LRU)), and 6) the degree of land transformation and degradation (LTD), which were used in combination of the other anthropogenic ranks to calculate a human threat measure (CHT). High impacts are in darker colours and light impacts in light shades.

Table 1. Spearman Rank order correlation (*R* – values) for the six-anthropogenic measures. Abbreviations are as follows: HD = human density, HC = human growth rate change (HC), EP = economy poverty, EA = economy affluence, LRU = land use roads and urbanization, LTD = land use transformed and degraded, and CHT = combined human threat. All bold values indicate a statistical significance of $P < 0.05$. Values with superscript **ns** is not statistically significant correlated.

	HD	**HC**	**EP**	**EA**	**LRU**	**LTD**
HD	**1.00**					
HC	**0.54**	**1.00**				
EP	**0.34**	0.003 ^{ns}	**1.00**			
EA	**-0.86**	**-0.37**	**-0.48**	**1.00**		
LRU	**0.57**	**0.26**	**0.10**	**-0.49**	**1.00**	
LTD	**0.73**	**0.54**	**0.25**	**-0.59**	**0.42**	**1.00**
CHT	**0.88**	**0.66**	**0.40**	**0.35**	**0.65**	**0.82**

Relationships between South African mammal richness and anthropogenic impact

OMR, the six anthropogenic variables, and CHT were all significantly correlated (Table 2). OMR was positively correlated with HD, HC, LRU, LTD, as well as with CHT. EP was weakly correlated with OMR. The GLZ model generally fitted poorly with six anthropogenic variables, with OMR accounting for very little of the percentage deviance explained (< 6.86 %; Table 2), and CHT explaining 12.26% of the deviance.

EMR and the six anthropogenic variables were all weakly correlated with each other (Table 2), and the independent anthropogenic variables did not substantially explain the variance found in EMR (Table 2), with CHT accounting for only 16.71% of the variance. Both EP and EA were weakly negatively correlated with EMR, with EP accounting for a small proportion of the variance. EA and EMR were negatively correlated with EA accounting for only 0.52% of the variation.

On the other hand, TMR and the six anthropogenic variables were all weakly significantly correlated, except for EP (Table 2). EA and TMR were negatively correlated, with EA contributing little to the total variance (Table 2). EP and LRU were not significantly correlated, while very little significant deviance (< 3.54%) was evident between the remaining anthropogenic variables (Table 2). CHT explained the highest proportion (17.09%) of the deviance observed within TMR.

Relationship between mammals and human activity measures

With reference to the recent regional IUCN Red List assessment (Friedmann & Daly 2004), 50 of the 249 terrestrial mammals included in the present analysis were identified as threatened (i.e., CR, EN, and VU)). Generally, CHT and the six anthropogenic data show considerable variation within each of the IUCN Red List categories (Table 3). The exclusion of large bodied mammals (those most likely to be restricted to conservation areas) from the analysis did not affect the outcome between mammal richness measures and the human variables (Keith unpublished data). Mammals categorized as CR taxa did not show the highest relationship with either CHT or the six anthropogenic variables. HD and LRU showed the highest relationship with all IUCN categories. The anthropogenic values for the components CHT and EP were significantly different when inter threat (CR-, EN-, and VU-assessed mammals) comparison were

Table 2. Spearman Rank (*R* - values) and *P* value, as well as the generalised linear model (a Poisson error distribution, using a Log Link function (McCullagh & Nelder 1989)) parameters for between overall mammal richness (OMR), endemic mammal richness (EMR), between threatened mammal richness (TMR) as well as combined human threat (CHT); human density (HD); human population rate change (HC); economy poverty (EP); economy affluence (EA); infrastructure (LRU) and land use transformed and degraded (LTD). (Statistical significance: *** = P < 0.001; ** = P < 0.01; * = P < 0.05; ns = not statistically significant)

	OMR Spearman *R* value	OMR Explained Deviance	*OMR Pearson* ^{2}	EMR Spearman *R* value	EMR Explained Deviance	*EMR Pearson* ^{2}	TMR Spearman *R* value	TMR Explained Deviance	*TMR Pearson* ^{2}
CHT	0.41 *	12.26 ***	38990.8	0.41 *	16.71 **	5299.3	0.4 *	17.09 **	5440.7
HD	0.43 *	5.7 **	43797	0.19 *	2.83 **	5497.66	0.14 *	3.54 **	5507.44
HC	0.4 *	6.86 **	43147.7	0.12 *	3.16 ***	5428.08	0.19 *	3.47 ***	5501.54
EP	0.05 *	0.03 *	45260.9	-0.13 *	6.06 **	4711.67	-0.28 ^{ns}	0.16 ^{ns}	5494.7
EA	-0.33 *	0.02 **	45218.1	-0.17 *	0.52 **	5515.78	-0.11 *	0.45 **	5438.64
LRU	0.21 *	2.37 **	45478.9	0.19 *	5.77 **	5279.96	0.06 *	0.18 ^{ns}	5537.99
LTD	0.3 *	2.17 **	45280.8	0.17 *	5.07 **	5084.94	0.14 *	1.13 ***	5586

Table 3. Layout of average human variables (Mean ± Standard Error) for the IUCN Red List assessment of all mammal taxa under consideration for the current study. IUCN Red List categories comprise of Critically Endangered (CR), Endangered (EN) and Vulnerable (VU) (Threatened categories), Near Threatened (NT), Data Deficient (DD) and Least Concern (LC). Human variables included Combined Human Threat measure (CHT) as well as the six human variables (HD = human density ($\overline{X}$ people/km^2), HC = human growth rate change ($\overline{X}$ % increase/decrease of people), EP= economy poverty (proportion of people earning < R200/month), EA = economy affluence (Rand (GGP) x R1 000 000), LRU = infrastructure (% area under urban or road cover), LTD = land use transformed and degraded (% area transformed or degraded). Values in bold indicate variable that is higher than the average IUCN threatened "average" value.

Red List assessment	*N*	CHT	HD	HC	EP	EA	LRU	LTD
CR	10	856.88 ± 328.27	81.19 ± 125.7	4.85 ± 14.45	57.97 ± 9.41	102.82 ± 153.55	7.75 ± 6.32	26.62 ± 18.87
EN	15	1048.59 ± 173.45	59.09 ± 30.67	9.42 ± 4.94	66.91 ± 8.88	738.59 ± 256.1	6.4 ± 1.97	30.63 ± 10.63
VU	25	982.3 ± 173.86	67.52 ± 68.46	9.74 ± 7.45	62.74 ± 9.34	833.48 ± 591.3	6.47 ± 2.97	30.19 ± 12.49
Threatened	50	970.64 ± 218.45	68.76 ± 74.34	8.49 ± 24288.42	62.69 ± 9.56	856.46 ± 797.83	6.72 ± 3.61	29.6 ± 13.0
NT	36	904.2 ± 197.29	44.64 ± 27.66	8.48 ± 7.63	60.56 ± 6.81	743.26 ± 244.76	5.88 ± 1.91	23.63 ± 10.74
DD	30	**978.65 ± 122.74**	53.8 ± 20.39	**10.64 ± 3.27**	62.35 ± 5.1	799.36 ± 230.87	6.54 ± 1.42	26.78 ± 5.89
LC	133	878.99 ± 151.02	41.55 ± 21.33	8.33 ± 5.63	60.31 ± 4.02	736.94 ± 211.49	6.15 ± 1.2	22.74 ± 7.91
Average	249	914.34 ± 175.51	48.73 ± 39.96	8.7 ± 6.47	61.14 ± 6.13	766.79 ± 407.66	6.27 ± 2.04	24.74 ± 9.8

undertaken. Similarly, a comparative analysis between threatened (i.e., CR, EN, and VU) and not threatened (i.e., NT, DD, and LC) assessed mammals indicated that only CHT and LTD were significantly different (Table 4). Of interest though is the relatively low average CHT value for the Critically Endangered (CR) mammals (Table 3). These low values can be attributed to the fact that CR assessed mammals were largely restricted to areas where the current study identified low anthropogenic impact in terms of low HC, EP, and EA (e.g. riverine rabbit, *Bunolagus monticularis* and Visagie's golden mole *Chrysochloris visagiei*).

However, when the means of CHT and anthropogenic variable values of threatened mammals were used as a threshold (average value calculated from the Threatened categories for each of the six human threat variables and CHT), mammals categorized as DD showed higher CHT and HC values than the average CHT and HC values for mammals categorized as Threatened. Neither CHT nor any of the six anthropogenic variables were statistically significantly different from each other when DD and threatened mammals were compared (Table 4). When Orders were compared, CHT, HD, and LTD differed significantly from each other (Table 4). When individual CHT rankings for all DD mammals were used, 15 of the 30 DD mammals showed a higher mean CHT ranking than that of the threatened mammals (average CHT = 977.10) (Table 5; Table 6).

When South African mammals were ranked with reference to CHT, various non-threatened and some threatened mammals occurring in areas of high human impact were identified (Appendix 2). From this ranking, some NT-, DD-, and LC-categorized mammals were ranked highly, and these mostly consisted of members of the Orders Insectivora, Rodentia, and Chiroptera. The top five ranked mammals included: 1) the Pretoria sub-population of Juliana's golden mole*, *Neamblysomus julianae* (CR A2c; B1ab (i-v)+B2ab (i-v)); 2) Large-eared free-tailed bat, *Otomops martiensseni* (VU D2); 3) Gunning's golden mole*, *Neamblysomus gunningi* (EN B1ab(i-iv) B2ab(i-iv)); 4) Nyika climbing mouse, *Dendromus nyikae* (NT), 5) and Sclater's forest shrew*, *Myosorex sclateri* (EN B1b(ii,iii), c(iv)+2b(ii,iii), c(iv)). Three of these five top-ranked mammals are endemic to South Africa (denoted by *). Some of the highly threatened Red List species, Visagie's golden mole, *Chrysochloris visagiei* (CR D) and the riverine rabbit, *Bunolagus monticularis* (CR C2a(i), E) (both endemic) received very low respective CHT scores.

Table 4. Statistical analysis (Kruskall Wallis *(H)* and Mann Whitney *U*) test statistics for comparisons between 1) three IUCN Red List categories comprising of Critically Endangered (CR), Endangered (EN) and Vulnerable (VU) (threatened categories), 2) Threatened taxa and not threatened taxa (Near Threatened (NT), Data Deficient (DD) and Least Concern (LC)), 3) Threatened taxa and DD taxa, and 4) comparisons between 13 Orders (Artiodactyla, Carnivora, Chiroptera, Hyracoidea, Insectivora, Lagomorpha, Macroscelidea, Perissodactyla, Pholidota, Primates, Proboscidea, Rodentia, and Tubulidentata). Analysis included combined human threat measure (CHT) as well as the six human variables (human density (HD); human growth rate change (HC); economy poverty (EP); economy affluence (EA); infrastructure (LRU) and land use transformed and degraded (LTD)). (Statistical significance: *** = $P < 0.001$; ** = $P < 0.01$; * = $P < 0.05$; ns = not statistically significant).

Variable	CR, EN and VU *Kruskal-Wallis H* $_{(2; 50)}$	Threatened vs. Not threatened *Mann Whitney U*	Threatened vs. Data Deficient *Mann Whitney U*	Between all Orders *Kruskal-Wallis H* $_{(12; 249)}$
CHT	6,65 **	3386.0 ***	668.0 ^{ns}	19.90 *
HD	2.59 ^{ns}	4401.000 ^{ns}	713.0 ^{ns}	20.72 *
HC	1.27 ^{ns}	4534.5 ^{ns}	688.0 ^{ns}	16.77 ^{ns}
EP	8.28*	4366.0 ^{ns}	742.0 ^{ns}	7.62 ^{ns}
EA	1.41 ^{ns}	4249.5 ^{ns}	573.0 ^{ns}	11.71 ^{ns}
LRU	0.67 ^{ns}	4958.0 ^{ns}	691.0 ^{ns}	16.90 ^{ns}
LTD	4.52 ^{ns}	3284.0 ***	598.0 ^{ns}	23.86 **

Table 5. Layout of average Combined Human Threat (CHT) rank and six human variables as calculated for all terrestrial mammal Orders (human density (HD); human growth rate change (HC); economy poverty (EP); economy affluence (EA); infrastructure (LRU) and land use transformed and degraded (LTD)). Human Density (HD); Human Increase (HI); Economy Poverty (EP); Economy Affluence (EA) (x R1 000 000); Land use Roads and Urbanization (LRU) and Land use Transformed and Degraded (LTD). Values in bold indicate to an Order with specific human variable that is higher than the average IUCN threatened "average" as calculated in Table 3

Order	**CHT**	**HD**	**HC**	**EP**	**EA**	**LRU**	**LTD**
Artiodactyla	946.85 ± 108.71	48.6 ± 20.45	**10.48 ± 4.44**	61.39 ± 5.17	774.57 ± 189.07	6.35 ± 1.11	25.76 ± 6.11
Carnivora	885.6 ± 94.34	39.61 ± 14.05	8.58 ± 3.91	60.59 ± 2.42	732.57 ± 151.89	6.04 ± 1.1	22.28 ± 4.93
Chiroptera	957.11 ± 150.5	61.67 ± 46.65	**9.55 ± 5.97**	61.29 ± 6.26	825.41 ± 330.12	6.1 ± 1.77	27.09 ± 10.89
Hyracoidea	957.82 ± 130.42	58.09 ± 31.52	**10.18 ± 5.73**	62.6 ± 6.93	633.81 ± 28.94	6.66 ± 1.65	27.46 ± 7.83
Insectivora	**975.58 ± 196.87**	63.44 ± 67.85	**10.97 ± 7.82**	60.84 ± 8.83	**970.99 ± 901.42**	**7.66 ± 3.73**	29.28 ± 8.68
Lagomorpha	814.35 ± 215.58	33.48 ± 27.4	5.09 ± 8.37	60.41 ± 3.22	648.35 ± 351.59	6.07 ± 1.17	18.33 ± 10.26
Macroscelidea	773.31 ± 214.23	25.9 ± 22.9	4.77 ± 7.13	60.4 ± 7.43	631.33 ± 286.25	5 ± 1.55	16.13 ± 10.56
Perissodactyla	835.46 ± 223.72	29.57 ± 26.12	**8.89 ± 7.76**	58.95 ± 3.89	635.89 ± 260.59	5.49 ± 1.26	19.88 ± 11.08
Pholidota	959.25 ± 0	32.88 ± 0	**10.2 ± 0**	61.92 ± 0	676.55 ± 0	5.1 ± 0	25 ± 0
Primates	**1006.75 ± 89.95**	55.7 ± 16.6	**9.64 ± 4.95**	**66.71 ± 9.51**	670.19 ± 341.11	6.03 ± 1.98	28.04 ± 4.2
Proboscidea	896.02 ± 0	36.41 ± 0	**12.26 ± 0**	58.29 ± 0	676.18 ± 0	4.35 ± 0	19.14 ± 0
Rodentia	871.77 ± 215.2	41.61 ± 34.42	6.67 ± 7.34	61.06 ± 6.15	693.11 ± 221.99	6.05 ± 1.79	23.15 ± 11.76
Tubulidentata	826.03 ± 0	33.55 ± 0	5.57 ± 0	61.2 ± 0	660.11 ± 0	6.12 ± 0	19.83 ± 0
Overall average	914.34 ± 175.51	48.73 ± 39.96	8.7 ± 6.47	61.14 ± 6.13	766.79 ± 407.66	6.27 ± 2.04	24.74 ± 9.8

Table 6. Sixteen Data Deficient taxa highlighted as having an above Threatened average Combined Human Threat (CHT) and their associated CHT rank.

Order	**Taxon**	**Common name**	**CHT value**	**CHT Rank**
Chiroptera	*Epomophorus gambianus crypturus*	Gambian epauletted fruit bat	982.4886	121
Chiroptera	*Hipposideros caffer*	Sundevall's leaf-nosed bat	1003.185	129
Insectivora	*Amblysomus hottentotus*	Hottentot's golden mole	1076.838	18
Insectivora	*Crocidura flavescens*	Greater musk shrew	983.044	65
Insectivora	*Crocidura fuscomurina*	Tiny musk shrew	1004.341	109
Insectivora	*Crocidura mariquensis*	Swamp musk shrew	1078	24
Insectivora	*Myosorex cafer*	Dark-footed forest shrew	1161.554	8
Insectivora	*Myosorex varius*	Forest shrew	980.3984	71
Insectivora	*Suncus infinitesimus*	Least dwarf shrew	1071.421	17
Insectivora	*Suncus lixus*	Greater dwarf shrew	1047.066	74
Rodentia	*Grammomys cometes*	Mozambique woodland mouse	1082.664	58
Rodentia	*Grammomys dolichurus*	Woodland mouse	1053.83	35
Rodentia	*Graphiurus platyops*	Rock dormouse	1042.439	73
Rodentia	*Lemniscomys rosalia*	Single-striped mouse	1053.89	56
Rodentia	*Mus neavei*	Thomas' pygmy mouse	1259.392	10
Rodentia	*Mus orangiae*	Free state pygmy mouse	1115.644	67

Discussion

Anthropogenic measures

Much of southern Africa has undergone extensive land transformation (Macdonald 1991; Deacon 1992; van Rensburg et al. 2004a), through agricultural development, urbanization, mining, as well as alien plant encroachment (Deacon 1992; Rebelo 1992; Richardson et al. 1996). Over the past 350 years, humans have preferred to settle in the Cape Floristic Region (CFR). These parts are known for the high concentration of endemic mammals (Siegfried & Brown 1992). Being predominantly present in winter rainfall Fynbos and Succullent Karoo Biomes (Cowling & Hilton-Taylor 1994). Siegfried & Brown (1992) reported that several mammals endemic to the south western parts of the country, such as the Riverine rabbit (*Bunolagus monticularis*), Van Zyl's Golden mole (*Cryptochloris zyli*), the Cape Mountain Zebra (*Equus zebra zebra*), and the Bontebok (*Damaliscus pygargus pygargus*) were also highly threatened. The CFR region also represents an area that has witnessed the greatest regional, mammal extinctions in South Africa, mainly human-induced (Rebelo 1992, Mckinney 2001). Each of South Africa's nine provinces has a unique set of characteristic natural resources, human demands, infrastructure provision, levels of urbanization, economic structure, and performance (Development Bank of South Africa (DBSA) 2000).

Relationship between mammals and human activity measures

Anthropogenic activities form a complex web of threats that is influenced by various socio-economic and political factors (e.g. national policies, economic conditions and a host of other factors varying among nations; Macdonald 1991; James 1994; Kerr & Currie 1995; Development Bank South Africa 2000; McKinney 2001; O'Neill et al. 2001; Liu et al. 2003). Clear evidence for these separate components affecting taxon extinction have been highlighted, yet it is difficult to assign a single risk value to separate impacts of these measures (Kerr & Currie 1995; Chertow 2001; Ceballos & Ehrlich 2002). Furthermore using certain human threat predictors (as used in the current study) should not be taken to mean that other human impacts are insignificant, as many additional human activities are also extremely important at local scales e.g. agriculture, alien invasive species etc. (Macdonald 1991).

The present study indicates an association/congruence between most of the anthropogenic variables with overall mammal richness (OMR), yet very little of the variation in OMR was explained by the anthropogenic variables. In addition, weak correlations were also evident between EMR, TMR and various anthropogenic variables. Other studies indicated significant, but weak relationships between human population density, human population growth, poverty, per capita income, urbanization and mammals per country (Ehrlich & Holden 1971; Kerr & Currrie 1995; Harcourt & Parks 2003, Cincotta et al. 2000; McKee et al 2003). For example, Balmford et al. (2001) found a marked congruence between high vertebrate richness and human population density across Africa, while Chown et al. (2003) found a strong significant positive relationship between South African bird richness and human population density at a quarter degree scale. However, none of the six anthropogenic variables considered in the present study showed similar relationships with any of the measures of mammal richness despite some significant degrees of correlation.

Andrews & O'Brien (2000) reported a strong association between mammal and plant richness, with woody plant richness explaining between 70 – 77% of the mammal richness in southern Africa. Strong evidence indicates that primary productivity, evapotranspiration, and annual precipitation are some factors driving plant richness patterns (see O'Brien et al. 1998; Rutherford & Westfall 1986; O'Brien et al. 2000; Hawkins et al. 2003). Mammal richness is most likely defined by plant richness, which in turn is characterized by water-energy dynamics (Andrews & O'Brien 2000; Hawkins et al. 2003). Similarly, it has been shown that human population density and subsequent human predictors respond positively to increases in net primary productivity, indicating a relationship between measures of human and vertebrate richness (Balmford et al. 2001; Chown et al. 2003; Hawkins et al. 2003; van Rensburg et al. 2004b). These findings seem to support our results that allude to similar responses by measures of both human density and mammal richness being concurrent with primary productivity (Chown et al. 2003), with both high mammal richness and human distribution prevalent in the southern and eastern parts of the country.

The results from the current study suggest human threats do not currently define any of the mammal richness measures, with landscape transformation possibly being too recent to exhibit any statistically noticeable effect (Chown et al. 2003) at a QDS scale. processes that define mammal richness as well as threats may be operating at a finer spatial scale, over a longer temporal scale or, other more important causal mechanisms may dominate the current patterns, e.g. climatic variables, topographic variables, β-diversity etc. (Bailey et al. 2002, Hawkins & Pausas 2004). In addition, further analyses are required to ascertain which of the current human impact measures included in the current study are proximate or ultimate threats. It has been shown that human density is clearly a proximate threat with agriculture, urbanization, land transformation, and roads denoted as ultimate threats (Thompson & Jones 1999). A clearer understanding to which threats are more relevant as an immediate threat will allow relevant actions to be implemented.

A serious dilemma with the current analyses are attributable to the different varying spatial scales of the data used. Most of the anthropogenic data were collected at municipality level and were consequently transformed to QDS scale with most measures calculated as weighted averages, which resulted in a possible loss of fine scale information. Taxon distribution data (in this case mammal data) are rarely representative and accurate, and in most cases old and out of date (Freitag & van Jaarsveld 1995; Lombard 1995; Maddock & Benn 2000; Maddock & Samways 2000). South African mammal distribution data (presence and extent of occurrence data) are not equally sampled, incomplete and uneven in coverage and most of all at the wrong scale quarter degree scale (QDS) (Rebelo 1994; Freitag & van Jaarsveld 1995; Lombard 1995). This scale is often too coarse to reflect finer scale topographical and vegetation differences and will most likely fail to pick up many of the finer interactions between human predictors and mammal richness measures (Rebelo & Tansley 1993; van Rensburg et al. 2004a).

Another major factor influencing statistical results and analysis is the marked differences between the temporal scales of all the databases. The mammal QDS data range from specimens collected in the early 1900’s up to present time (Freitag & van Jaarsveld 1995); with the additional distribution range maps also based on potential distribution ranges of species (Freitag & van Jaarsveld 1995). Conversely the anthropogenic variables used in the current study generally dates from 1994 to present. The discrepancy between the varying time lines of the data sources could be a plausible cause for the resulting poor statistical correlations and variation found within the current study.

It is possible that the limited difference detected in the analysis of the recommended measures of richness (Rebelo & Tansley 1993; Freitag & van Jaarsveld 1995, 1997; Chown et al. 2003, van Rendburg et al. 2004)) reflects the OMR measure that also include EMR and TMR mammals. It is also possible that further insight will be gained if additional measures representing ubiquitous taxa are included in this kind of analysis in future studies

Anthropogenic variables as threat proxy

The IUCN Red List is a well established and a widely accepted technique for assessing a taxon's probability of going extinct in the near future. It is based on quantitative data e.g., the taxon's' population size, rate of population decline, and its geographic range. By using the Red List, one gains an understanding of the taxon's probability of going extinct. However to fully understand a species' exact priority for conservation, one has to include a measure of threat. Harcourt and Parks (2003) found human density to be a reasonably good threat predictor, and yet some evidence suggests that human density alone may be a rather poor predictor of threat in certain taxonomic groups (Woodroffe 2000; Manne & Pimm 2001). The inclusion of additional anthropogenic demographic measures functioned well as threat predictors, with the data being up to date and easily accessible.

Threatened taxa seem to experience higher human density in their geographic range than do the non-Threatened taxa throughout their range in South Africa. On the contrary, the average combined human threat (CHT) and human change (HC) for DD taxa were all above that of threatened taxa. Harcourt & Parks (2003) suggests that such a measure can be used to highlight DD taxa that may be facing some severe human threat. Sixteen of the DD taxa can be regarded as provisionally Threatened (Table 6), with most of these taxa representing the Orders Rodentia, Insectivora and Chiroptera. These Orders were shown to be highly threatened according to the regional IUCN Red List (Chapter 2; Friedmann & Daly 2004), and are often under represented in conservation priorities and assessments (Chapter 2, Chapter 4; Entwistle & Stephenson 2000).

The largest and heaviest mammal in the top 50 CHT ranked mammals was the Blesbok *Damaliscus pygargus phillipsi*. The lower CHT ranks, which were assigned to mainly the larger bodied taxa, can most likely be attributed to most of the larger taxa experiencing lower human impact as they are limited to nature reserves, parks, and game farms (Freitag & van Jaarsveld 1995). Therefore these mammals would not be found in areas of high CHT measured ranks (Entwistle & Stephenson 2000), although evidence indicates that reserves are going to be under more human related pressures in the future (Balmford et al. 2001; Harcourt et al. 2001; Hansen & Rotella 2002). An analysis excluding data from conservation areas did not reveal any significant different CHT rankings (Keith. unpubl data), and did not reflect more accurate threats to species outside of these conservation areas.

Furthermore some of the highly threatened taxa for example the riverine rabbit, *Bunolagus monticularis* (CR C2a(i), E) and Visagie's golden mole, *Chrysochloris visagiei* (CR D) yielded very low CHT rankings due to low human threat measures, as these taxa are situated in low human impacted areas, for which was measured in the current study. Despite this, these taxa remained highly threatened due to their inherent life history traits making them more prone to extinction (Gaston 1998). Not only do these threatened taxa remain highly susceptible to extinction, but should a new threat (e.g. new land use practises) come into play these taxa would experience increased threat or extinction.

When using human variables to predict possible threats to mammals, one should keep in mind that there might be several "weedy" taxa or generalist as indicated by Harcourt and Parks (2003). It is known that various taxa react differently to the same threat, and additionally with the use of various human demographic variables to indicate potential risk, a concern is that that various taxa which benefit, or associate with certain human altered habitats will be considered as experiencing "high" human risk. Such "weedy" taxa (Harcourt & Parks 2003) (e.g. woodland mouse *Grammomys dolichurus*, and red duiker, *Cephalophus natalensis*) function well and often favour human altered environments (de la Peña et al. 2003). Yet as Harcourt & Parks (2003) indicate, such "weedy" taxa may be under considerable human threat and can still face extinction if certain detrimental conditions are met.

Conclusion

The conservation movement today, sets conservation targets by incorporating a wide variety of suitable data, ranging from taxa/species information, land types and habitat types, and various forms of threats (Pressey et al. 2003). Incorporating anthropogenic measures into threat assessments of mammals does allow for additional perspectives to the conservation prioritisation of inherently higher threatened taxa due to human impact and threats (Harcourt & Parks 2003).Yet it is imperative that we obtain a better understanding of the relationship between the different variables used in the current study. Furthermore we fully acknowledge the shortcomings of the mammal distribution data, and the use thereof in the current study are a "necessary evil" (Freitag et al. 1998). The combination of presence and distribution range maps as used in the current study have hopefully proven to be effective in representing mammal biodiversity, circumventing current data constraints (Freitag & van Jaarsveld 1995; Gelderblom & Bronner 1995).

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CHAPTER 4

Conservation priority-setting at a regional scale: a case study based on South African terrestrial mammals

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Abstract

Species' threat assessments are an essential part of regional conservation interventions. In the current study, Regional Priority Scores (RPS) were computed for 221 South African terrestrial mammals using more readily available data. These data included vulnerability (IUCN Red List assessments and regional occupancy), irreplaceability (relative endemism and taxonomic distinctiveness), and measures of threat (relative body mass and human density), and were subjected to two conservation priority assessment techniques. The RPS scores obtained from two RPS techniques differed significantly, resulting in a broad range of mammals being recognised as of conservation importance. Despite this variance, 13 mammal species were consistently emphasised to be of high conservation priority across both techniques. The top 22 species from each technique included 12 of the 2004 regional IUCN Red List threatened mammals. The two RPS techniques may represent a simplified approach for determining regional conservation priorities for taxa under various region-specific conditions.

Keywords: Regional conservation prioritisation, vulnerability, threat assessment, terrestrial mammals, South Africa

Introduction

Halting the present spate of species extinctions requires the identification and subsequent conservation of threatened species and their habitats. At a practical level, this requires incorporating threat assessments into regional conservation interventions (Master 1991; Mace 1995), which is usually based on prioritisation of areas or taxa. Due to limited resources for conservation actions, it is important to emphasise and prioritise taxa that have been identified as of importance for the conservation of biodiversity (Freitag & van Jaarsveld 1997).

However, setting conservation priorities is difficult (Harris et al. 2000) because prioritisation systems vary greatly, not only with reference to factors that are deemed important to include, but also how these factors are scored, weighted, or incorporated (Mehlman et al. 2004). In general, species conservation prioritisation traditionally focus on species that are highly vulnerable, including predictors of species extinction risk, such as population sizes and trends (Master 1991; Freitag & van Jaarsveld 1997; Dunn et al. 1999; Burgman 2002, Mehlman et al. 2004). Vulnerability and rarity information on factors that predispose species to high levels of threat or some level of extinction (Gaston, 1994; Gaston and Blackburn, 1997; Kunin and Gaston, 1997; Purvis et al., 2000; Manne and Pimm, 2001) have to date dominated conservation prioritisation exercises.

One such measure, the World Conservation Union (IUCN) Red Lists (IUCN, 1994; 2001) is probably the most widely used assessment method to identify species at the risk of extinction. The Red List categories provide a relatively simple and widely used method for identifying species under higher risk of extinction, an approach that can lead to appropriate conservation measures designed to protect such species. These Red List categories of "threat" are based on considerable ecological knowledge defined by strict sets of criteria, supported by decision rules derived from thresholds of parameters such as distributional ranges, population sizes, and life histories (IUCN 2001; Lamoreux et al. 2003).

When assessing the conservation status of a taxon against the IUCN Red List criteria, these threshold parameters are tested against the criteria, working downward through threat categories that range from Critically Endangered (CR), through Endangered (EN), to Vulnerable (VU). For example, if it is established that the taxon partly does not meet the necessary criteria to be categorized as VU, then Near Threatened (NT) may be applied. A taxon that has been evaluated and meets none of the criteria is listed as a taxon of Least Concern (LC), while an evaluated taxon that has insufficient data to test against the criteria is designated Data Deficient (DD) (IUCN 2001)

Subsequently, it is generally accepted that if a taxon is listed as threatened on the Red List (CR, EN or VU), it can be regarded as of higher conservation concern because it is considered to be more prone to extinction in the near future. Consequently, the IUCN Red List assessments and measures of rarity (relative occupancy) can function as a proxy with regard to vulnerability to extinction, and are therefore, used in the current study to express 'vulnerability'. However it is important to note that the measure of vulnerability to extinction is most often not uniform across a taxon's distribution range, but refers to the general trends of the population(s) under consideration. Often the different populations within the area under consideration respond differently to a variety of factors, and do not have a uniform threat of going extinct.

Previous studies have identified a variety of factors that are important when attempting to assess the conservation value or 'irreplaceability', and not just the vulnerability of species (Pressey et al. 1993; Williams &. Araújo 2002; Noss et al. 2002; Knapp et al. 2003). Irreplaceability as used here is a conservation value that is used as a measure of how a taxon contributes to the overall biodiversity within a specific region of interest (Pressey et al. 1993; Noss et al. 2002). Factors such as endemism (Myers et al. 2000; Williams &. Araújo 2002; Mace et al. 2003), as well as systematic significance (taxonomic and phylogenetic distinctiveness; Millsap et al. 1990; Vane-Wright et al. 1991; Posadas et al. 2001; Keith et al. 2005)) have also been high-lighted as useful surrogate measures for assessing conservation priority.

Southern African mammals are characterised by a large proportion of non-endemic widely distributed taxa (Coe & Skinner 1993), and yet 36 mammal species are classified as endemic to South Africa (Friedmann & Daly 2004). Endemic taxa are often considered to be of national conservation importance (Rebelo & Tansley 1993). The level of endemism of a taxon to a specific region usually refers to the taxon's dependence on the region conservation actions for survival (Freitag & van Jaarsveld 1997). These species are solely reliant on South Africa's conservation actions to prevent their possible extinction. Similarly, phylogenetically distinct taxa are usually deemed to be of a higher conservation value than with close genetic relatives (Vane-Wright et al. 1991; Heard & Mooers 2000; Polasky et al. 2001). Phylogenetic analyses have allowed the ranking of species according to their degrees of phylogenetic diversity, therefore, high-lighting the evolutionary history and genetic diversity of unique taxa (Freitag & van Jaarsveld 1997; Virolainen et al. 1999; Rodrigues & Gaston 2002).

Recent reviews have high-lighted that the inclusion of explicit criteria of human threats to taxa may be relevant for conservation prioritisation and conservation planning (Master 1991; Harcourt & Parks 2003; Pressey et al. 2003; van Rensburg et al. 2004). Mills et al. (2001) in their assessment of geographic priorities for terrestrial carnivores in Africa, incorporated body size as a potential estimator for human conflict in their analysis. The rationale behind the inclusion of body size was that large-bodied species are more likely to be negatively influenced by human populations (Entwistle & Stephenson 2000; Mills et al. 2001, Harcourt & Parks 2003). Secondly, a measure of human population density throughout a taxon's range has been considered to be a good indicator of human threat, more specifically to mammals at a global scale (Ceballos & Ehrlich 2002; Harcourt & Parks 2003). Both body size and human population density are deemed relevant proxies of human threat, and are consequently, included in the our priority setting analysis in the present study in order to gain an insight into current threats to South African mammals.

To this end, the current study relies on three key concepts, namely, vulnerability, irreplaceability and threat (Pressey et al. 1993; Noss et al. 2002, Harcourt & Parks 2003) that are included into the regional priority setting exercise for South African mammals.

Freitag and van Jaarsveld (1997) proposed a qualitative taxon-specific technique for assigning regional conservation priorities. The technique evaluates the regional conservation importance of taxa, assigns a Regional Priority Score (RPS) to each taxon, and was used to evaluate the conservation priority for mammals in the former Transvaal Province, South Africa (Freitag & van Jaarsveld 1997). The RPS provides a relational approach where the conservation importance of taxa is derived with reference to measures of rarity, vulnerability, and irreplaceability (Mills et al. 2001). In essence, the RPS adds value to the traditional risk assessment of the IUCN, but incorporates additional measures of the taxon's value and threat.

Consequently, the aim of the present study is threefold. First, we attempt to prioritise South African mammals with reference to measures of vulnerability, irreplaceability, and threat. Second, apart from the traditional RPS components (Freitag & van Jaarsveld 1997), we also attempt to assess the effect of the inclusion of body mass and a human density index, as additional measures of threat. Third, in order to facilitate and improve regional conservation practice, we attempt to assess the interaction between factors that may contribute to the level of threat experienced by species. To this end, we evaluate the relationships between the six RPS components included in the current regional conservation priority assessment, namely relative vulnerability (RV), relative occupancy (RO), relative endemism (RE), and taxonomic distinctiveness (RTD), relative body mass (RBM) and relative human density (RHD) (Freitag & van Jaarsveld 1997; Mills et al. 2001). Apart from contributing to our current understanding of the conservation importance/priority of South Africa terrestrial mammals, this study also attempts to assess the value of various conservation assessment tools for prioritising conservation actions and in formulating appropriate management decisions at a regional scale.

Materials and Methods

The study is based on the extant mammals of South Africa and the taxonomic treatments of Wilson and Reeder (1993) and augmented by that of Taylor (2000) for the Order Chiroptera and conforms to that used by the recent regional Red List (Friedmann & Daly 2004). For taxa with taxonomic discrepancies between these authorities, taxon specialists working on the specific problematic groups were consulted (see Friedmann & Daly 2004). The final species list, excluding subspecies and sub-populations was matched with presence data obtained from distributional records (Freitag & van Jaarsveld 1995; Keith 2004). Several taxa were excluded from the current study because no relevant distribution data were available. All subsequent distribution data were generalised to a common resolution at the quarter degree square level (QDS) representing an area of 25 x 25 km or 625km^2) (Freitag & van Jaarsveld 1995) prior to the computation of regional priority scores.

RPS Components

Six different components were used to compute regional conservation priority scores for South African terrestrial mammals. These included the four components, described by Freitag & van Jaarsveld (1997) as well as two additional components. These components were groups into three subsets that were considered to represent measures of vulnerability, irreplaceability, and threat and were calculated as follows:

Vulnerability components

(a) *Relative vulnerability (RV)* - The regional IUCN Red Data List assessment of the regional Conservation Assessment and Management Plan (CAMP) for South African mammals (Friedmann & Daly 2004) was used to score the vulnerability categories as follows::

1.0: Critically Endangered (CR);

0.80: Endangered (EN);

0.70: Vulnerable (VU);

0.56: Near Threatened (NT);

0.42: Data Deficient (DD); and

0.00: Least Concern (LC).

(b) *Relative Occupancy (RO)* – calculated based on presence data from museum distributional records (Freitag & van Jaarsveld, 1995) as follows:

$$RO = \frac{1}{\text{No. of quarter degree squares (QDS) occupied in South Africa}}$$

Irreplaceability components

(c) *Relative Endemism (RE)* – (modified from Freitag and van Jaarsveld (1997). The extent of occurrence, obtained from various sources (Haltenorth and Diller 1980; Skinner and Smithers 1990; Mills and Hes 1997; Boitani et al. 1999; Kingdon, 2001) was categorised as follows:

1.0: Endemic to South Africa only;

0.8: 75-99% distribution in South Africa;

0.6: 50-74% distribution in South Africa;

0.4: 25-49% distribution in South Africa; and

0.2: 0-24% distribution in South Africa.

(d) *Relative Taxonomic Distinctiveness (RTD)* - calculated following the method of Freitag and van Jaarsveld (1997) as follows:

$$RTD = \frac{1}{\sqrt{\text{No. of regionally represented families x genera x species}}}$$

Threat components

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

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

Body mass was log-transformed and divided by the transformed maximum South African terrestrial mammal mass (BM_{max} = African elephant, *Loxodonta Africana* value of 14.74). RBM was incorporated in the current assessment as a potential surrogate measure of human conflict following Mills et al. (2001).

(f) *Relative Human Density (RHD)* - Included as a measure of potential human interaction or "threat" based on the rationale that the higher the human density within a taxon's 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:

$$\text{Human Density (HD)} = \frac{\sum (\text{Averaged human density across a taxon's distribution (QDS)})}{\text{No. of QDS the species occur in}}$$

In order to obtain a relative human density value for each taxon across its known distribution (in QDS), relative human density per km^2 was calculated and standardised by dividing the relative human density of a taxon by the taxon scoring the highest human density value (HD_{max}):

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

The large-eared free-tailed bat (*Otomops martiensseni*) scored the highest HD value among all mammals considered, with most of its QDS distribution falling within the Durban metropolitan and surrounding area, 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 for the HD_{max} value. Instead, the second highest HD value (178 people/km^2) obtained for the Juliana's golden mole (*Neamblysomus julianae*) was used instead as HD_{max}.

Regional Priority Scoring

Two different RPS techniques for determining the relative conservation importance of South African terrestrial mammals were evaluated. The first approach (RPS_{01}) applies the RPS technique proposed by Freitag and van Jaarsveld (1997) to a national scale assessment. This method employs four components, namely, relative vulnerability (RV), relative occupancy (RO), relative endemism (RE), and taxonomic distinctiveness (RTD), subsequently ranks taxa in order of their conservation importance and is computed as follows:

$$RPS_{01} = \frac{RV + RO + RE + RTD}{4}$$

The second conservation assessment technique (RPS_{02}) was essentially based on the RPS_{01} structure, but included relative body mass (RBM) and relative human density (RHD) components, the latter two incorporated as indices of potential ‘human impact’ and was calculated as follows:

$$RPS_{02} = \frac{RV + RO + RE + RTD + RBM + RHD}{6}$$

Species with the top 10% RPS scores were deemed to be of the highest conservation priority for each of the two regional RPS techniques.

Statistical analyses:

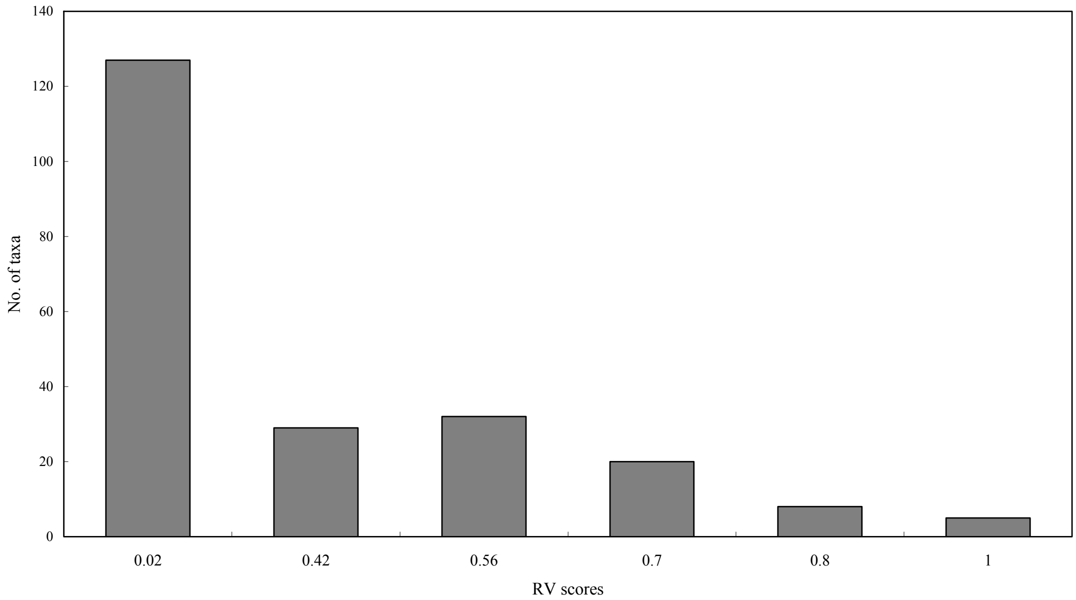
Mann Whitney *U*, Kruskal-Wallis Analysis of Variance (ANOVA) by Ranks, Wilcoxon Matched Pair tests and Spearman’s *R* correlation analysis (Sokal and Rohlf 1981; Zar, 1996) were used to test for statistically significant differences and correlations between the six components. All statistical analyses were executed using Microsoft® Excel 2000 and STATISTICA version 6 (StatSoft Inc. 2001).

Results and Discussion

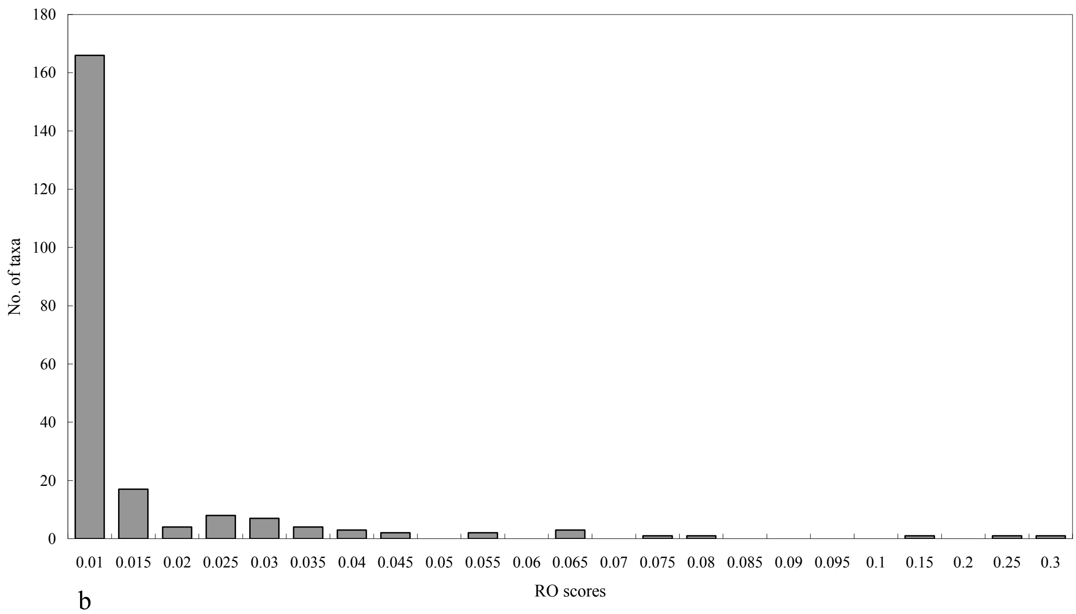
Two hundred and twenty one terrestrial mammal species in 13 orders and 38 families for which data were available, were used to assess the two RPS techniques and their respective regional priority scores.

Table 1. Spearman Rank order correlations of pairs of Regional Priority Score components (r-values included): Relative Vulnerability (RV), Relative Occupancy (RO), Relative Taxonomic Distinctiveness (RTD), Relative Endemism (RE), Relative Body Mass (RBM) and Relative Human Density (RHD). All values in bold indicate statistical significance of P < 0.05. Non-bold values denote no statistically significant values.

	RV	**R 0**	**RE**	**RTD**	**RHD**
RO	**0.5**	-			
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

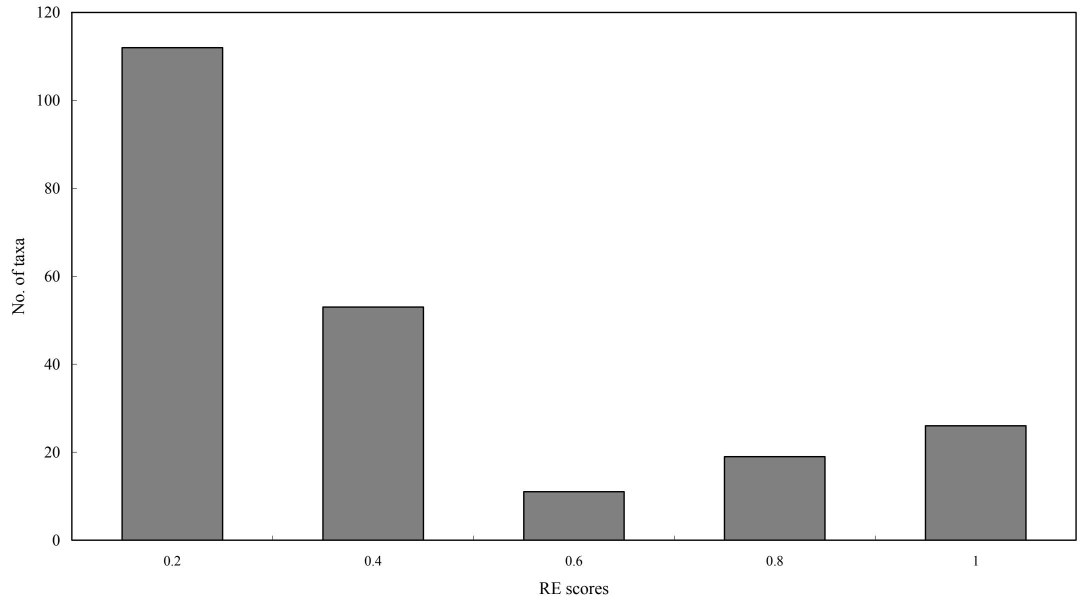


a



b

Fig. 1 a-b. The frequency distributions of two component scores: Relative Vulnerability (RV) and Relative Occupancy (RO) for 221 South African terrestrial mammals.



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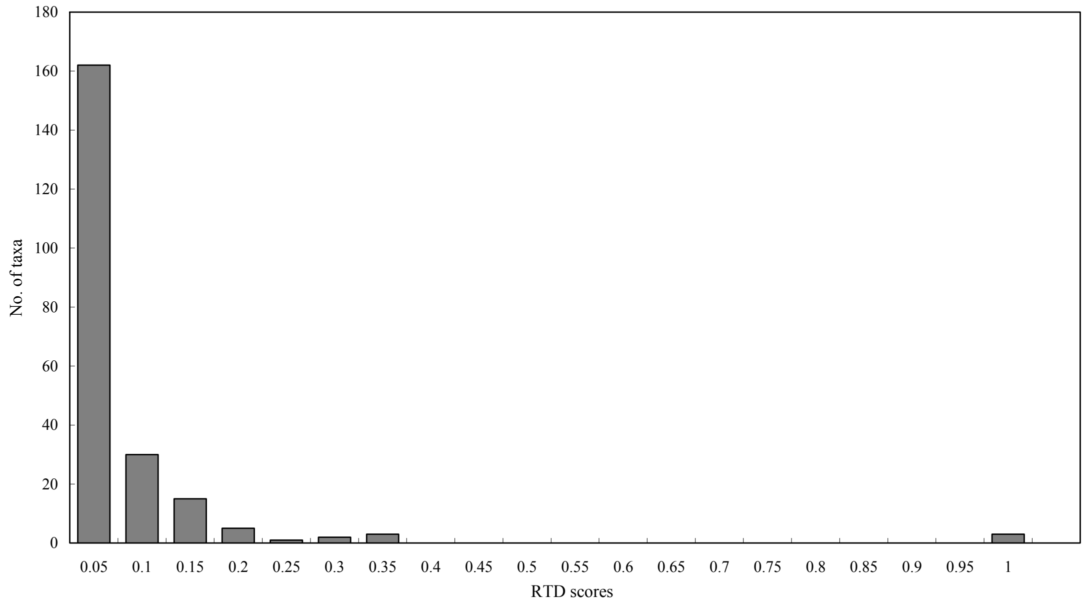
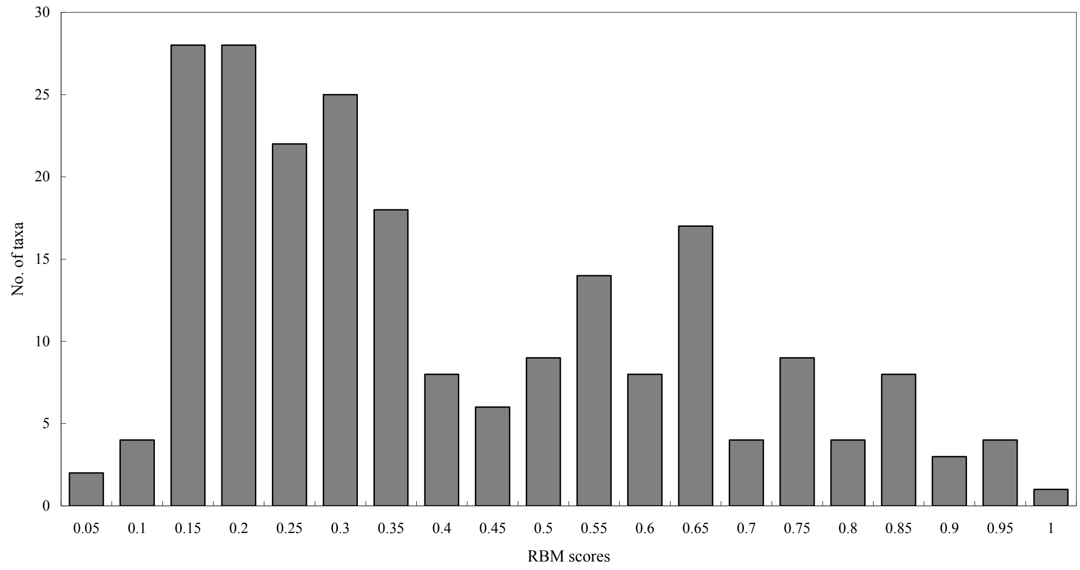


d

Fig. 1 c-d. The frequency distributions of two component scores: Relative Endemism (RE), and Relative Taxonomic Distinctiveness (RTD), for 221 South African terrestrial mammals.



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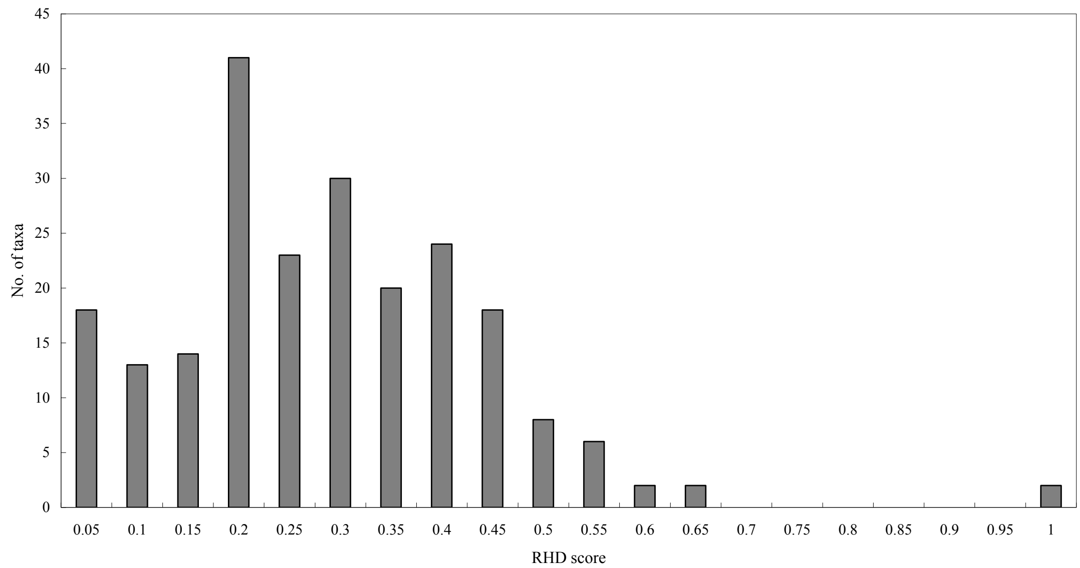

f

Fig. 1 e-f. The frequency distributions of two component scores: Relative Body Mass (RBM) and Relative Human Density (RHD) for 221 South African terrestrial mammals.

RPS components:

All of the RPS components were significantly different from each other (Kruskall Wallis $H_{5,\ 1326}$ = 584.76; $P < 0.001$). Analysis of paired RPS components indicated significant correlations among most pairs (Table 1). The strongest significant correlations among paired components were found between RTD and RBM as well as between RO and RV. The strongest significant negative correlation was between RO and RBM. Similar to Freitag and van Jaarsveld (1997), the RPS components were positively skewed suggesting that priority taxa are easily identified at the regional level when using the different RPS components (Fig. 1a – f).

Five of the paired components were not significantly correlated (Table 1). These included the correlations between RTD and vulnerability (RV), as well as between RTD and RHD. Relative endemism (RE), RV and RO, well as RHD and RBM were not significantly correlated. The weak significant negative correlation between RHD and RE contradicts the findings of Balmford et al. (2001) obtained at a continental scale, which showed that in densely human populated areas (i.e., areas with high RHDs), the majority of taxa were geographically restricted (i.e., with high RE). Because the current study was only limited to South Africa and a species-level rather than including sub-species-level analyses, the delineated pattern may be locally dominated by the more widespread taxa (Freitag & van Jaarsveld 1995; Lennon et al. 2004).

A statistically significant positive correlation has also been shown to exist between human population density and mammal (Balmford *et al.* 2001) and bird species richness (Chown *et al.*, 2003), both at a continental and South African scale. Reed (1990) cautions about the inherent absence or weak relationships that may exist between selected life history, extinction, and rarity variables, which usually feature as components in setting conservation priority exercises. In kind Chown et al. (2003) comments "[that] it is not clear why the relationship between bird species richness and human population density has persisted" (see Chown et al 2003 for further discussion). In addition, a possible explanation for the differences in the results between the current and the previously cited studies may be attributed to the lack of spatially explicit measures, as well as differences in scale (spatial and temporal) and/or taxa used (Freitag & van Jaarsveld 1995; Lombard 1995).

RV scores indicated 127 species to have RV values of 0.00 (i.e., Least Concern (LC)) (Fig. 1a), while 33 species were included in the threatened categories (i.e., Critically Endangered, Endangered or Vulnerable). The majority of threatened taxa scoring high RV scores were grouped in the orders

Insectivora and Chiroptera (Mugo et al. 1995; Friedmann & Daly 2004). The integration of regional Red List assessments (Friedmann & Daly 2004) into the current study incorporates not only the most up-to-date regional extinction risk data but also the more quantitative method for Red List assessment, as was suggested by Freitag & van Jaarsveld (1997). On the other hand, RO scores ranged from 0.008 to 0.28 (Fig. 1b), with van Zyl's golden mole (*Cryptochloris zyli*), known from only one locality in the Northern Cape Province (Skinner & Smithers 1990) having the highest RO value. Freitag & van Jaarsveld (1997) encountered similar small RO values for most taxa with few of the more range-restricted taxa attaining larger RO values. This is could be related to the limited distributional data for most mammals in South Africa (Freitag & van Jaarsveld 1995).

RTD scores ranged from 0.007 to 1.00, with a median value of 0.029 (Fig. 1c), a considerably lower median value compared with the other RPS components. Three monotypic species, the African elephant (*Loxodonta africana*), aardvark (*Orycteropus afer*), and the pangolin (*Manis temminckii*) scored RTD values of 1, while rodents and the chiropteran had relatively low RTD scores (also see Freitag & van Jaarsveld 1997). RE values for most species were around 0.20, indicating that 0 - 24% of their distributional range occurs in South Africa (Fig. 1d). Twenty-six of these were classified as endemic (i.e., RE = 1), with a large proportion of them being threatened by extinction (see Chapter 1) and are consequently, of great conservation concern within a national conservation framework (Danell & Aava-Olsson 2002).

The RBM component (Fig. 1e) resulted in a more even distribution of log mass categories (0.01-1.00). Similar to the findings of Entwistle and Stephenson (2000), most species were found to weigh less than 7 kg, as a large proportion (61%) of South African mammals are rodents, bats, and insectivores. The human density component (RHD) had a median of 0.25 (Fig. 1f) with values ranging from 0.005 to 1.00. Various species such as the large-eared free-tailed bat (*Otomops martiensseni*), the peak-saddle horseshoe bat (*Rhinolophus blasii*), and the Damara woolly bat, (*Kerivoula argentata*) had high RHD values and this could be attributed to their distributions being mainly restricted to large metropolitan areas and some coastal regions (Western Cape, Eastern Cape and Eastern KwaZulu-Natal Provinces). Although some bats are considered to be expanding their distributional ranges by exploiting artificial roosting sites (such as house roofs, under bridges, and abandoned mines), they are also inherently subjected to eradication through increased human interaction and pest control measures (Gelderblom et al. 1995).

Although having usually low RTD values, smaller mammals generally exhibit higher levels of endemism and vulnerability values. The top-ranked species with reference to human density are also generally represented by the smaller mammals. It therefore, appears that when considering most of the priority setting components (except for RTD and RBM), smaller species are generally ranked higher in terms of conservation priorities in South Africa. This view is supported by the negative relationship between body mass and the other priority setting variables assessed in the present study.

Regional Priorities Scores

Although the values of the two RPS techniques (RPS_{01} and RPS_{02}) used in the present investigation were strongly correlated with each other (Spearman $R = 0.79$; d.f. = 220; $P < 0.05$), there were marked differences in individual RPS scores. The majority (> 83.74%) of the 221 taxa had RPS_{01} and RPS_{02} scores of less than 0.30 (Fig. 2). Based on RPS_{01}, 33 species (25.33%) were placed within the 0.10 - 0.14 RPS score category. In contrast, the majority of taxa (26.69%) were placed in the 0.21 – 0.25 RPS score category by the RPS_{02} technique (Fig. 2).

From the species that were identified as of conservation importance in South Africa by each of the two RPS techniques, the top 22 species (top 10%) indicated the effect of the various RPS components and their influence on the composite regional priority scoring. Apart from a few members of the Carnivora and Chiroptera, the Order Insectivora dominated (63.63%) the top 22 RPS_{01}-ranked taxa (Table 2; Fig. 3). When body mass (RBM) was incorporated into the RPS assessment, a number of larger/heavier taxa were included in the top 22 species that were identified to be of high conservation priority in South Africa (e.g. African elephant, *Loxodonta africana*). The subsequent incorporation of relative human density (RHD) into the RPS assessment included additional taxa that were not shown to be of high conservation priority in South Africa by the RPS_{01} technique. Van Zyl's golden mole (*Cryptochloris zyli*) scored the highest RPS_{01} score (0.58) and was ranked ninth by the RPS_{02} technique (Table 2). The incorporation of relative human density (RHD) and relative body mass (RBM) in the RPS_{02} technique placed Juliana's golden mole (*Neamblysomus julianae*) at the top of the conservation priority list for South Africa.

Only the RPS_{02} technique identified some carnivores as conservation priority taxa, listing the wild dog (*Lycaon pictus*) and the brown hyaena (*Hyaena brunnea*) as of high conservation priority in South Africa. Mills et al. (2001) identified the wild dog as the second highest conservation priority species in Africa, while the brown hyena was ranked sixth. Ginsberg (2001) noted that priority-setting exercises

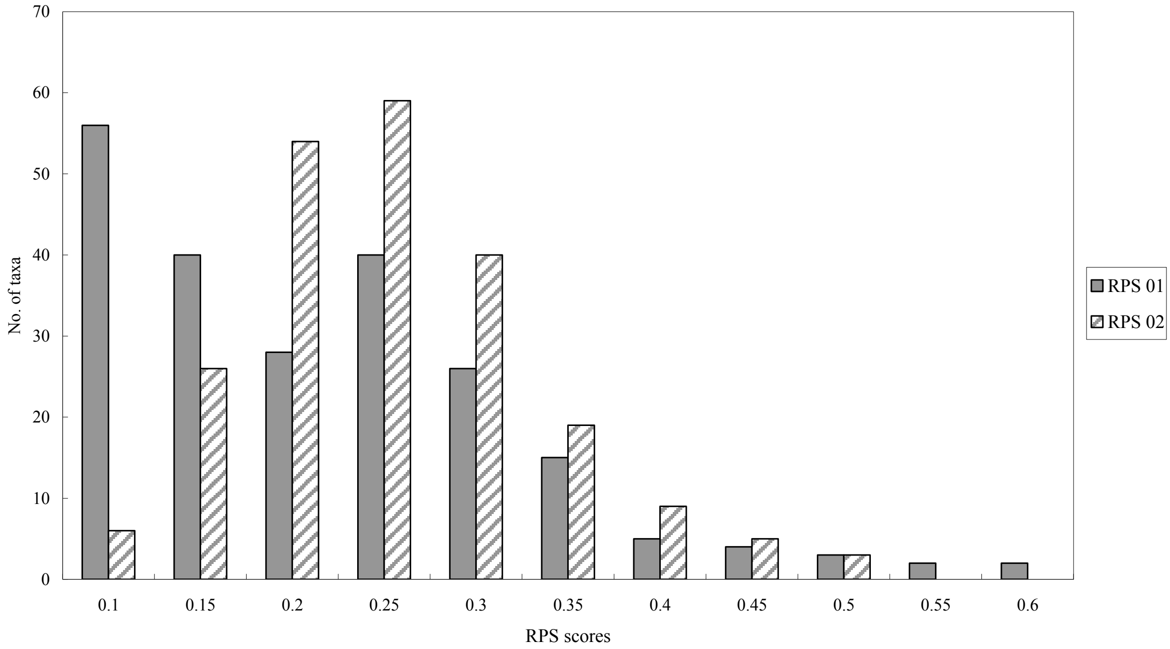

Fig. 2. Regional Priority Scores (RPS) distributions for the two RPS techniques RPS_{01} (Freitag & van Jaarsveld 1997) and RPS_{02} for the South African terrestrial mammals.

Table 2. Regional Priority Score rankings of the top 22 priority taxa (top 10%) based on the two RPS techniques (RPS_{01} (Freitag & van Jaarsveld 1997), and RPS_{02}) (highlighted in bold), as well as the IUCN Red List assessed taxa (Friedmann & Daly 2004) not identified to be in the top 22 RPS priority list. * = 13 species which were consistently identified, by all three RPS techniques, as priority species). V* =corrected coefficient of variation values calculated for the RPS scores. Bold ranks of $Rank_{01}$ and $Rank_{02}$ indicate the top 22 taxa for each RPS technique.

Order	Taxon name	IUCN Red List	RPS_{01}	$Rank_{01}$	RPS_{02}	$Rank_{02}$	V*
Chiroptera	***Cloeotis percivali****	CR A2, a	0.38	**13**	0.33	**20**	33.75
Insectivora	***Cryptochloris wintoni****	CR B1ab(iii), B2ab(iii), D	0.56	**2**	0.38	**11**	110.15
Insectivora	***Cryptochloris zyli****	CR B1ab(iii)+2ab(iii); D	0.58	**1**	0.39	**9**	127.28
Insectivora	***Chrysospalax villosus****	CR C2a(i), D	0.51	**4**	0.48	**2**	53.03
Lagomorpha	***Bunolagus monticularis****	CR C2a(i), E	0.54	**3**	0.44	**5**	39.77
Rodentia	***Mystromys albicaudatus****	EN A3c	0.41	**10**	0.37	**13**	20.75
Chiroptera	*Kerivoula argentata*	EN B1ab (iii) & 2ab (iii)	0.26	42	0.30	34	16.75
Insectivora	***Neamblysomus gunningi****	EN B1ab(i-iv) B2ab(i-iv)	0.47	**6**	0.45	**4**	31.82
Insectivora	***Myosorex sclateri****	EN B1b(ii,iii), c(iv)+2b(ii,iii), c(iv)	0.47	**7**	0.41	**7**	0
Chiroptera	*Rhinolophus swinnyi*	EN C2a (i)	0.26	50	0.28	60	14.46
Artiodactyla	***Ourebia ourebi***	EN C2a(ii)	0.26	47	0.37	**14**	86.07
Macroscelidae	*Petrodromus tetradactylus*	EN D	0.29	32	0.29	50	34.92
Carnivora	***Lycaon pictus***	EN D	0.27	37	0.33	**21**	43.89
Primates	*Cercopithecus mitis*	VU B1ab (ii,iii,iv)	0.25	59	0.32	23	69.85
Artiodactyla	*Neotragus moschatus zuluensis*	VU B1ab (ii,iii,iv,v)	0.24	65	0.29	47	25.57
Insectivora	*Calcochloris obtusirostris*	VU B1ab(ii,iii),B2ab(ii,iii)	0.25	58	0.22	112	50.54
Hyracoidea	***Dendrohyrax arboreus arboreus***	VU B1ab(iii) + 2ab(iii), C1	0.31	26	0.39	**10**	70.71

Order	**Taxon name**	**IUCN Red List**	**RPS_{01}**	**$Rank_{01}$**	**RPS_{02}**	**$Rank_{02}$**	**V***
Insectivora	***Neamblysomus julianae****	VU B2 ab (ii,iii)	0.44	**8**	0.5	**1**	123.74
Insectivora	***Chrysospalax trevelyani****	VU B2 ab (ii,iii, iv)	0.44	**9**	0.43	**6**	31.82
Insectivora	***Crocidura maquassiensis****	VU B2a,c(ii,iv)	0.33	**20**	0.34	**18**	8.37
Insectivora	***Eremitalpa granti***	VU B2ab (ii,iii,iv)	0.34	**19**	0.27	66	87.97
Rodentia	*Cricetomys gambianus*	VU C1	0.24	69	0.30	43	36.93
Pholidota	***Manis temminckii****	VU C1	0.48	**5**	0.45	**3**	39.77
Artiodactyla	*Hippotragus niger niger*	VU C1 + 2a(i)	0.23	74	0.36	**15**	105.47
Artiodactyla	*Philantomba monticola*	VU C1, C2a(i)	0.23	70	0.32	25	75.36
Carnivora	*Acinonyx jubatus*	VU D1	0.24	66	0.31	30	59.66
Carnivora	*Panthera leo*	VU D1	0.24	68	0.32	24	76.09
Artiodactyla	*Hippotragus equinus*	VU D1	0.23	73	0.32	27	73.19
Chiroptera	*Laephotis wintoni*	VU D2	0.29	33	0.26	73	60.04
Chiroptera	***Otomops martiensseni***	VU D2	0.25	53	0.38	**12**	100.35
Chiroptera	*Laephotis botswanae*	VU D2	0.24	67	0.20	138	55.10
Chiroptera	*Cistugo seabrai*	VU D2	0.23	71	0.18	157	60.01
Chiroptera	*Rhinolophus blasii*	VU D2	0.23	75	0.27	63	13.83
Rodentia	***Bathyergus janetta***	NT	0.36	**16**	0.31	31	50.78
Insectivora	***Myosorex longicaudatus***	NT	0.4	**11**	0.31	32	77.7
Chiroptera	***Rhinolophus capensis***	NT	0.39	**12**	0.32	29	65.97
Chiroptera	***Miniopterus fraterculus***	NT	0.35	**17**	0.32	26	33.3
Chiroptera	***Cistugo lesueuri***	NT	0.35	**18**	0.27	67	91.72
Carnivora	***Hyaena brunnea***	NT	0.27	38	0.33	**19**	53.03
Insectivora	***Chrysochloris asiatica***	DD	0.36	**14**	0.29	46	84.85

Order	Taxon name	IUCN Red List	RPS_{01}	$Rank_{01}$	RPS_{02}	$Rank_{02}$	V*
Insectivora	***Amblysomus hottentotus****	DD	0.36	**15**	0.35	**17**	9.94
Insectivora	***Chlorotalpa sclateri***	DD	0.32	**21**	0.27	65	81.4
Insectivora	***Suncus lixus***	DD	0.31	**22**	0.31	33	31.82
Insectivora	***Myosorex cafer****	DD	0.31	25	0.33	**22**	10.16
Tubulidentata	***Orycteropus afer***	LC	0.3	31	0.35	**16**	50.78
Proboscidea	***Loxodonta africana***	LC	0.3	30	0.4	**8**	92.11

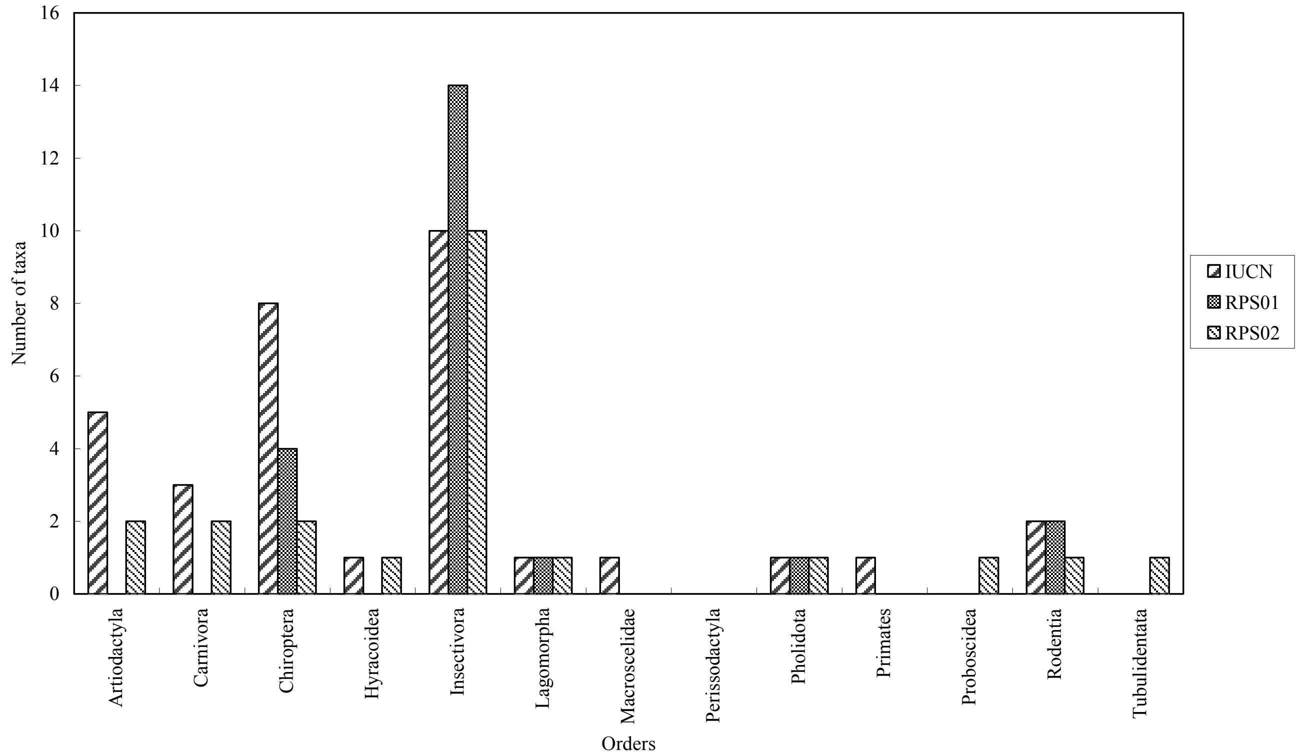

Fig. 3. Rankings per Order of the 33 threatened IUCN Red List species included in the current study (Friedmann & Daly 2004), as well as the top 22 South African terrestrial mammal species based of two RPS techniques (RPS_{01} (Freitag & van Jaarsveld 1997), and RPS_{02}).

rarely assign carnivores the conservation priorities they deserve. In the present study, the cheetah (*Acinonyx jubatus*) (VU D1) was ranked 66th by RPS_{01} technique and in the 30th position by the RPS_{02} technique. It is possible that since the majority of the larger carnivores mainly occur in protected areas as well as the northern parts/borders of South Africa (Gelderblom et al. 1995) may result in low RHD, RE, RO, and RTD scores, therefore, leading to lower overall regional conservation priority rankings.

The IUCN Red List identified 57 South African marine and terrestrial mammals as threatened or at the risk of extinction in the near future (Friedmann & Daly 2004), of which 33 were included in the present study. Similar to the IUCN threat categories, the top 22 priority species identified by the two RPS techniques in the present study mostly comprised insectivores. All Critically Endangered (CR) and some of the Endangered (EN) and Vulnerable (VU) species identified within South Africa by the IUCN Red List (Friedman & Daly 2004) were among the top 22 species identified by the two RPS techniques. Species ranked as Vulnerable (VU) by the IUCN Red List (Friedman & Daly 2004) were not always identified by the two RPS techniques used in the present investigation (Tables 2).

Various Data Deficient (DD) and Near Threatened (NT) mammals were included in priority lists based on the RPS techniques used in the present study. Of particular relevance is that the RPS_{02} technique identified two non-top 22 RPS_{01} as well as Least Concern (LC) mammals, the African elephant (*Loxodonta africana*), and aardvark (*Orycteropus afer*) to be of high priority. It is possible that the listing of these two taxa may be attributed to their scoring relative high RBM and RTD values.

Using the two RPS techniques, this study detected considerable variation in RPS scores and rankings obtained for South African mammals. The *among*-technique RPS coefficients of variation (CV) for the top 22 species ranged between 0.00 and 105.7% (Table 2), with only three of the species that occur in both the top 22 lists, yielding CVs of less than 10%. This may indicate that priority-setting techniques are highly dependant on the components considered in the analysis, and how these components are scored, weighted, and integrated (Mehlman et al. 2004; Keith et al. 2005).

Of significance in this study, however, is that 13 species were consistently placed among the top 22 species identified to be of conservation priority in South Africa by both the RPS_{01} and RPS_{02} techniques (Table 2). Twelve of these 13 species were also categorised as threatened by the IUCN Red List (Friedmann & Daly 2004), with the Hottentot's golden mole (*Amblysomus hottentotus*) being assessed as Data Deficient (DD) (Table 2). However, these taxa are not deemed to be of high conservation priority based merely on the high extinction risk assessment contribution by the regional IUCN Red List. Their RPS rankings are further strengthened by additional irreplaceability and threat components included in the current priority setting exercise. For example, despite a low RV value and being Data Deficient (DD), the Hottentot's golden mole (*A. hottentotus*) still scored high in both RPS_{01} and RPS_{02} listings being an endemic taxon with a relatively high RHD score.

Conclusion

Yu and Dobson (2000) demonstrated that many mammalian species exhibit a strong tendency towards rarity. Rarity varies both in space and time, regardless of whether they are in a pristine or an altered ecosystem (Ferrar, 1991; Gaston, 1994). Since the identification of conservation priorities for species at risk of extinction is usually determined by rarity and vulnerability, the question arises as to how to incorporate irreplaceability and threat variables, and how these should be used to develop a sound methodology for species conservation prioritisation (Ferrar 1991; Pressey et al. 1993; Gaston 1994; Gaston and Blackburn 1997; Reed 1999).

We do not presume that the RPS components used in the current study are necessarily optimal. However, unlike the IUCN Red List assessment for example, the RPS technique as used here incorporates various other measures and not only those solely related to the risk of extinction. These other measures also include those that are related to conservation value (i.e., measures of irreplaceability such as endemism and taxonomic distinctiveness) as well as measures of threat. This approach, therefore, attempts to quantify the vulnerability, uniqueness, and importance of a taxon to qualify for conservation action 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 a taxon, the use of body mass and human densities as surrogates measures for threat in the present study high-lights their importance in determining conservation prioritisation outcomes.

Red List categories reflect the extinction risk of a taxon and not the actual priority for conservation (Gärdenfors et al. 1999; Ginsberg 1999; Harcourt& Parks 2003). Despite published Red Lists being available for taxa, these do not constitute a conservation priority-setting tool (Ginsberg 1999; 2001; Tobias & Seddon 2002). Given the clear need for a regional conservation priority-setting tool for South African species, any of the RPS techniques may offer a useful conservation priority assessment tool that can easily be applied in many areas of the world using a minimum of available data. Nevertheless, the Red List is probably the most widely used assessment method for identifying species at risk of extinction. It offers an invaluable source of information and acts as a baseline for taxa that require immediate attention for conservation priority. The Red List is also particularly useful in the absence of alternative, more encompassing species conservation priority-setting strategies.

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CHAPTER 5

Taxonomic and phylogenetic distinctiveness in regional conservation assessments: A case study based on extant South African Chiroptera and Carnivora

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Abstract

The current study investigates whether a simple measure of taxonomic diversity (Taxonomic Distinctiveness - TD) can be used as a proxy for different measures of phylogenetic diversity (Phylogenetic Distinctiveness - PD) in determining species of regional conservation priority, and uses extant South African Chiroptera and Carnivora as a case study. Published phylogenies for the two mammalian Orders allowed the quantification of a node-based measure that was considered to represent phylogenetic diversity (PD_{NODE}), as well as a branch length-based measure that was considered to represent the amount of evolutionary change over time (PD_{BRANCH}). Both the PD_{NODE} and PD_{BRANCH}, together with TD were included in our regional conservation priority assessment. Although no statistically significant differences were detected between the PD_{NODE}, PD_{BRANCH} and the TD for both the Chiroptera and Carnivora, these measures were also shown to be correlated with each other. More importantly, inclusion of either the PD_{NODE}, PD_{BRANCH}, or TD in our analysis did not significantly alter the species that were identified to be of regional conservation priority. Both regional priority scores for the South African Chiroptera and Carnivora and their respective rankings were broadly consistent across the three potential indicators of conservation status utilised. These results suggest that the inclusion of either the PD_{NODE} and/or PD_{BRANCH} in conservation prioritisation exercises may not add value to that currently provided by the TD. Consequently, this implies that in the absence of relevant PD data, the utilisation of the TD in regional conservation priority settings may provide the appropriate information on evolutionary diversity.

Key words: Phylogenetic/Taxonomic diversity/distinctiveness, regional conservation assessments, Chiroptera, Carnivora, South Africa.

Introduction

Setting conservation priorities for species is a crucial first step in developing conservation strategies, particularly in the context of increasing financial and logistical constraints (Master 1991; Dunn, Hussel & Welsh 1999). In general, species conservation prioritisation focuses on taxa that are rare and threatened with extinction (Master 1991; Freitag & van Jaarsveld 1997; Dunn et al. 1999). Using rarity as the sole indicator of a species' potential conservation status (or risk of extinction) is considered insufficient, as various secondary components, such as body mass, population variability and dispersal ability may also be important in determining the vulnerability to extinction (Terborgh 1974; Burke & Humphrey 1987; Lande 1993; Dobson, Yu & Smith 1995; Cardillo & Bromham 2001). Consequently, additional variables have been proposed for use in species priority setting exercises, such as ecological specialization, systematic significance, and a series of threat variables (Millsap et al. 1990; Master 1991; IUCN 1994; Freitag & van Jaarsveld 1997; Dunn et al. 1999; Harcourt & Parks 2003).

In addition to the risk of extinction, determining the conservation value of a species is also important in conservation priority setting exercises. While there are a variety of approaches for determining conservation values for species (Vane-Wright, Humphries, & Williams 1991; Crozier 1992; Faith 1992; Heard & Mooers 2000), phylogenetically distinct species are generally considered to be of a higher conservation value than species with close genetic relatives (Vane-Wright et al. 1991; Freitag & van Jaarsveld 1997; Gittleman & Purvis 1998; Heard & Mooers 2000; Polasky et al. 2001; Rodriguez & Gaston 2002). Phylogenetic analyses have allowed the ranking of species according to their degrees of phylogenetic diversity, therefore, highlighting the evolutionary history and genetic diversity of unique species (Freitag & van Jaarsveld 1997; Virolainen et al. 1999; Rodrigues & Gaston 2002). Nevertheless, the paucity of comprehensive and inclusive phylogenies has led to a search for alternative measures for identifying distinct species (Polasky et al. 2001; Rodrigues & Gaston 2002). In some studies, simple measures of generic species richness (e.g., see Rodrigues & Gaston 2002) served as a surrogate for more complex measures of phylogenetic diversity (Whiting et al. 2000; Polasky et al. 2001; Rodrigues & Gaston 2002).

During the past few years, a variety of comprehensive published ordinal phylogenies for some South African mammals have become available, such as that for the extant Primata (Purvis 1995), Chiroptera (Jones et al. 2002), Carnivora (Bininda-Emonds, Gittleman & Purvis 1999), Insectivora (Greyner & Purvis 2003), and the Lagomorpha (Stoner et al. 2003). In order to explore the relationship between an assortment of surrogate measures of phylogenetic diversity for conservation prioritisation purposes, the phylogenies of members of two extant orders, the Chiroptera and Carnivora, were used as a case study in the present investigation. Apart from the availability of published phylogenies, members of these two Orders also represent a large proportion of South African species.

From the large number of potential measures of phylogenetic diversity, including those proposed by Vane-Wright et al. (1991), Faith (1992, 1994), Williams & Humphries (1996), Hacker, Colishaw & Williams (1998); Posadas, Miranda Esquivel & Crisci (2001), Polasky et al. (2001), and Alexandre & Diniz-Fihlo (2004), we opted to use the following two measures of Phylogenetic Diversity (PD):

1.) The node-based phylogenetic diversity (PD_{NODE}) score following Vane-Wright et al. (1991) and Posadas et al. (2001). The PD measure was selected due to its simplicity and sensitivity. It reflects the number of phylogenetically informative statements derived from the number of nodes on a phylogenetic tree to which each species belongs (Vane Wright et al. 1991; Crozier 1992; Posadas et al. 2001).

2.) Branch lengths (PD_{BRANCH}) extracted from a recent complete carnivore phylogeny (Bininda-Emonds et al. 1999). PD_{BRANCH} represents the amount of evolutionary change over time (in millions of years) for each species with reference to its terminal branch. Such an approach allows for a comparative analysis of the average ages of species in a phylogeny (Sechrest et al. 2002).

For comparison with both the PD_{NODE} and PD_{BRANCH} as PD measures, a "simple" measure of taxonomic distinctiveness (TD) was also used in this study. The TD has previously been applied to terrestrial African mammals across various geographic scales in Southern Africa in particular and Africa as a continent in general (Freitag & van Jaarsveld 1997; Mills, Freitag & van Jaarsveld 2001). The TD measure is based on the number of regionally represented species relative to the number of genera within the Family and the number of Families within the Order under consideration (Freitag & van Jaarsveld 1997). This approach assumes that taxonomically more distinct taxa contribute more to regional biodiversity than more speciose species (Freitag & van Jaarsveld 1997).

In an attempt to explore the impact of using either the PD measures or the TD approach when conducting conservation priority setting, we employ a multi-criteria conservation setting technique, the Regional Priority Score (RPS - Freitag & van Jaarsveld 1997). The present investigation uses phylogenetic data of extant members of the Chiroptera and Carnivora from South Africa as a case study to assess if a "simple" measure of taxonomic distinctiveness can be a substitute for PD measures in the absence of complete phylogenies.

Materials and Methods

The recently available comprehensive ordinal phylogenies for bats (Jones et al. 2002) and carnivores (Bininda-Emonds et al. 1999) were used to extract data for 51 and 34 extant South African bat and carnivore species, respectively.

In order to calculate PD_{NODE}, the technique described by Vane-Wright et al. (1991) and Posadas et al. (2001) was applied (see Figure 1). PD_{NODE} essentially attempts to reflect phylogenetic information for each species based on the number of nodes on a phylogenetic tree to which each species belongs. This basic measure of phylogenetic information (I) for each terminal species is in turn allocated a phylogenetic weight (Q) that reflects each species' contribution to the total diversity of the group (Vane-Wright et al. 1991), and is calculated as:

$$Q_j = \frac{\sum I}{I_j}$$

where, *j* represents a specific species.

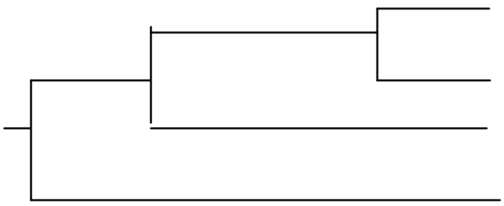
The resulting phylogenetic weight is then standardized (W) by dividing a terminal species' Q value with the lowest derived Q value among all terminal taxa under consideration, i.e.:

$$W_j = \frac{Q_j}{Q_{min}}$$

Such an adjustment allows for the lowest ranking species to be equal to one. To obtain the required PD_{NODE} value, the standardised weight value (W) is further adjusted as:

$$PD_{NODE\ j} = \frac{W_j}{\sum W}$$

The associated "best estimate" branch lengths obtained from the terminal node (Beninda-Emonds et al 1999) of each of the 34 extant South African carnivores were used to compile PD_{BRANCH} in order to assess the relative evolutionary age for each species in a phylogeny over time (in millions of years). The Chiroptera were not considered in the current PD_{BRANCH} analysis because Chiropteran branch length data are currently not available in the literature (K. Jones, pers comm.).



	I	Q	W	PD_{NODE}
A	3	3	1	0.154
B	3	3	1	0.154
C	2	4.5	1.5	0.231
D	1	9	3	0.462
T	9	19.5	6.5	1.00

Figure 1. An example of the calculation of Phylogenetic Distinctiveness (PD_{NODE}). Column I indicates the number of groups to which each terminal species belongs, I being the basic measure of taxonomic information. Q gives the quotient of the total information for each species. W is standardised weight of each species. PD gives the contribution of each terminal species to the total diversity in terms of the aggregated values for Q and W (Modified from Vane-Wright et al. 1991)

In order to assess the taxonomic distinctiveness, the TD was calculated following the procedure outlined by Freitag & van Jaarsveld (1997) as:

$$TD = \frac{1}{\sqrt{\#\text{ of regionally represented Families x } \#\text{ of Genera x } \#\text{ of Species}}}$$

TD reflects the taxonomic rarity of a species where species with fewer rather than many extant relatives are considered to be of a higher conservation value.

Regional Priority Scores (RPS) components

The RPS technique used in the current study has the advantage of systematically evaluating indigenous species in terms of various components that could also accommodate for the inclusion and subsequent assessment of the effect of any specific measure of phylogenetic rarity. Two bat species, the flat-headed free-tail bat, *Sauromys petrophilus* (Family Molossidae) and the butterfly bat, *Glauconycteris variegates* (Family Vespertilionidae) were omitted from all RPS analyses because they are not represented in the Chiropteran super tree (Jones et al. 2002).

In order to evaluate the effect of incorporating PD_{NODE} and PD_{BRANCH} in regional priority assessments, the RPS technique proposed by Freitag & van Jaarsveld (1997) was used. To include the PD_{NODE} and PD_{BRANCH} values in the respective RPS technique, an adjustment to the score was required. The PD values for each species were expressed as a value less than one (Vane-Wright et al. 1991; Posadas et al. 2001). Consequently, to allow for carnivore PD_{BRANCH} to be expressed as a value less than 1.0, PD_{BRANCH} was adjusted as:

$$PD_{BRANCH} = \frac{\text{Millions of years}}{100}$$

In addition to the use of measures of either a taxonomic distinctiveness or a phylogenetic diversity, the conventional rarity and threat components used by the RPS technique include Regional Occupancy (RO), Relative Endemism (RE) and Relative Vulnerability (RV) (Freitag & van Jaarsveld 1997), as well as components of Body Mass (BM) (M. Keith unpubl. data) and Human Population Density (HD) (Central Statistical Services 1998; M. Keith unpubl. data).

The calculation of the employed rarity and threat components were undertaken as follows:

(a) Relative Occupancy (RO): Based on species distributional data derived from museum records at quarter degree grid squares (QDS; Freitag & van Jaarsveld 1995; Freitag & van Jaarsveld 1997) and computed as:

$$\text{RO} = \frac{1}{\text{number of quarter degree squares (QDS) occupied in South Africa}}$$

(b) Relative Endemism (RE): Denotes the extent to which a species' total African distribution is limited to South Africa and was scored as:

1.0: Endemic to South Africa only (excluding Swaziland and Lesotho);

0.8: 75-99% distribution in South Africa;

0.6: 50-74% distribution in South Africa;

0.4: 25-49% distribution in South Africa; and

0.2: 0-24% distribution in South Africa.

(c) Relative Vulnerability (RV): Based on Mills et al. (2001). The regional IUCN Red Data List assessment of the regional Conservation Assessment and Management Plan (CAMP) for South African mammals (Friedmann and Daly 2004) were used in scoring the vulnerability categories as:

1.0: Critically Endangered (CR);

0.80: Endangered (EN);

0.70: Vulnerable (VU);

0.56: Near Threatened (NT);

0.42: Data Deficient (DD);

0.00: Least Concern (LC) or Not evaluated (NE) or not listed.

(d) Relative Human Density (RHD): Initially computed for each species as:

$$\text{HumanDensity(HD)} = \frac{\sum \text{(Averaged human density across a species' distribution (QDS))}}{\text{Number of QDS in which the species occurs in}}$$

In order to obtain a relative human density (Central Statistical Service 1998) value for each species across its known distributional range (in QDS), HD was standardised by dividing it by the species that scored the highest human density value (HD_{max}) within each of the two Orders, i.e.:

$$\text{RHD} = \frac{\text{HD}}{\text{HD}_{max}}$$

By so doing, the large eared free tailed bat, *Otomops martiensseni* scored the highest HD value for bats, with most of its QDS distribution falling within the Durban metropolitan area, with 256 people/km^2. This HD value was not used as HD_{max} for bats and was treated as an outlier value, and converted to 1. Consequently, the second ranking bat species, the peak-saddle horseshoe bat, *Rhinolophus blassii* with an HD value of 207.88 people/km^2 was instead used as the HD_{max} value for bats. The carnivore HD_{max} value was based on the human density value obtained for the white-tailed mongoose, *Ichneumia albicauda* that had an HD value of 87.84 people/km^2.

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

$$RBM = \frac{\log(\text{body mass (g) (BM)})}{\log(BM_{max})}$$

RBM was incorporated in this current assessment as a potential estimator for human conflict following Mills et al (2001). The rationale behind this was that larger-bodied species are more likely to be negatively influenced by human populations (Mills *et al.*, 2001, Harcourt and Parks, 2003). However, despite numerous documented relationships between body size and ecological and taxonomic variables (see Kunin & Gaston, 1997; Gittleman 1985; Jones, Purvis and Gittleman. 2003), the effects of body size and characteristics of threat remain unclear (Dobson and Yu, 1993; Arita *et al.*, 1997; Dobson, Smith & Yu, 1997).

Regional Priority Score (RPS)

To ascertain standard regional priority without any influence of either PD_{NODE}, PD_{BRANCH} or TD, RPS_S was calculated, using five rarity and threat criteria:

$$RPS_S = \frac{RO + RE + RV + RHD + RBM}{5}$$

The PD_{NODE} measure was included within the priority setting exercise in addition to the components used to calculate RPS_S, for both carnivore and chiropteran species, as:

$$RPS_{NODE} = \frac{RO + RE + RV + RHD + RBM + PD_{NODE}}{6}$$

Carnivore branch length data were incorporated into the RPS technique as follows:

$$RPS_{BRANCH} = \frac{RO + RE + RV + RHD + RBM + PD_{BRANCH}}{6}$$

RPS_{TD} was subsequently calculated in similar fashion to PD RPS as:

$$RPS_{TD} = \frac{RO + RE + RV + RHD + RBM + TD}{6}$$

Statistical analysis

The PD_{NODE}, PD_{BRANCH}, and TD values for the extant South African chiroptera and carnivora species were tested for statistically significant differences using a Mann-Whitney *U* test (Zar 1996). Statistical correlations were explored using Spearman's *R* (Zar 1996). Jackknife randomisation tests (re-sampling without replacement) (Manly 1991; MathSoft 1999) for correlations between PD_{NODE}, PD_{BRANCH} and TD were also undertaken. Statistical analyses to assess differences and correlations (Zar 1996) between the derived RPS scores for RPS_S, RPS_{NODE}, RPS_{BRANCH} and RPS_{TD} included Kruskal-Wallis Analysis of Variance (ANOVA) by Ranks as well as Wilcoxon Matched Pair tests (Zar 1996). Spearman's *R* correlation was also used to test for statistical correlations between the various different RPS scores. The derived RPS scores and associated rankings were used to calculate a corrected coefficient of variation (*CV** for small sample sizes; $n = 3$ in this case; Sokal & Rohlf 1981) to assess the nature and extent of variation in RPS scores associated with each of the three techniques for both the Carnivore and Chiropteran species. All statistical analyses were executed using STATISTICA, version 5.5 (StatSoft Inc. 1995).

Results

Chiroptera

A Mann-Whitney *U* test shows that the PD_{NODE} and TD values for the 51 bat species were not significantly different from each other ($U = 1442$, $n = 51$; $P = 0.40$), and were weakly negatively correlated with each other ($R = -0.29$; $n = 51$; $P < 0.05$). The jackknife randomisation tests indicated that the Spearman *R* value between PD_{NODE} and TD were not significantly different from random ($R = -0.29$; $n = 50$; $P = 0.66$). Only the Family Vespertilionidae ($R = 0.051$; $n = 23$; $P < 0.05$) indicated towards a very weak positive correlation between taxa.

The Mann-Whitney *U* test revealed statistically significant differences between RPS_S and RPS_{NODE} values ($U = 927.0$, $n = 51$; $P < 0.05$) and between RPS_S and RPS_{TD} values ($U = 1660.00$, $n =$

51; P < 0.05) (Table 1). RPS_{NODE} and RPS_{TD} values did not differ significantly from each other. Although the RPS_S values for bats were considerably larger than the values of RPS_{NODE} and RPS_{TD}, the chiropteran RPS_S, RPS_{NODE} and RPS_{TD} values and their associated rankings yielded broadly similar priority scores (Wilcoxon Matched Pair test: $T \geq 10.5$, $n = 51$, $P > 0.058$). Generally, the corrected coefficients of variation (*CV**) were low for all South African chiropteran species (Table 2). However, Spearman's *R* correlation analysis of the Chiroptera showed all three RPS techniques to be highly and significantly correlated with each other (Table 1). The large-eared free-tailed bat, *Otomops martiensseni* with an IUCN threat categorization of VU D2 (Friedmann & Daly 2004) scored the highest value in all three priority-scoring techniques and was consequently ranked highest with regard to bat conservation importance in South Africa. The additional four top priority bat species were the short-eared trident bat, *Cloeotis percivali*, Welwitsch's hairy bat, *Myotis welwitschii*, hairy slit-faced bat, *Nycteris hispida*, and Cape horseshoe bat, *Rhinolophus capensis* which retained a reasonably steady RPS score by both RPS_{NODE}, RPS_{TD}, and RPS_S, although some shifts in rank occurred between these species. Only two of the top five bats were regarded as Threatened by the regional IUCN Red List (*C. percivali*: CR A2a, and *O. martiensseni*: VU D2), while the remaining three species were assessed as Near Threatened (NT).

Carnivora

PD_{NODE} and PD_{BRANCH} were not significant different ($U = 486$; $n = 34$; $P = 0.19$), and were strongly positively correlated ($R = 0.58$; $n = 34$; $P < 0.05$). For carnivores, PD_{NODE} and TD values were significantly different from each other ($U = 152$, $n = 34$; $P < 0.001$), and were weakly correlated with each other ($R = 0.31$; $n = 34$; $P < 0.05$). PD_{BRANCH} and TD values were

not significantly different ($U = 592$, $n = 34$; $P = 0.54$), and were weakly negatively correlated ($R = -0.10$; $n = 34$; $P < 0.05$). Correlation analysis for various Families within in the Carnivora was not possible due to relatively small sample sizes, but with regard to the negative correlation between PD_{BRANCH} and TD, all but the Felidae were very weakly negatively correlated. The jackknife randomisation test between PD_{BRANCH} and TD indicated that the Spearman *R* regression value obtained was not significantly different from random data ($R = -0.10$; $n = 34$; $P = 0.56$).

Similar to the Chiropteran results, the carnivore RPS_S, RPS_{NODE}, RPS_{BRANCH} and RPS_{TD}, and the Mann-Whitney *U* test revealed statistically significant differences between the scores of the

Table 1. Mann Whitney *U* test and Spearman Rank order correlation (*R* - values included in parenthesis) for extant South African Chiroptera RPS scores using three different RPS techniques (RPS_S, RPS_{PD} and RPS_{TD}; see text) (Statistical significance: * = $P < 0.05$; ns = not statistically significant)

	RPS_{NODE}	RPS_{TD}
RPS_S	927.0^{*} (0.99^{*})	1660.0* (0.99^{*})
RPS_{NODE}	-	1318.0^{ns} (0.99^{*})

Table 2. Regional Priority Scores and ranking of extant South African Chiroptera species based on the three RPS techniques (RPS_S, RPS_{TD}, and RPS_{PD}; see text). Regional IUCN assessments of risk of extinction from the recent regional IUCN Red List (Friedmann & Daly 2004). *CV** = corrected coefficient of variation values calculated for the RPS scores. Taxa highlighted in bold form the top five ranking taxa as identified by the three priority techniques.

Species name	IUCN Red List	RPS_S	RPS_{NODE}	RPS_{TD}	Rank RPS_S	Rank RPS_{NODE}	Rank RPS_{TD}	CV*
Chaerephon ansorgei	LC	0.27	0.23	0.23	42	42	42	10.6
C. pumila	LC	0.26	0.22	0.22	46	46	46	9.28
Cloeotis percivali	CR A2 a	0.5	0.42	0.43	**5**	**5**	**2**	10.3
Epomorphorus gambianus	DD	0.37	0.31	0.32	26	26	23	10.3
E. wahlbergi	LC	0.39	0.33	0.33	20	20	19	10.6
Eptesicus hottentotus	LC	0.37	0.31	0.32	24	25	24	10.9
Glauconycteris variegatus	NT	0.37	0.31	0.32	25	24	25	10.5
Hipposideros caffer	DD	0.31	0.26	0.27	35	35	34	9.92
H. commersoni	NA	0.38	0.32	0.33	22	22	21	10.6
Kerivoula argentata	EN B1ab (iii) & 2ab (iii)	0.46	0.39	0.39	10	10	10	10.9
K. lanosa	NT	0.34	0.28	0.28	31	31	31	10.7
Laephotis botswanae	VU D2	0.4	0.34	0.34	17	17	17	10.9
L. wintoni	VU D2	0.44	0.37	0.37	11	11	11	11
Miniopterus fraterculus	NT	0.48	0.4	0.4	8	8	8	11.1
M. schreibersi	NT	0.35	0.3	0.3	29	29	29	10.8
Mops condylurus	LC	0.27	0.23	0.23	43	43	43	10.6
M. midas	LC	0.29	0.25	0.25	38	38	38	10.7
Myotis bocagei	DD	0.43	0.37	0.36	12	12	12	11
M. lesueuri	NT	0.49	0.41	0.41	7	6	7	11.3
M. seabrai	VU D2	0.41	0.35	0.35	15	15	16	11.1
M. tricolour	NT	0.47	0.4	0.39	9	9	9	11.1
M. welwitschii	NT	0.5	0.42	0.42	**4**	**3**	**5**	11.2
Neoromicia capensis	LC	0.21	0.18	0.18	51	51	51	10.6
N. melckorum	NA	0.23	0.2	0.2	49	49	49	10.7
N. somalicus	NA	0.18	0.15	0.15	52	52	52	10.4
Nycteris hispida	NT	0.5	0.42	0.43	**2**	**2**	**3**	10.7
N. thebaica	LC	0.22	0.18	0.19	50	50	50	9.91
N. woodi	EN B2 ab(v)	0.41	0.35	0.35	14	14	14	10.5
Nycticeius schlieffenii	LC	0.16	0.14	0.14	53	53	53	9.74
Otomops martiensseni	VU D2	0.64	0.54	0.54	**1**	**1**	**1**	11.1
Pipistrellus anchietai	NT	0.39	0.33	0.33	18	18	20	10.9
P. kuhlii	LC	0.25	0.21	0.21	47	47	47	10.9

Species name	IUCN	RPS_S	RPS $_{NODE}$	RPS_{TD}	Rank RPS_S	Rank RPS_{NODE}	Rank RPS_{TD}	CV*
P. nanus	LC	0.25	0.21	0.21	48	48	48	10.9
P. rueppellii	NA	0.27	0.23	0.23	45	45	45	10.9
P. rusticus	NT	0.3	0.25	0.25	37	36	37	10.6
Rhinolophus blasii	VU D2	0.49	0.41	0.41	6	7	6	11.3
R. capensis	NT	0.5	0.42	0.42	**3**	**4**	**4**	11.4
R. clivosus	NT	0.38	0.32	0.32	21	21	22	11.1
R. darlingi	NT	0.35	0.29	0.29	30	30	30	11
R. denti	NT	0.37	0.31	0.31	23	23	26	11.1
R. fumigatus	NT	0.36	0.3	0.3	28	28	28	11
R. hildebrandtii	NT	0.36	0.31	0.31	27	27	27	11
R. landeri	NT	0.33	0.27	0.27	33	33	33	10.9
R. simulator	LC	0.32	0.27	0.27	34	34	36	11.2
R. swinnyi	EN C2a (i)	0.42	0.35	0.35	13	13	13	11
Rousettus aegyptiacus	LC	0.4	0.34	0.35	16	16	15	10.3
Sauromys petrophilus	LC	0.28	0.24	0.24	39	39	39	10.4
Scotophilus dinganii	LC	0.28	0.23	0.23	40	40	41	11
S. viridis	LC	0.27	0.23	0.23	41	41	44	10.9
Tadarida aegyptiaca	LC	0.27	0.23	0.24	44	44	40	10.6
T. fulminans	NA	0.33	0.28	0.28	32	32	32	11
Taphozous mauritianus	LC	0.3	0.25	0.27	36	37	35	10
T. perforatus	NA	0.39	0.33	0.34	19	19	18	10.4

conventional RPS_S and RPS_{NODE} (U = *817.0*; n = 34; $P < 0.001$), between RPS_S and RPS_{BRANCH} (U = *830.0*; n = 34; $P < 0.001$), and between the RPS_S and RPS_{TD} (U = 844.0; n = 34; $P <$ 0.001), but RPS_{NODE}, RPS_{BRANCH} and RPS_{TD} values did not differ significantly from each other (Table 3). The RPS associated rankings yielded broadly similar priority scores (Wilcoxon Matched Pair test: $T \geq 57.7$; n = 34 P = 0.54) and rankings, with relatively low CV^* (Table 4).

The three RPS techniques yielded highly significantly correlated RPS scores for the carnivore species (Table 4). The wild dog, *Lycaon pictus* (EN D) scored the highest value in all three priority scoring techniques applied and is consequently ranked highest with regard to carnivore conservation importance in South Africa. In turn, the other four carnivore taxa contributing to the top five ranking taxa were the cheetah *Acinonyx jubatus*, brown hyaena, *Parahyaena brunnea*, lion, *Panthera leo*, and the spotted hyaena, *Crocuta crocuta*. These five species were evidently stable in priority scores and ranking. Three of the top five carnivore species were regarded as being threatened (*A. jubatus*: VU D1, *L. pictus*: EN D and *P. leo*: VU D1).

Discussion

Phylogenetic (PD_{NODE} and PD_{BRANCH}) and taxonomic (TD) diversity measures used in the current study, revealed statistically varying results between PD and TD values for both South African bats and carnivores. The PD_{NODE} and TD values for the Chiroptera, as well as PD_{BRANCH} and TD for carnivores were weakly negatively correlated with each other. The reason(s) for the observed negative correlations between the Chiroptera PD_{NODE} and TD values, as well as the carnivore PD_{BRANCH} and TD remains unclear. The relationship between PD and TD should be generated by both the phylogeny (Crozier 1992) and the relative number of species per Genus and number of genera per Family (Freitag & van Jaarsveld 1997). These would most likely to be influenced by disproportionately large families (e.g., the Vespertilionidae and the Herpestidae), and yet the correlation between the Vespertilionidae species' PD_{NODE} and TD were for example, yielded positive values suggesting a significant contribution by one of the smaller Families. The jackknife randomisation tests (resampling without replacement) for both PD and TD correlations between bats and carnivores indicated that the Spearman R correlations were not significantly different from random, demonstrating that none of the species are having a disproportionate effect on the correlations found.

Table 3. Mann Whitney *U* test and Spearman Rank order correlation (*R* – values included in parenthesis) for extant South African Carnivora RPS scores using four different RPS techniques (RPS_S, RPS_{NODE} RPS_{BRANCH} and RPS_{TD}; see text) (Statistical significance: * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$; ns = not statistically significant)

	RPS_{NODE}	RPS_{BRANCH}	RPS_{TD}
RPS_S	817.0^{***} (0.98^{*})	830.0^{***} (0.88^{*})	844.0^{***} (0.98^{*})
RPS_{NODE}	-	486.0^{ns} (0.89^{*})	656.0^{ns} (0.98^{*})
RPS_{BRANCH}		-	544.0^{ns} (0.89^{*})

Table 4. Regional Priority Scores and ranking of the extant South African Carnivora species based on the four RPS techniques (RPS_S, RPS_{NODE}, RPS_{BRANCH} and RPS_{TD}). Regional IUCN assessments of risk of extinction from the recent regional IUCN Red List (Friedmann & Daly 2004) are also included. *CV** = corrected coefficient of variation values calculated for the RPS scores. Taxa highlighted in bold form the top five ranking taxa as identified by the four priority techniques.

Species names	IUCN Red List	RPS_S	RPS_{NODE}	RPS_{BRANCH}	RPS_{TD}	Rank RPS_S	Rank PD_{NODE}	Rank PD_{BRANCH}	Rank RPS_{TD}	CV*
Acinonyx jubatus	VU D1	0.39	0.34	0.35	0.34	**3**	**3**	**1**	**3**	7.84
Aonyx capensis	LC	0.23	0.19	0.2	0.2	23	24	26	20	8.41
Atilax palundinosus	LC	0.22	0.19	0.21	0.19	30	29	18	30	8.18
Canis adustus	NT	0.23	0.2	0.2	0.2	20	20	25	22	8.49
C. mesomelas	LC	0.26	0.22	0.22	0.22	11	11	12	11	8.56
Caracal caracal	LC	0.22	0.19	0.2	0.19	29	30	27	28	7.41
Civetticis civetta	LC	0.23	0.2	0.21	0.2	22	21	19	24	7.74
Crocuta crocuta	NT	0.36	0.31	0.32	0.32	**6**	**5**	**5**	**5**	7.6
Cynictis penicillata	LC	0.24	0.2	0.2	0.21	16	16	23	19	8.61
Felis nigripes	LC	0.27	0.23	0.23	0.23	8	8	10	9	9.08
F. silvestris	LC	0.2	0.17	0.17	0.17	32	32	32	32	8.54
Galerella pulverulenta	LC	0.32	0.27	0.29	0.27	7	7	7	7	8.38
G. sanguinea	LC	0.2	0.17	0.19	0.17	31	31	31	31	7.85
Genetta genetta	LC	0.22	0.19	0.19	0.19	28	28	29	29	8.91
G. tigrina	LC	0.26	0.22	0.22	0.22	12	12	13	12	9.07
Helogale parvula	LC	0.19	0.16	0.16	0.17	33	33	33	34	8.78
Herpestes ichneumon	LC	0.23	0.19	0.19	0.2	26	25	28	26	8.29
Ichneumia albicauda	LC	0.24	0.2	0.22	0.2	18	19	11	21	8.21
Ictonyx striatus	LC	0.19	0.16	0.16	0.17	34	34	34	33	8.78
Leptailurus serval	NT	0.23	0.2	0.22	0.2	24	23	14	23	7.61
Lutra maculicollis	NT	0.36	0.31	0.3	0.31	5	6	6	6	9.22
Lycaon pictus	EN D	0.4	0.34	0.34	0.35	**2**	**1**	**3**	**1**	9.05
Mellivora capensis	NT	0.23	0.2	0.21	0.21	21	22	17	18	7.3
Mungos mungo	LC	0.22	0.19	0.19	0.19	27	27	30	27	8.96
Otocyon megalotis	LC	0.23	0.2	0.21	0.21	19	13	20	15	6.83
Panthera leo	VU D1	0.4	0.34	0.34	0.34	**1**	**2**	**2**	**2**	9.39
P. pardus	LC	0.24	0.2	0.2	0.21	13	18	22	16	8.93
Paracynictis selousi	DD	0.24	0.2	0.2	0.21	15	15	21	17	8.61
Parahyaena brunnea	NT	0.37	0.32	0.33	0.33	**4**	**4**	**4**	**4**	7.68
Poecilogale albinucha	LC	0.24	0.2	0.22	0.21	17	17	15	14	7.43
Proteles cristatus	LC	0.26	0.22	0.24	0.24	10	10	9	8	6.12

Species names	IUCN Red List	RPS_S	RPS_{NODE}	RPS_{BRANCH}	RPS_{TD}	Rank RPS_S	Rank PD_{NODE}	Rank PD_{BRANCH}	Rank RPS_{TD}	CV*
Rhynchogale melleri	DD	0.26	0.23	0.25	0.23	9	9	8	10	8.04
Suricata suricatta	LC	0.23	0.19	0.21	0.2	25	26	16	25	8.15
Vulpes chama	LC	0.24	0.2	0.2	0.21	14	14	24	13	8.47

Interestingly, Whiting et al. (2000) found a clear correlation between measures of phylogenetic diversity, although these correlations decreased with an increasing number of species. A similar trend is evident in the current study, where small number of species per Family seems to influence an analysis. Consequently, although in some cases the TD seems a reasonable surrogate measure for the more data intensive PD measures, it does not perform statistically well and should be therefore used with caution when substituting it for any measure of PD. It is evident that the implementation of a direct measure of evolutionary history such as PD_{BRANCH} into regional conservation setting exercises rather than a diversity derivative such as PD_{NODE} is advantageous. Various arguments against the use of PD_{NODE} have been raised in the literature such as Crozier (1992) who argued that PD_{NODE} is dependent on the topology of the inferred phylogeny as well as the subsequent taxonomic decisions that can be made from the phylogeny. It is also argued that this technique does not take branch lengths into account and may result in some anomalies during analysis (Crozier 1992). In the current study, however, the carnivore PD_{NODE} and PD_{BRANCH} values were not statistically significantly different and were also strongly positively correlated with each other. This suggests that both PD_{NODE} and PD_{BRANCH} values may reflect the evolutionary history of species under consideration, at least for the groups investigated here.

More importantly, the PD_{NODE} can be utilized with limited detailed phylogeny and distance information. It is therefore possible that the PD_{NODE} technique as proposed by Vane-Wright et al. (1991) and Posadas et al. (2001) can act as a suitable proxy for the more complex PD_{BRANCH} measure. The PD_{NODE} as defined here also allows all species to contribute equally to the weighting procedure, and is regarded to be sensitive to phylogenetic diversity (Faith 1994; Posadas et al. 2001). Consequently, this allows information from diverse taxa to be combined and gives priority to phylogenetically rare basal taxa (Vane-Wright et al.1991; Faith 1994; Posadas et al. 2001). Phylogenetically more distinct species receive higher scores than more speciose taxa because of the consideration that such unique species contribute proportionally more to regional biodiversity (Vane-Wright et al. 1991; Freitag & van Jaarsveld 1997).

With data and time constraints being a major factor when choosing components to include in conservation priority techniques, it is essential that components used for evaluation should be those that are easily obtainable and analysed (Whiting et al. 2000; Harcourt & Parks 2003). Currently, there are limited comprehensive phylogenies for most taxonomic groups, lack of appropriate data such as branch lengths for large groups of taxa, unresolved phylogenies, as well as conflicting phylogenies arising from the use of independent data sets and techniques (Miyamoto 1981; Whiting et al. 2000; Wiens & Hollingsworth, 2000; Carstens, Lundringan & Myers 2002). Consequently, the application of either complex phylogenetic or character diversity measures on various South African mammals would not be considered a feasible option. For the current analysis, the TD as proposed by Freitag & van Jaarsveld (1997) and Mills et al. (2001), like other RPS components is logistically simple and more feasible for incorporating an evolutionary diversity measure when setting regional conservation priorities.

With limited resources available for conservation, the identification of species that demand special conservation measures or which need to be regionally prioritised provides invaluable information for the execution of conservation plans (Freitag & van Jaarsveld 1997; Whiting et al. 2000; Andelman & Willig 2002). With the recent emphasis on priority setting techniques to incorporate some gauge of evolutionary history and/or genetic diversity/distinctiveness, the use of either PD and/or TD may be the most appropriate procedure. Apart from regions being prioritised with reference to evolutionary and phylogenetic data, these approaches also contribute towards a better understanding of the regional conservation status of species. However, all these analyses ought to take cognisant that the geographic scale under consideration will always have influence arising from components such as rarity, endemism, rates of decline and IUCN Red List assessments (IUCN 1994; Freitag & van Jaarsveld 1995; Mills et al. 2001; Hartley & Kunin 2003).

After including phylogenetic/taxonomic criteria (PD_{NODE}, PD_{BRANCH} and TD) in the RPS_{NODE}, RPS_{BRANCH}, and RPS_{TD} assessments, there was a significant difference in RPS values obtained for the chiropteran and carnivore species as compared to the use of the conventional $RPS_{S.}$ However, the RPS_{NODE}, RPS_{BRANCH} and RPS_{TD} scores and their associated rankings did not differ significantly from each other. However, despite the TD, PD_{NODE} and PD_{BRANCH} measures not significantly changing the ranking of a species' conservation status, the incorporation of phylogenetic or taxonomic measures had an influence in the final priority scores. Therefore, the assignment of conservation priority scores appears to be insensitive to the specifics of the phylogenetic/taxonomic information included. It is possible that this may be a result of the expected lack of independence and some influence by other criteria included in the RPS assessment, such as endemism and/or vulnerability (Gittleman 1985; Beissinger 2000; Carter et al. 2000; Danell & Aava-Olsson 2002). It is noteworthy that scores for some components are correlated with each other (Purvis et al. 2000) such that it may not necessarily be due to the lack of biological independence and visa versa. It is possible that some species are exhibiting correlations between components suggesting a pattern of the need for conservation rather than a lack of independence (Carter et al. 2000).

The nature of PD and TD as well as the variation within the two taxonomic groups included in this study may not have been sufficiently large to detect their affect in the scoring and ranking in the RPS technique used. The real impact of introducing any phylogenetic or taxonomic measure in regional priority scoring would most likely emerge when assessing a phylogenetic distinctiveness value across a much broader range of taxa. In the absence of phylogenies spanning various taxonomic Orders, either PD measures would not be a feasible conservation assessment tool (Rodrigues & Gaston 2002). The TD component, however, seems to have performed reasonably well in the past as an across-Order taxonomic measure (Freitag & van Jaarsveld 1997; Mills et al. 2002).

Conclusion

In the absence of complete phylogenies, phylogenies lacking branch lengths, and especially for conservation priority assessment for species that span various Orders and Families, the inclusion of the Taxonomic Distinctiveness still appears a viable alternative, although it should be implemented with caution. The varying statistically significant findings between PD_{NODE}, PD_{BRANCH} and TD require further investigation. As more phylogenies become available for South African mammal taxa, it may be advisable to further investigate the application of a more comprehensive phylogenetic diversity measure (e.g., Faith 1994; Rodrigues & Gaston 2002; Faith 2002; Knapp, Russel, & Swihart 2003; Mace et al. 2003), in regional conservation setting techniques.

Carter et al. (2000) cautioned that relying solely on total scores and rankings to set conservation goals may be misleading and may probably be the most common misuse of the prioritisation process. In addition, no scoring system will give the "right" answer for every species or user of the system, no matter how many different components are included or how they are weighted (Millsap et al. 1990, Knapp et al. 2003). The differences among priority ranking systems may be less important than the need for a priority setting process to be undertaken. A much better understanding of the factors driving species warranting conservation action will encourage conservationists to consider their goals carefully and to develop strategies that will focus activities and resources more effectively (Dunn et al. 1999).

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CHAPTER 6

The Orange List: a safety net for biodiversity in South Africa

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Abstract

We introduce the concept of an Orange List as a way of assessing and recording the conservation importance of rare and special concern taxa that are not on the Red List. We highlight the necessity for additional recognition of taxa at risk of becoming threatened, including organisms that are Near Threatened, Data Deficient, Rare or Declining but do not meet the IUCN criteria for Red List categories. The Orange List will comprise taxa that require anticipatory conservation planning endeavours, to prevent future Red Listing. We propose a systematic method for assessing rarity of plant taxa that should be listed on the Orange Lists. The Orange List therefore aims to be used in addition to the Red List to highlight additional taxa of special concern that should be conserved to pre-empt the possibility of such species becoming threatened in the future.

Introduction

In 1996, Hilton-Taylor's publication of the Red Data List of southern African plants provided the most widely used and comprehensive list of threatened plants and their threat status to date.[1,2,3] This compilation used subjective criteria that had been in place for more than 20 years.[1,2,3,4,5] The Species Survival Commission (SSC) developed a new objective approach for determining the status of threatened taxa which was formally adopted by the World Conservation Union (IUCN) Council in 1994[6,7,8] and the revised version 3.1 was adopted in 2001.[9] The main change that came about with the introduction of this new system was the improved objectivity, and resulted in exclusion of many taxa formerly included in the Rare category, so that only extremely rare taxa that have a potential threat of becoming extinct now qualify for a category of threat.

Red lists are usually the only tools available for use by conservationists that are based on substantial sound ecological knowledge.[10, 11] In many cases, the Red Lists are regarded as an easy to use conservation priority list or as a benchmark to influence Environmental Impact Assessments (EIAs) or resource allocation for conservation of certain taxa.[11, 12] It is generally accepted that if a taxon is on the Red List, it will (or should) be a conservation priority. Likewise the assumption follows that if a taxon does not qualify for Red Listing, it will be dismissed and therefore would not be subjected to conservation efforts. Some taxa listed as Least Concern (LC) are extremely rare but are not declining or facing possible future decline, and therefore do not meet the criteria for a category of threat in the Red Listing process. A frequent response to the LC listing such rare species are awarded, is scepticism as to the value of the Red Listing process. However the Red List is not intended as the sole means with which to set conservation priorities,[6,9,10,11] therefore the implication of listing rare taxa as "Least Concern" should not be to create the impression that these taxa are not worthy of consideration for conservation. There is currently no method in place for assessing and recording the conservation importance of rare and special concern taxa that are not on the Red List. For this reason the IUCN system could be, and often is, misused through incorrect interpretation (deliberate or subconscious) of the IUCN criteria or data to ensure that rare and other taxa of special concern are afforded protection through having Red List status.

To improve the information provided for end-users such as conservationists or EIA consultants, an additional step taken by Victor & Dold[13] in providing a Red List for the Albany Centre of Endemism, was to provide an indication of rarity for taxa listed as LC. These are the taxa that do not qualify for a category of threat but are in essence Rare, either small stable populations, or sparsely distributed severely fragmented populations of a taxon. The aim of doing this was to highlight additional taxa that should be considered for conservation protection over and above those that are threatened according to the IUCN.

The IUCN system for assessing extinction risk has a more narrow focus than the pre-1994 system, in being concerned only with taxa facing immediate risk of extinction. This has resulted in eliminating the Rare category and numerous taxa on the Red List with it. The concept of the "Rare" category defined by Davis et al.[14] and as used by Hilton-Taylor[1,2,3] is therefore now upheld and quantified. These Rare taxa, along with any other taxa for which there is some concern (e.g. due to medicinal harvesting, horticultural interest) will form the basis of the Orange List. We are not attempting to prioritise or rank taxa in order of importance for conservation purposes, but rather to provide a complete list of all taxa that should be afforded a measure of protection according to the Biodiversity Act.[15] Because of their rarity, decline in population numbers of Orange List taxa could result in the criteria for a category of threat to be met. The Orange List will therefore be a list of taxa that need to be protected and sometimes monitored.

Procedure

The Orange List for plants is currently proposed to consist of four categories, but this can be expanded or modified as more insight is gained into its use and effectiveness. These Orange List categories are defined as follows:

1. Near Threatened

A taxon is Near Threatened when it has been evaluated against the IUCN criteria for threat but does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future.[9]

2. Data Deficient

A taxon is Data Deficient when there is inadequate information to make an assessment of its risk of extinction based on its distribution and/or population status.[9] This category is not a category of threat but acknowledges the possibility that future research will show that threatened classification is appropriate.

3. Rare

Various methods of assessing rarity have been proposed, the most notable being that of Rabinowitz[16] in which she proposed seven forms of rarity based on abundance and size of distribution area. These principles have been indirectly incorporated into the IUCN system[9] by way of specifying maximum values in measurement of extent of occurrence (total distribution area of the population), area of occupancy (total area occupied by each separate subpopulation of a taxon added together), number of locations and number of mature individuals. These quantifiable limits indirectly conform to the principles of analysing rarity but in the IUCN system they are used in conjunction with rates of decline to measure extinction probability. The criteria as set out by the IUCN,[9] have been applied across a large range of taxonomic groups,[9] and have been shown to be suitable and adequate, capturing pertinent information for assessment of extinction risk. Here we propose the use the same quantified values as used in the IUCN system, as an indication of rarity, including the additional factor of relative abundance (as indicated by fragmentation) to capture sparsely distributed taxa. This technique combines assessment of rarity (in terms of quantitatively delimiting critical cut-off levels for distribution area and/or population size) with rates of decline.

Three categories of rarity, with criteria based on IUCN version 3.1,[9] are proposed as follows:

Rare—Critically (RC): A taxon is critically rare (RC) when it has an extremely small world population, typically with an area of occupancy of < 10 km^2 or an extent of occurrence of < 100 km^2, and known from only one location or is severely fragmented.

Rare (R): A taxon is rare (R) when it has a small world population, typically with an area of occupancy of < 500km^2 or an extent of occurrence of < 5 000km^2, and known from no more than five locations or is severely fragmented.

Rare—Sparse (RS): A taxon is rare in terms of its sparse distribution when it is severely fragmented or is known from < 10 locations in an area of occupancy of < 20 000km^2 or an extent of occurrence of < 20 000 km^2.

Definitions used are adapted from IUCN,[9] as follows:

Area of occupancy: the area occupied by the taxon within the total distributional area, taking into consideration the fact that the taxon will not occupy all the area throughout its distribution range.

Extent of occurrence: total distributional area in which the taxon occurs.

Location: Geographically or ecologically distinct area in which a single threatening event could affect all individuals of the taxon present.

Severely fragmented: most individuals are found in small isolated subpopulations or are solitary. As a guideline for the Rare-Sparse category, no subpopulation should contain more than 50 individuals.

4. Declining taxa

Plant or animal taxa that are not on the Red List and are declining, will be listed on the Orange List. This will enable all taxa that do not meet the IUCN requirements (because of having large population numbers or distributional areas) to be listed and monitored until such time that the levels fall below a critical point (defined by the IUCN criteria) that would then result in being listed on the Red List. Plant taxa sought after for horticultural purposes, such as some widespread *Lithops* species, are an example; as well as many insect species are captured and sold commercially (e.g. *Colophon izardi*) and various mammals that are declining for various reasons. The African Wild Cat (*Felis sylvestris*) is declining through its hybridisation with the domestic house cat (*Felis catus*), but since it has a very large extent of occurrence, it does not meet the criteria for listing as threatened according to the IUCN; however its decline would warrant it being listed on the Orange List.

Discussion

The Orange List is an effective way of dealing with many taxa that would have formerly been included as R (Rare), K (Insufficiently Known) and I (Indeterminate) according to the pre-1994 system of determining threat status and are now excluded from the Red List. The intention of proposing the Orange List is not to solve the problems of priority setting for conservation purposes, or to replace the function of the Red List. This is a proposal to provide lists from which conservationists and decision makers can prioritise what to conserve according to all factors that need to be considered e.g. financial feasibility, practicality, urgency.[4,6,17] In some ways the Orange List proposed here is similar to the "amber list" concept proposed by Avery et al.[18] for birds, however it differs in that the intention here is not priority setting.

The Red List is often relied upon by consultants doing surveys for threatened taxa for Environmental Impact Assessments (EIAs) or scoping reports.[12] However the impacts of developments on rare taxa or other taxa of special concern are also (or should also be) considered, and the Orange List will facilitate this process by guiding the taxa that also need to be considered. This is unlikely to increase the numbers of taxa taken into consideration significantly because the new IUCN system for determining threat status is currently resulting in the exclusion of numerous taxa that were previously included, and the Orange List will be comprise mostly these taxa.

It is recommended that, should subpopulations of Orange List taxa particularly those in the Rare and Near Threatened categories be encountered during the EIA process, the burden of proof should be placed upon the developer/consultant[19] to provide proof that the impact of the development on the subpopulation(s) does not effect the total population. This information should then be used to re-evaluate the taxon to assess whether the impact would cause the taxon to qualify for a Red List category. If such an impact would change the status of the taxon then mitigation measures or conservation efforts should be put into place. If not, no mitigation measures would be necessary.

A further recommendation is that if a Data Deficient taxon is encountered by consultants during the EIA process, the Threatened Species Programme should be contacted so that a proper assessment can be made.

Conclusions

The Threatened Species Programme intends to compile an Orange List for South Africa and invites commentary on the proposed methodology. We hope that in this way we will achieve our aims of providing guidance regarding taxa in need of conservation, as well as facilitating the work of all end users of conservation related information. We believe that the Orange List can provide a valuable system in which we can protect South Africa's heritage of a rich biodiversity.

Amendment to Victor & Keith 2004

A preliminary list of potential Orange List taxa has been drawn up (Appendix 3). Relevant information were extracted from the South African Red List for mammals[20], to identify taxa that could be possibly listed according to the Orange List criteria and categories set out by the current work. Although being a preliminary list, all regionally IUCN Near Threatened (38) and Data Deficient (53) taxa automatically qualified to be Orange Listed (see Appendix 1 for NT and DD listed taxa). Taxa listed as LC by Friedmann & Daily[20] were scrutinised for possible inclusion onto the Orange List, under either the Rare or Declining categories, highlighting 42 of the 147 LC assessed taxa. Information from the Red List assessments, all pointed to these taxa undergoing some and varying levels of decline in either population numbers or suitable habitat. Most of the taxa were however placed into the LC categories, but noting that many of them are undergoing "unknown levels of decline" and often based on inference[20]. The current list needs to be verified by experts, and is therefore only preliminary. Three potential Orange List taxa previously identified as Rare by the previous Red Data Book[21], were the African weasel, *Poecilogale albinucha* and red duiker, *Cephalophus natalensis* and the hippopotamus *Hippopotamus amphibious*. Various LC taxa were placed on the Orange List, as they were known to be "scarce" and to have very restricted area of occupancy, yet were allegedly stable within this area (e.g. Woosnam's desert rat, *Zelotomys woosnami*).

However compiling the preliminary Orange List for mammals, the process was hampered by incomplete and limited information, to extract even relevant Orange List assessments. A more detailed analysis of the implications of the Orange List assessments for South African mammals will be undertaken once the preliminary list has been verified. This will allow for more informative conservation strategies to assist in effective mammal conservation. We hope that in this way we will achieve our aims of providing direction regarding mammal taxa in need of conservation.

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CHAPTER 7

Revisiting Green Data Species Lists

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Abstract

The management and active enforcement of the increasing number of conservation-related instruments (e.g. the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), The World Conservation Union (IUCN) Red Data Lists and pending invasive species regulations), and the number of listed plant and animal taxa that they are likely to incorporate, are already straining national regulatory, enforcement and border control agencies. Against the backdrop of increasing capacity constraints (financial and logistic) and uncertainty faced by these authorities, we support calls for a radical shift in the traditional approach to the management of threatened species (either Red Data List or CITES listed) and the maintenance of the integrity of biological systems (*viz.* the control of potentially invasive species). This entails the establishment of National Green Data Species Lists (proposed by Imboden 1987 in World Birdwatch 9: 2). The Green List would, be a reciprocal list of species that are not threatened (not Red Data listed), not affected by trade (not CITES listed) or pose little threat of invasion according to importing authorities. This reciprocal list does not require negotiation of new international treaties and will simply piggy-back on existing treaties. In addition, it will shift the 'burden of proof,' including the financial investment required for species Green Data listing, the verification of origins, taxonomic and conservation status determination, from regulating authorities to traders.

Key words: CITES; Green Data Species List; invasive species; IUCN Red Data List

Introduction

Well-known instruments for documenting global taxa losses or threats have existed for over 20 years. For example, the Convention for Trade in Endangered Species (CITES) and IUCN Red Data Lists generated by the World Conservation Union (Baillie and Groombridge 1996) have gained universal acceptance and have been applied across the taxonomic spectrum.

Conservation efforts to slow biodiversity losses have traditionally placed considerable focus on species with few remaining individuals (Flather et al. 1998). Threat-listed species typically have low population numbers and/or restricted distributions and generally appear vulnerable to local or global extinction (Purvis et al. 2000). The rate at which taxa are listed as threatened has accelerated greatly over the last twenty years (Flather et al. 1998). The updated IUCN Red List for 2000 identified over 11 046 plants and animals threatened with extinction, with over 200 new animal taxa added to the critically endangered category (IUCN 2000). Traditionally, the implicit assumption behind the Red Data Listing process for species was "extant unless proven extinct" (Diamond 1987). Consequently, most officially listed endangered taxa were large, well-known charismatic vertebrates. This is in contrast with the majority of small, inconspicuous and poorly surveyed taxa that we now know to be threatened (Mace 1995; Mickleburgh 2000). For most of these taxa, data on systematics, population and conservation status are outdated and/or of insufficient quality. This, in turn, affects the correct assessment of these taxa as IUCN Red Data List categories are based on thresholds of parameters such as distributional range, population size and history (Burgman et al. 1999). For some taxa, such as marine or many invertebrates, these data may never exist (Mace 1995; Mickleburgh 2000) and one would never be able to assess the species. A sensible way to confront this dilemma is to incorporate the precautionary principle into Red Data Listing procedures (Coone 2000; IUCN/SSC Criteria Review Working Group 1999; Mickleburgh 2000), and follow the revised IUCN (2001) protocol of the use of the data deficient category.

Widespread application of the precautionary principle is likely to increase the rapidly growing taxa listed (Flather et al. 1998), and partially re-enforce the feeling of negativity sometimes associated with Red Data Lists (Gigon et al. 2000). One suggested remedy is to implement the proposed Blue List (Gigon et al. 2000). This list forms a subset of existing Red Data Lists, and serves to reinforce public and scientific resolve through the recognition of success stories. On the other hand, the proposed Blue Lists suffer from similar weaknesses to Red Data Lists (see Gigon et al. 2000 for discussion).

Effective regulation of wildlife trade is largely dependent on sound legislation that assists conservation authorities (Bürgener et al. 2001). However, these agencies face budgetary and capacity constraints, inconsistencies in permit issuing procedures and a lack of knowledge about the conservation status of species which further impedes the effective control on wildlife trade.

At present most countries actively attempt to comply with their Red Data List and CITES obligations. However, this requires a certain level of expertise not generally available in the relevant agencies who are often unable to recognise endangered species or products, and/or timeously access appropriate systematic expertise for the control of obscure taxa.

In addition, the threat of invasive taxa necessitates their control which will require another list (Scott 2001). This list may also need to engage the precautionary principle. One-way forward is to develop Green Data Species Lists (as proposed by Imboden 1987). Green Data Species Lists would essentially represent the flip side of the conventional approach of ‘extinct, threatened or harmful unless proven extant, secure or benign’ (Diamond 1987). Taxa ‘Green Listed’ would not be present on Red Data Lists, or in any CITES appendix, or stand any chance of being threat listed in the near future. National Green Data Species Lists would include taxa with recent and certain population data. These taxa would also not be in any danger of becoming threatened under conditions of controlled trade as they form part of a ‘viable population’ as indicated by adequate data or by demonstrated sustainable harvesting regimes. Taxa identified by National Green Data Species Lists would also pose little threat of becoming invasive (see Ruesink et al. 1995).

The “burden of proof” about the conservation, trade status or invasive potential of taxa would be shifted from the regulatory authorities onto the collectors, dealers or importers (as suggested by Ruesink et al. 1995). The responsibility would then reside with them to demonstrate to the permit issuing authorities that specimens in question are included on their National Green list, or alternatively, fund their placement on such a list through appropriate scientific enquiry and the provision of evidence that they are not represented on any appropriate Red Data, CITES or invasive species lists.

Any financial burden will fall with the importing agency, and permits for import will only be issued once the importers have conclusively demonstrated the presence of the taxon on the National Green Data Species List (e.g. DNA testing, conservation status assessment, systematic study etc.) and regulatory authorities are satisfied that the specimens may be imported at little conservation risk. Thus, taxa will be treated “guilty until proven innocent” (Ruesink et al. 1995).

This Green Data Species List system would also restrict the use of the precautionary principle to the scientific lists (Red Data, CITES, etc.) where the principle is most appropriately employed, without escalating the numbers of taxa to be included in the Green Data Species List. If anything, the expected rapid expansion of the Red Data Lists, CITES and other lists will reduce the number of taxa that may be transferred across international boundaries and that are incorporated in National Green Data Species Lists. This approach will also act as an incentive for the establishment of appropriate species restoration programmes, conservation action campaigns as well as promote appropriate population and distribution data acquisition.

In short, the Green Data Species list represents a radical shift in the management approach of vulnerable, threatened and potentially harmful taxa. It will hopefully circumvent the ‘old data and data deficiency’ problem, shift the financial burden and ‘burden of proof’ away from stretched regulatory authorities to importers or traders, and restrict the use of the precautionary principle to management regimes where it is most effective.

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CHAPTER 8

Conclusion and a synopsis of the conservation assessment of South African mammals

At the outset of this study, the aims were to understand the value and applicability of various conservation assessment tools for prioritising mammals for conservation action at a regional scale (South Africa) using a variety of techniques and data.

Prioritisation of taxa will always remain an integral part of any conservation action plan. First and most importantly, it is impossible to determine which of the prioritisation methods described in the current study provide the "best" priority assessment system. Without a true and independent measure of prioritising taxa, it can only be possible to compare and consider the results between the various methods, as each method is designed and implemented under different circumstances and has its own specific strengths and weaknesses. The differences among priority ranking systems may be less important than the need for a priority setting process to be undertaken, as well as obtaining a much better understanding of the factors driving species warranting conservation action. By using a variety of techniques (data permitting) as undertaken in the current study, has at the very least, allowed an invaluable insight into the various taxon prioritisation techniques for South African marine and terrestrial mammals.

Red Data Book and Red List Assessments

Generally, the IUCN Red Lists of threatened taxa play a vital role in setting conservation priorities for taxa at both the global and regional levels (Chapter 2). By ranking taxa according to their extinction risk, the process of planning for biodiversity conservation is considered to be simplified (Burgman 2002). Possingham et al. (2002) noted that Red List assessments for the fauna and flora of South Africa are some of the most complete among African countries. The recent Red List assessment of South African mammals (Friedman & Daly 2004) based on IUCN (2003) criteria, has allowed a review and an analysis of three generations of Red List and Red Data Book assessments that included both marine and terrestrial mammals. This provided an invaluable insight into the characteristics and the nature of the differences between the qualitative Red Data Book categories and the quantitative IUCN Red List assessments. Results from the current study suggest that not only were the 1986 Red Data Book assessments (Smithers 1986) out-dated but that they were also based on limited data. The regional Red List for mammals (Friedmann & Daly 2004) was on the other hand inclusive in that where available, it incorporated as much relevant regional life history and threat information as possible. Compared to the

1986 Red Data Book assessment and categories, the new Red List categories provided a more objective method for the classification of taxa according to their extinction risk.

The current regional Red List assessment for South African mammals identified more mammals to be in the higher threat category than its global counterpart. This supports the previous conclusion that regional Red List assessments may lead to a higher percentage of threatened taxa than global Red List assessments (Gärdenfors et al. 2001). Of particular relevance in the present assessment, however, is the increase in regionally identified Data Deficient mammals. The present study concluded that approximately 18% of South African mammals were Data Deficient, while less than 1% were identified as Data Deficient in the global Red List assessment. The majority of the assessments used category B that relates to the distribution/range size in conjunction with fragmentation, meta-population structure, continuing decline, and extreme fluctuations. This reliance on existing knowledge of the historical distributions and extant range sizes (often regarded as out-dated and inaccurate (Freitag & van Jaarsveld 1995; Rouget et al. 2004)), is disconcerting.

Conservation Prioritisation Techniques

Conservation assessments do not only depend on a taxon's susceptibility to threat (i.e., risk of extinction or Red List assessments), but also the conservation value, irreplaceability of a taxon, and the nature and intensity of the threat itself (Reed 1992; Harcourt & Parks 2003; Hartley & Kunin 2003). In the present study, the inclusion of additional, explicit criteria of threat such as rarity and irreplaceability suggest an improvement in priority and threat assessments (Chapter 3, 4 & 5). With data and time being major constraints during priority assessments, it was essential to utilise components that are up-to-date, easily obtainable, and conducive to yield relevant results and outputs (Dunn et al. 1999; Whiting et al. 2000; Harcourt & Parks 2003).

The availability of the spatial human demographic data, and its associated threats to the environment and particularly to taxa, allowed the incorporation of a proxy into a prioritisation exercise. This allowed some insight into the relationship between human activity measures, mammal richness patterns and biological extinction risks (Harcourt & Parks 2003). The human activity components used in the present study (Chapter 3), suggest a concordance between the three measures of mammal richness measures used despite some difficulties in assigning a single risk value to separate impacts of such measures (Kerr & Currie 1995; Ceballos & Ehlrich 2002; Chertow 2001). The selected human activity measures used in this study correspond to that of mammal richness across South Africa and, to some extent, with endemic as well as threatened mammal richness.

Of particular importance in the present study is that it took cognisance that there may be other potential factors that drive mammal richness patterns in South Africa, such as climate and environmental factors (Andrews & O'Brien 2000; Chown et al. 2003). The inclusion of the six human activity variables suggests complex structuring within and among these variables (McDonald 1991; Liu et al. 2003). The use of the human activity variables in conjunction with the present regional Red List assessments (Friedmann & Daly 2004) provided insights into taxa that are threatened with extinction while also being exposed to high human activity throughout their distributional ranges. The analyses in this study also high-lighted Data Deficient and taxa not deemed to be highly threatened, that are also exposed to high human activity, suggesting that these taxa may need to be re-evaluated not only with reference to their life history traits but also with regard to potential threats that may be posed by human-activities.

Yu and Dobson (2000) reported that many mammals show a tendency towards rarity. However, rarity varies both in space and time because the identification of conservation priorities for taxa at risk of extinction is usually determined by rarity and vulnerability. Therefore, the questions that arise are how to incorporate additional biological, irreplaceability, and threat variables, and how these should be used to develop an appropriate methodology for the conservation prioritisation of taxa (Ferrar 1991; Pressey et al. 1993).

Consequently, three key components, namely, vulnerability, irreplaceability, and threat (Pressey et al. 1994; Noss et al. 2002; Harcourt & Parks 2003), were included into a regional priority scoring (RPS) technique (Chapter 4). Each of the three components was based on available data, such as: 1) the IUCN Red List assessments and regional occupancy as measures of vulnerability; 2) relative endemism and taxonomic distinctiveness as measures of irreplaceability; and 3) relative body mass and human density as measures of threat. The RPS scores obtained in the two assessments differed significantly, resulting in a broad range of mammals being highlighted as of conservation importance in South Africa. Both RPS techniques (RPS_{01} & RPS_{02},) however, consistently identified 13 mammals as of high conservation priority, with 12 species highlighted by the regional Red List as being threatened.

The RPS technique is regarded as a relational approach where the conservation importance of taxa is derived from a broad suite of relevant and informative data (Freitag & van Jaarsveld 1997; Mills et al. 2001; Reyers 2004). Unlike the IUCN Red List assessment for example, the RPS technique as used in the present study not only incorporated measures based solely on rarity and related to the risk of extinction but also to irreplaceability and threat. This approach was considered an appropriate conservation priority assessment tool that could be applied world-wide using the minimal available data.

Generally, there are a range of quantifiable biological measures that could function as alternatives when there is limited population and life history data that may prevent relevant prioritization assessments. However, many of these alternative measures are problematic to apply, either conceptually or in practise, therefore, preventing their incorporation in objective priority-setting exercises (Gärdenfors 1996; Mehlman et al. 2004). For example, although the incorporation of phylogenetic diversity in conservation priority assessments has been considered to be of critical importance in priority-setting, its incorporation is often precluded because of the general lack of comprehensive and inclusive phylogenies (Polasky et al. 2001). As a result, this has led to a search for alternative measures for identifying taxonomically distinct taxa (Polasky et al. 2001; Rodrigues & Gaston 2002).

The analyses in the present study (Chapter 5), suggest that a “simple” measure of taxonomic distinctiveness (TD) may function as a surrogate measure for the more data-intensive measures of phylogenetic diversity (PD), such as the node-based (PD_{NODE}; Vane-Wright et al. 1991; Posadas et al. 2001) and the branch length based (PD_{BRANCH}; Bininda-Emonds et al. 1999) measures of phylogenetic diversity. Each of these PD (PD_{NODE} and PD_{BRANCH}) and TD measures used in the present study (Chapter 4) seem to reflect the evolutionary history of taxa under consideration that focused on the Chiroptera and the Carnivora (as case study groups). Similar to the other RPS components (Chapter 4; Freitag & van Jaarsveld 1997; Mills et al. 2001; Reyers 2004), the TD measure is considered to be a logistically simple and feasible option when setting regional conservation priorities.

The last two sections of this study (Chapters 6 & 7) were essentially related to the development of a more theoretical framework that dealt with several shortcomings highlighted by the preceding parts of the study. First, the concept of an Orange List (Chapter 6) was proposed due to the critical need to assess and record the conservation importance of stable, rare, and taxa of special concern that are often disregarded in conservation exercises, due to the nature of the new Red List categories and criteria. However, these taxa are often very rare (either small stable populations, severely sparsely distributed, or fragmented populations). In addition, such taxa are frequently under severe threat, such as hybridisation and medicinal use, and should, therefore, be regarded as "….*of high national importance or of high conservation value*" (South African National Environmental Management: Biodiversity Act 2004).

The Orange List concept was originally developed for plants and could also be applied to other taxa because its methodology conforms to the criteria and methodology of the Red List (IUCN 2001), which have been applied across a large range of taxonomic groups. It may only be through the rigorous implementation of this technique that it will be established whether the concept is pertinent for the identification of taxa that require anticipatory conservation planning actions to prevent possible extinction or to prevent them from threatened populations in the near future (Caughley 1994).

Related to the Orange List is the concept of a Green Data Species List (Chapter 7). This concept represents a radical conceptual departure from the traditional approach to the management of threatened species (i.e., Red Data or CITES Lists) and the protection of the integrity of biodiversity (i.e., the control of potentially invasive species). The Green data Species List concept presents an approach that can resolve the logistical and financial constraints forced on national regulatory, enforcement and border control agencies, especially in the milieu of limited conservation funding and the inevitable decline in efficiency. This approach places the burden of proof firmly in the hands of the importer of biological materials.

Conservation Priorities for South African Mammals

The various prioritisation and assessment techniques investigated in the current study suggest that small mammals require immediate conservation attention. Based on the IUCN Red List assessment (Friedmann & Daly 2004), the Order Insectivora dominated the list of threatened mammals. Including a measure of threat through incorporating human activity (Chapter 3) also highlighted the Order Insectivora to be of great conservation importance but also reaffirmed the suggestion that many of the smaller mammals are highly threatened by extinction due to human-induced threats. Subsequent RPS assessments (Chapter 4) also identified numerous taxa from the Orders Insectivora, Rodentia, as well as the Chiroptera as priorities for conservation intervention.

Consequently, additional information and conservation action is therefore urgently required for the smaller, less charismatic, and lesser-known carnivores, rodents, and bats in South Africa. Insectivores, bats, and rodents have been reported to be internationally under-represented in conservation policies with most taxa from these Orders having already become extinct (Ceballos & Brown 1995; Yu & Dobson 2000). Nevertheless, the larger mammals within the Orders Carnivora, Perissodactyla, and Artiodactyla still receive disproportionately greater research and conservation funding attention (Amori & Gippoliti 2000; Polishchuk 2002).

Future recommendations

The proposed five-year interval between successive Red List assessments as proposed by IUCN (2001) is imperative. It is anticipated that the identification of threatened and priority taxa in this study may be useful, not only in drawing research and conservation attention to these taxa, but also to influence and foster a better understanding of the causes and reasons why certain taxa face an extinction risk, and most importantly also to focus on their declining and threatened habitats (Ferrar 1991; Possingham et al. 2002). Furthermore a better understanding towards the effect of human demographics on the extent of threat to mammals as well as their habitats is crucial. Comprehensive and up-to-date taxonomic classification is also imperative for inclusion into conservation planning, and relevant attention should be granted to meet future requirements. The main setback during this study was the lack of basic biological, population and most importantly up-to-date representative distribution data. Not only is the distribution data most of the time spatially and temporally incorrect, but also the current resolution of distribution data (quarter degree square) are highly undesirable. Relevant steps to circumvent this deficiency are urgently required, as it impacts not only on single species conservation strategies, but severely hampers national conservation planning actions (Rouget et al. 2004).

Conclusion

It is essential that researchers, conservationist, and developers refrain from using the Red List and similar priority assessments as an automatic assessment of conservation status of taxa. The use of prioritisation or assessment techniques is not only dependant on the information used but also the purpose for which the technique was developed, and merely represents a starting point from which conservation actions and subsequent conservation status should be derived (Possingham et al. 2002). However, the greatest challenge is still the implementation of conservation assessments and actions to reach the intended targets where they can be effective.

The techniques utilized in this study offered insights into the factors that affect taxa warranting conservation interventions. They also allow for the inclusion of more relevant information on prioritisation to be fed into any "*protected species of high national importance or of high conservation value*" (South African National Environmental Management: Biodiversity Act 2004) assessment exercise. It is also anticipated that this study has assisted in identifying priority taxa for conservation action in South Africa, and contributed to techniques for identifying taxa before they become listed as endangered in regional or global Red List assessment processes.

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APPENDIX 1: Regional IUCN Red List assessments for South African terrestrial and marine mammals: An overview

Regional Red Data Book (RRDB; Smithers 1986; Mugo et al. 1995), Friedmann & Daly (2004) regional Red List (RRL) and global IUCN Red List (GRL) assessments for all extant 295 marine and terrestrial taxa. RDB categories were as follows: Endangered (E), Vulnerable (V) Rare (R), Out of Danger (O) and Indeterminate (I). Regional and global IUCN RL categories ranged between that of IUCN RL version 2.4 and 3.1. The following abbreviations are used within the Appendix: Critically Endangered (CR); Endangered (EN); and Vulnerable (VU), Near Threatened (NT) (also including Lower Risk/near threatened (LR/nt)), Data Deficient (DD), Lower Risk/conservation dependant (CD) and, Least Concern (LC) (also including the old Lower Risk/least concern (LR/lc) category) and Not Evaluated (NE).

Order	**Taxon name**	**Common Name**	**RRDB 1986**	**GRL 2003**	**RRL 2004**
Artiodactyla	*Aepyceros melampus*	Impala	Not Listed	LR/cd	LC
Artiodactyla	*Alcelaphus buselaphus*	Red hartebeest	Not Listed	LR/cd	LC
Artiodactyla	*Antidorcas marsupialis*	Springbok	Not Listed	LR/cd	LC
Artiodactyla	*Cephalophus natalensis*	Red duiker	R	LR/cd	LC
Artiodactyla	*Connochaetes gnou*	Black wildebeest	Not Listed	LR/cd	LC
Artiodactyla	*C. taurinus taurinus*	Blue wildebeest	Not Listed	LR/cd	LC
Artiodactyla	*Damaliscus lunatus lunatus*	Tsessebe	R	LR/cd	EN A2ac, C2a(i)
Artiodactyla	*D. pygargus phillipsi*	Blesbok	Not Listed	LR/cd	LC
Artiodactyla	*D. pygargus pygargus*	Bontebok	R	VU D2	VU D1
Artiodactyla	*Giraffa camelopardalis*	Giraffe	Not Listed	LR/cd	LC
Artiodactyla	*Hippopotamus amphibius*	Hippopotamus	R	LR/lc	LC
Artiodactyla	*Hippotragus equinus*	Roan antelope	E	LR/cd	VU D1
Artiodactyla	*H. niger niger*	Sable antelope	V	LR/cd	VU C1 + 2a(i)
Artiodactyla	*Kobus ellipsiprymnus ellipsiprymnus*	Waterbuck	Not Listed	LR/cd	LC
Artiodactyla	*Neotragus moschatus zuluensis*	Suni	V	LR/cd	VU B1ab (ii,iii,iv,v)
Artiodactyla	*Oreotragus oreotragus*	Klipspringer	Not Listed	LR/cd	LC

Artiodactyla	*Oryx gazella*	Gemsbok	Not Listed	LR/cd	LC
Artiodactyla	*Ourebia ourebi*	Oribi	V	LR/cd	EN C2a(ii)
Artiodactyla	*Pelea capreolus*	Grey rhebok	Not Listed	LR/cd	LC
Artiodactyla	*Phacochoerus africanus*	Warthog	Not Listed	LR/lc	LC
Artiodactyla	*Philantomba monticola*	Blue duiker	R	LR/lc	VU C1, C2a(i)
Artiodactyla	*Potamochoerus porcus koiropotamus*	Bushpig	Not Listed	LR/lc	LC
Artiodactyla	*Raphicerus campestris*	Steenbok	Not Listed	LR/lc	LC
Artiodactyla	*R. melanotis*	Cape grysbok	Not Listed	LR/cd	LC
Artiodactyla	*R. sharpei*	Sharp's grysbok	R	LR/cd	NT
Artiodactyla	*Redunca arundinum*	Reedbuck	Not Listed	LR/cd	LC
Artiodactyla	*R. fulvorufula*	Mountain reedbuck	Not Listed	LR/cd	LC
Artiodactyla	*Sylvicapra grimmia*	Common duiker	Not Listed	LR/lc	LC
Artiodactyla	*Syncerus caffer*	Cape buffalo	Not Listed	LR/cd	LC
Artiodactyla	*Taurotragus oryx*	Eland	Not Listed	LR/cd	LC
Artiodactyla	*Tragelaphus angasii*	Nyala	Not Listed	LR/cd	LC
Artiodactyla	*T. scriptus*	Bushbuck	Not Listed	LR/lc	LC
Artiodactyla	*T. strepsiceros*	Kudu	Not Listed	LR/cd	LC
Carnivora	*Acinonyx jubatus*	Cheetah	O	VU C2a(1)	VU D1
Carnivora	*Aonyx capensis*	Cape clawless otter	Not Listed	LR/lc	LC
Carnivora	*Arctocephalus gazella*	Antarctic fur seal	Not Listed	LC	NT
Carnivora	*A. pusillus pusillus*	Cape fur seal	Not Listed	NE	LC
Carnivora	*A. tropicalis*	Subantarctic fur seal	Not Listed	NE	LC
Carnivora	*Atilax paludinosus*	Water mongoose	Not Listed	LR/lc	LC
Carnivora	*Canis adustus*	Side-striped jackal	Not Listed	LR/lc	NT

Carnivora	*C. mesomelas*	Black-backed jackal	Not Listed	LR/lc	LC
Carnivora	*Caracal caracal*	Caracal	Not Listed	LC	LC
Carnivora	*Civettictis civetta*	African civet	R	LR/lc	LC
Carnivora	*Crocuta crocuta*	Spotted hyaena	Not Listed	LR/cd	NT
Carnivora	*Cynictis penicillata*	Yellow mongoose	Not Listed	LC	LC
Carnivora	*Felis nigripes*	Black-footed cat	R	VU C2a (i)	LC
Carnivora	*F. silvestris*	African wild cat	V	LC	LC
Carnivora	*Galerella pulverulenta*	Small grey mongoose	Not Listed	LR/lc	LC
Carnivora	*G. sanguinea*	Slender mongoose	Not Listed	LR/lc	LC
Carnivora	*Genetta genetta*	Small-spotted genet	Not Listed	LR/lc	LC
Carnivora	*G. tigrina*	Large-spotted genet	Not Listed	LR/lc	LC
Carnivora	*Helogale parvula*	Dwarf mongoose	Not Listed	LR/lc	LC
Carnivora	*Herpestes ichneumon*	Large grey mongoose	Not Listed	LR/lc	LC
Carnivora	*Hyaena brunnea*	Brown hyaena	R	LR/nt	NT
Carnivora	*Ichneumia albicauda*	White-tailed mongoose	Not Listed	LR/lc	LC
Carnivora	*Ictonyx striatus*	Striped polecat	Not Listed	LR/lc	LC
Carnivora	*Leptailurus serval*	Serval	R	LC	NT
Carnivora	*Lutra maculicollis*	Spotted-necked otter	Not Listed	VU A1c	NT
Carnivora	*Lycaon pictus*	African wild dog	E	EN C1	EN D
Carnivora	*Mellivora capensis*	Honey badger	V	LR/lc	NT
Carnivora	*Mirounga leonina*	Southern elephant seal	Not Listed	NE	EN A 2b
Carnivora	*Mungos mungo*	Banded mongoose	Not Listed	LR/lc	LC
Carnivora	*Otocyon megalotis*	Bat-eared fox	Not Listed	LR/lc	LC
Carnivora	*Panthera leo*	Lion	Not Listed	VU C2a (i)	VU D1

Carnivora	*P. pardus*	Leopard	R	LC	LC
Carnivora	*Paracynictis selousi*	Selous' mongoose	R	LR/lc	DD
Carnivora	*Poecilogale albinucha*	African weasel	R	LR/lc	DD
Carnivora	*Proteles cristatus*	Aardwolf	R	LR/lc	LC
Carnivora	*Rhynchogale melleri*	Meller's mongoose	R	LR/lc	DD
Carnivora	*Suricata suricatta*	Suricate	Not Listed	LR/lc	LC
Carnivora	*Vulpes chama*	Cape fox	Not Listed	LR/lc	LC
Cetacea	*Balaenoptera acutorostrata subsp.*	Dwarf minke whale	Not Listed	NE	DD
Cetacea	*B. bonaerensis*	Antarctic minke whale	Not Listed	LR/cd	LC
Cetacea	*B. borealis schlegellii*	Sei whale	Not Listed	EN A1abd	DD
Cetacea	*B. brydei*	Bryde's whale	Not Listed	DD	VU D1
Cetacea	*B. musculus brevicauda*	Pygmy blue whale	Not Listed	NE	DD
Cetacea	*B. musculus intermedia*	Antarctic "true" blue whale	Not Listed	EN D	EN D
Cetacea	*B. physalus quoyi*	Southern hemisphere fin whale	Not Listed	EN A1abd	DD
Cetacea	*Berardius arnuxii*	Arnoux's beaked whale	Not Listed	LR/cd	DD
Cetacea	*Caperea marginata*	Pygmy right whale	Not Listed	LC	LC
Cetacea	*Cephalorhynchus heavisidii*	Heaviside's dolphin	Not Listed	DD	DD
Cetacea	*Delphinus capensis*	Longbeaked common dolphin	Not Listed	LC	LC
Cetacea	*D. delphis*	Shortbeaked common dolphin	Not Listed	LC	LC
Cetacea	*Eubalaena australis*	Southern right whale	Not Listed	LR/cd	LC
Cetacea	*Feresa attenuata*	Pygmy killer whale	Not Listed	DD	DD
Cetacea	*Globicephala macrorhynchus*	Short-finned pilot whale	Not Listed	LR/cd	DD
Cetacea	*G. melas edwardii*	Long-finned pilot whale	Not Listed	LR/lc	LC
Cetacea	*Grampus griseus*	Risso's dolphin	Not Listed	DD	DD

Cetacea	*Hyperoodon planifrons*	Southern bottlenose whale	Not Listed	LR/cd	LC
Cetacea	*Indopacetus pacificus*	Longman's beaked whale	Not Listed	DD	DD
Cetacea	*Kogia breviceps*	Pygmy sperm whale	Not Listed	LR/cd	LC
Cetacea	*K. sima*	Dwarf sperm whale	Not Listed	LR/cd	LC
Cetacea	*Lagenodelphis hosei*	Fraser's dolphin	Not Listed	DD	DD
Cetacea	*Lagenorhynchus obscurus*	Dusky dolphin	Not Listed	DD	DD
Cetacea	*Megaptera novaeangliae*	Humpback whale	Not Listed	VU A1 ad	NT
Cetacea	*M. densirostris*	Blainville's beaked whale	Not Listed	DD	DD
Cetacea	*M. grayi*	Gray's beaked whale	Not Listed	DD	DD
Cetacea	*M. hectori*	Hector's beaked whale	Not Listed	DD	DD
Cetacea	*M. layardii*	Layard's beaked whale	Not Listed	DD	DD
Cetacea	*M. mirus*	True's beaked whale	Not Listed	DD	DD
Cetacea	*Orcinus orca*	Killer whale	Not Listed	LR/cd	DD
Cetacea	*Peponocephala electra*	Melonheaded whale	Not Listed	LR/cd	LC
Cetacea	*Physeter macrocephalus*	Sperm whale	Not Listed	VU A1bd	VU A2 b d
Cetacea	*Pseudorca crassidens*	False killer whale	Not Listed	LR/cd	LC
Cetacea	*Sousa plumbea*	Indian humpback dolphin	Not Listed	DD	VU B1 ab(ii iii)
Cetacea	*Stenella attenuata*	Pantropical spotted dolphin	Not Listed	LR/cd	DD
Cetacea	*Stenella coeruleoalba*	Striped dolphin	Not Listed	LR/cd	LC
Cetacea	*Stenella longirostris longirostris*	Spinner dolphin	Not Listed	LR/cd	DD
Cetacea	*Steno bredanensis*	Rough-toothed dolphin	Not Listed	DD	DD
Cetacea	*Tursiops aduncus*	Indian ocean bottlenose dolphin	Not Listed	NE	VU B2 ab(ii,iii,v); C2a(ii)
Cetacea	*T. aduncus* (migratory subpopulation)	Indian ocean bottlenose dolphin	Not Listed	NE	EN C2 a(ii)
Cetacea	*T. truncatus*	Bottlenose dolphin	Not Listed	DD	DD

Cetacea	*Ziphius cavirostris*	Cuvier's beaked whale	Not Listed	DD	DD
Chiroptera	*Chaerephon ansorgei*	Ansorge's free-tailed bat	Not Listed	LR/lc	LC
Chiroptera	*C. pumila*	Little free-tailed bat	Not Listed	LR/lc	LC
Chiroptera	*Cistugo lesueuri*	Lesueur's wing-gland bat	I	VU A2c, D2	NT
Chiroptera	*C. seabrai*	Angolan wing-gland bat	I	VU A2c, D2	VU D2
Chiroptera	*Cloeotis percivali*	Short-eared trident bat	I	LR/nt	CR A2, a
Chiroptera	*Epomophorus gambianus crypturus*	Gambian epauletted fruit bat	Not Listed	LR/lc	DD
Chiroptera	*E. wahlbergi*	Wahlberg's epauletted fruit bat	Not Listed	LR/lc	LC
Chiroptera	*Eptesicus hottentotus*	Long-tailed serotine bat	Not Listed	LR/lc	LC
Chiroptera	*Glauconycteris variegatus*	Butterfly bat	I	LR/lc	NT
Chiroptera	*Hipposideros caffer*	Sundevall's leaf-nosed bat	Not Listed	LR/lc	DD
Chiroptera	*Kerivoula argentata*	Damara woolly bat	I	LC	EN B1ab (iii) & 2ab (iii)
Chiroptera	*K. lanosa*	Lesser woolly bat	I	LR/lc	NT
Chiroptera	*Laephotis botswanae*	Botswana long-eared bat	I	LR/nt	VU D2
Chiroptera	*L. wintoni*	De winton's long-eared bat	I	LR/nt	VU D2
Chiroptera	*Miniopterus fraterculus*	Lesser long-fingered bat	Not Listed	LR/nt	NT
Chiroptera	*M. schreibersii*	Schreibers' long-fingered bat	Not Listed	LR/nt	NT
Chiroptera	*Mops condylurus*	Angolan free-tailed bat	Not Listed	LR/lc	LC
Chiroptera	*M. midas*	Midas free-tailed bat	Not Listed	LR/lc	LC
Chiroptera	*Myotis bocagei*	Rufous hairy bat	I	NE	DD
Chiroptera	*M. tricolor*	Temminck's hairy bat	Not Listed	NE	NT
Chiroptera	*M. welwitschii*	Welwitsch's hairy bat	I	LR/lc	NT
Chiroptera	*Neoromicia capensis*	Cape serotine bat	Not Listed	LR/lc	LC
Chiroptera	*N. nanus*	Banana bat	Not Listed	LR/lc	LC

Chiroptera	*N. rendalli*	Rendall's serotine bat	Not Listed	LR/lc	CR B2 ab(iii)
Chiroptera	*Neoromicia zuluensis*	Aloe bat	Not Listed	LR/nt	LC
Chiroptera	*Nycteris hispida*	Hairy slit-faced bat	Not Listed	LR/lc	NT
Chiroptera	*N. thebaica*	Egyptian slit-faced bat	Not Listed	LR/lc	LC
Chiroptera	*N. woodi*	Wood's slit-faced bat	I	LR/nt	NT
Chiroptera	*Nycticeinops schlieffeni*	Schlieffen's bat	Not Listed	LR/nt	LC
Chiroptera	*Otomops martiensseni*	Large-eared free-tailed bat	I	VU A2c	VU D2
Chiroptera	*P. anchietae*	Anchieta's pipistrelle	Not Listed	NE	NT
Chiroptera	*P. hesperidus*	African pipistrelle	Not Listed	LR/lc	LC
Chiroptera	*Pipistrellus rusticus*	Rusty bat	I	LR/lc	NT
Chiroptera	*Rhinolophus blasii*	Peak-saddle horseshoe bat	I	LR/nt	VU D2
Chiroptera	*R. capensis*	Cape horseshoe bat	Not Listed	VU A2c, D2	NT
Chiroptera	*R. clivosus*	Geoffroy's horseshoe bat	Not Listed	LR/lc	NT
Chiroptera	*R. darlingi*	Darling's horseshoe bat	Not Listed	LR/lc	NT
Chiroptera	*R. denti*	Dent's horseshoe bat	I	LR/lc	NT
Chiroptera	*R. fumigatus*	Rüppell's horseshoe bat	Not Listed	LR/lc	NT
Chiroptera	*R. hildebrandtii*	Hildebrandt's horseshoe bat	Not Listed	LR/lc	NT
Chiroptera	*R. landeri*	Lander's horseshoe bat	I	LR/lc	NT
Chiroptera	*R. simulator*	Bushveld horseshoe bat	Not Listed	LR/lc	LC
Chiroptera	*R. swinnyi*	Swinny's horseshoe bat	I	LR/lc	EN C2a (i)
Chiroptera	*Rousettus aegyptiacus*	Egyptian fruit bat	Not Listed	LR/lc	LC
Chiroptera	*Sauromys petrophilus*	Flat-headed free-tail bat	Not Listed	LR/lc	LC
Chiroptera	*Scotoecus albofuscus*	Thomas' house bat	Not Listed	LR/nt	VU D2
Chiroptera	*Scotophilus dinganii*	Yellow house bat	Not Listed	LR/lc	LC

Chiroptera	*S. viridis*	Lesser yellow house bat	Not Listed	LR/lc	LC
Chiroptera	*Tadarida aegyptiaca*	Egyptian free-tailed bat	Not Listed	LR/lc	LC
Chiroptera	*Taphozous mauritianus*	Mauritian tomb bat	Not Listed	LR/lc	LC
Hyracoidea	*Dendrohyrax arboreus arboreus*	Tree hyrax	R	VU B1+2c	VU B1ab(iii) + 2ab(iii), C1
Hyracoidea	*Heterohyrax brucei*	Yellow-spotted rock hyrax	Not Listed	LR/lc	LC
Hyracoidea	*Procavia capensis*	Rock hyrax	Not Listed	LR/lc	LC
Insectivora	*Amblysomus corriae*	Fynbos golden mole	I	NE	NT
Insectivora	*A. hottentotus*	Hottentot's golden mole	Not Listed	NE	DD
Insectivora	*A. marleyi*	Marley's golden mole	Not Listed	NE	EN B2ab (ii,iii)
Insectivora	*A. robustus*	Robust golden mole	Not Listed	NE	EN B1ab (i-iv) B2ab (i-iv)
Insectivora	*A. septentrionalis*	Highveld golden mole	I	NE	NT
Insectivora	*Atelerix frontalis*	South african hedgehog	I	LR/lc	NT
Insectivora	*Calcochloris obtusirostris*	Yellow golden mole	R	LR/lc	VU B1ab(ii,iii),B2ab(ii,iii)
Insectivora	*Chlorotalpa duthieae*	Duthie's golden mole	I	VU B1+2c	LC
Insectivora	*C. sclateri*	Sclater's golden mole	I	VU B1+2c	DD
Insectivora	*Chrysochloris asiatica*	Cape golden mole	Not Listed	LR/lc	DD
Insectivora	*C. visagiei*	Visagie's golden mole	I	CR B1 +2c	CR D
Insectivora	*Chrysospalax trevelyani*	Giant golden mole	V	EN B1 +2c	VU B2 ab (ii,iii, iv)
Insectivora	*C. villosus*	Rough-haired golden mole	V	VU B1+2c	CR C2a(i), D
Insectivora	*Crocidura cyanea*	Reddish-grey musk shrew	Not Listed	LR/lc	DD
Insectivora	*C. flavescens*	Greater musk shrew	Not Listed	VU B1+2c	DD
Insectivora	*C. fuscomurina*	Tiny musk shrew	Not Listed	LR/lc	DD
Insectivora	*C. hirta*	Lesser red musk shrew	Not Listed	LR/lc	DD
Insectivora	*C. maquassiensis*	Maquassie musk shrew	I	LR/lc	VU B2a,c(ii,iv)

Insectivora	*C. mariquensis*	Swamp musk shrew	Not Listed	LR/lc	DD
Insectivora	*C. silacea*	Lesser grey-brown musk shrew	Not Listed	LR/lc	DD
Insectivora	*Cryptochloris wintoni*	De winton's golden mole	I	VU B1+2c	CR B1ab(iii), B2ab(iii), D
Insectivora	*C. zyli*	Van zyl's golden mole	I	CR B1+2c	CR B1ab(iii)+2ab(iii); D
Insectivora	*Eremitalpa granti*	Grant's golden mole	R	VU B1+2c	VU B2ab (ii,iii,iv)
Insectivora	*Myosorex cafer*	Dark-footed forest shrew	Not Listed	LR/lc	DD
Insectivora	*M. longicaudatus*	Long-tailed forest shrew	I	VU B1+2c	NT
Insectivora	*M. sclateri*	Sclater's forest shrew	Not Listed	VU B1+2c	EN B1b(ii,iii), c(iv)+2b(ii,iii), c(iv)
Insectivora	*M. varius*	Forest shrew	Not Listed	NE	DD
Insectivora	*Neamblysomus gunningi*	Gunning's golden mole	I	VU B1+2c	EN B1ab(i-iv) B2ab(i-iv)
Insectivora	*N. julianae*	Juliana's golden mole	I	CR B1+2c	VU B2 ab (ii,iii)
Insectivora	*N. julianae* (Pretoria subpopulation)	Juliana's golden mole (Pta subpopulation)	Not Listed	NE	CR A2c; B1ab (i-v)+B2ab (i-v)
Insectivora	*Suncus infinitesimus*	Least dwarf shrew	I	LR/lc	DD
Insectivora	*S.lixus*	Greater dwarf shrew	I	LR/lc	DD
Insectivora	*S. varilla*	Lesser dwarf shrew	Not Listed	LR/lc	DD
Lagomorpha	*Bunolagus monticularis*	Riverine rabbit	E	EN B1+2c	CR C2a(i), E
Lagomorpha	*Lepus capensis*	Cape hare / desert hare	Not Listed	LR/lc	LC
Lagomorpha	*L. saxatilis*	Scrub / savannah hare	Not Listed	LR/lc	LC
Lagomorpha	*P. crassicaudatus*	Natal red rock rabbit	Not Listed	LR/lc	LC
Lagomorpha	*P. randensis*	Jameson's red rock rabbit	Not Listed	LR/lc	LC
Lagomorpha	*P. rupestris*	Smith's red rock rabbit	Not Listed	LR/lc	LC
Lagomorpha	*P. saundersiae*	Hewitt's red rock rabbit	Not Listed	LR/lc	LC
Macroscelidea	*E. brachyrhynchus*	Short-snouted elephant-shrew	Not Listed	LR/lc	DD
Macroscelidea	*E. edwardii*	Cape rock elephant-shrew	Not Listed	VU B1+2c	LC

Macroscelidea	*E. intufi*	Bushveld elephant-shrew	Not Listed	LR/lc	DD
Macroscelidea	*E. myurus*	Rock elephant-shrew	Not Listed	LR/lc	LC
Macroscelidea	*E. rupestris*	Smith's rock elephant shrew	Not Listed	VU B1+2c	LC
Macroscelidea	*Macroscelides proboscideus*	Round-eared elephant-shrew	Not Listed	VU B1+2c	LC
Macroscelidea	*Petrodromus tetradactylus*	Four-toed elephant-shrew	R	LR/lc	EN D
Perissodactyla	*Ceratotherium simum*	White rhinoceros	Not Listed	LR/nt	LC
Perissodactyla	*Diceros bicornis bicornis*	Black rhinoceros - arid ecotype	Not Listed	VU D1	CR D
Perissodactyla	*D. bicornis minor*	Black rhinoceros	V	CR A2abc	VU D1
Perissodactyla	*Equus burchellii*	Plains zebra	Not Listed	LC	LC
Perissodactyla	*E. zebra hartmannae*	Hartmann's mountain zebra	Not Listed	EN A1a	EN D
Perissodactyla	*E. zebra zebra*	Cape mountain zebra	V	EN C2a/EX	VU D1
Pholidota	*Manis temminckii*	Pangolin	V	LR/nt	VU C1
Primates	*Cercopithecus aethiops pygerythrus*	Vervet monkey	Not Listed	LR/lc	LC
Primates	*C. mitis*	Samango monkey	Not Listed	LR/lc	VU B1ab (ii,iii,iv)
Primates	*C. mitis erythrarchus*	Samango monkey	R	LR/lc	VU B1ab(i, ii, iii)+2abi,ii,iii)
Primates	*C. mitis labiatus*	Samango monkey	R	NE	EN B1ab (ii,iii,iv,v)
Primates	*Galago moholi*	Southern lesser galago	Not Listed	LR/lc	LC
Primates	*Otolemur crassicaudatus*	Thick-tailed bushbaby	Not Listed	LR/lc	LC
Primates	*Papio ursinus*	Chacma baboon	Not Listed	LC	LC
Proboscidea	*Loxodonta africana*	African elephant	O	EN A1b	LC
Rodentia	*Acomys spinosissimus*	Spiny mouse	Not Listed	LR/lc	LC
Rodentia	*A. subspinosus*	Cape spiny mouse	Not Listed	LR	LC
Rodentia	*Aethomys chrysophilus*	Red veld rat	Not Listed	LR/lc	LC
Rodentia	*A. granti*	Grant's rock mouse	R	LR/lc	LC

Rodentia	*A. ineptus*	Tete veld rat	Not Listed	LR/lc	LC
Rodentia	*A. namaquensis*	Namaqua rock mouse	Not Listed	LR/lc	LC
Rodentia	*Bathyergus janetta*	Namaqua dune mole-rat	V	LR/nt	NT
Rodentia	*B. suillus*	Cape dune mole-rat	Not Listed	LR/lc	LC
Rodentia	*Cricetomys gambianus*	Giant rat	O	LR/lc	VU C1
Rodentia	*Cryptomys damarensis*	Damaraland mole-rat	Not Listed	LR/lc	LC
Rodentia	*C. hottentotus*	Common mole-rat	Not Listed	LR/lc	LC
Rodentia	*Dasymys incomtus*	Water rat	R	DD	NT
Rodentia	*Dendromus melanotis*	Grey climbing mouse	Not Listed	LR/lc	LC
Rodentia	*D. mesomelas*	Brant's climbing mouse	Not Listed	LR/lc	LC
Rodentia	*D. mystacalis*	Chestnut climbing mouse	Not Listed	LR/lc	LC
Rodentia	*D. nyikae*	Nyika climbing mouse	I	LC	NT
Rodentia	*Desmodillus auricularis*	Short-tailed gerbil	Not Listed	LR/lc	LC
Rodentia	*Georychus capensis*	Cape mole-rat	R	LR/lc	LC
Rodentia	*G. capensis* (KZN Population)	Cape mole-rat (KZN subpopulation)	Not Listed	NE	EN D
Rodentia	*Gerbillurus paeba*	Hairy-footed gerbil	Not Listed	LR/lc	LC
Rodentia	*G. vallinus*	Brush-tailed hairy-footed gerbil	Not Listed	LR/lc	LC
Rodentia	*Grammomys cometes*	Mozambique woodland mouse	I	LR/lc	DD
Rodentia	*G. dolichurus*	Woodland mouse	Not Listed	LR/lc	DD
Rodentia	*Graphiurus murinus*	Woodland dormouse	Not Listed	LR/lc	LC
Rodentia	*G. ocularis*	Spectacled dormouse	O	VU A1cd	LC
Rodentia	*G. platyops*	Rock dormouse	Not Listed	LR/lc	DD
Rodentia	*Hystrix africaeaustralis*	Porcupine	Not Listed	LR/lc	LC
Rodentia	*Lemniscomys rosalia*	Single-striped mouse	Not Listed	LC	DD

Rodentia	*Malacothrix typica*	Large-eared mouse	Not Listed	LR/lc	LC
Rodentia	*Mastomys coucha*	Multimammate mouse	Not Listed	LR/lc	LC
Rodentia	*M. natalensis*	Natal multimammate mouse	Not Listed	LR/lc	LC
Rodentia	*Mus indutus*	Desert pygmy mouse	Not Listed	LR/lc	LC
Rodentia	*M. minutoides*	Pygmy mouse	Not Listed	LR/lc	LC
Rodentia	*M. neavei*	Thomas' pygmy mouse	Not Listed	NE	DD
Rodentia	*M. orangiae*	Free state pygmy mouse	Not Listed	NE	DD
Rodentia	*Myomyscus verreauxi*	Verreaux's mouse	Not Listed	LR/lc	LC
Rodentia	*Mystromys albicaudatus*	White-tailed rat	R	VU A1c	EN A3c
Rodentia	*Otomys angoniensis*	Angoni vlei rat	Not Listed	LC	LC
Rodentia	*O. irroratus*	Vlei rat	Not Listed	LR/lc	LC
Rodentia	*O. laminatus*	Laminate vlei rat	Not Listed	LC	LC
Rodentia	*O. saundersiae*	Saunders' vlei rat	Not Listed	LR/nt	LC
Rodentia	*O. sloggetti*	Sloggett's rat	Not Listed	LR/nt	DD
Rodentia	*O. unisulcatus*	Karoo bush rat	Not Listed	LC	LC
Rodentia	*Paraxerus cepapi*	Tree squirrel	Not Listed	LR/lc	LC
Rodentia	*P. palliatus*	Red squirrel	Not Listed	VU A1c	NT
Rodentia	*P. palliatus ornatus*	Ongoye red squirrel	R	NE	CR B1,B2a,b(ii,iv,v)
Rodentia	*P. palliatus tongensis*	Tonga red squirrel	R	NE	EN B1,B2ab (ii,iii, iv,v)
Rodentia	*Parotomys brantsii*	Brants' whistling rat	Not Listed	LC	LC
Rodentia	*P. littledalei*	Littledale's whistling rat	Not Listed	LC	NT
Rodentia	*Pedetes capensis*	Springhare	Not Listed	VU A1cd	LC
Rodentia	*Petromus typicus*	Dassie rat	Not Listed	LR/lc	NT
Rodentia	*Petromyscus barbouri*	Barbour's rock mouse	R	EN B1+2c	LC

Rodentia	*P. collinus*	Pygmy rock mouse	Not Listed	LR/lc	LC
Rodentia	*Rhabdomys pumilio*	Striped mouse	Not Listed	DD	LC
Rodentia	*Saccostomus campestris*	Pouched mouse	Not Listed	LR/lc	LC
Rodentia	*Steatomys krebsii*	Krebs' fat mouse	Not Listed	LR/lc	LC
Rodentia	*S. pratensis*	Fat mouse	Not Listed	LR/nt	LC
Rodentia	*Tatera afra*	Cape gerbil	Not Listed	LR/lc	LC
Rodentia	*T. brantsii*	Highveld gerbil	Not Listed	LR/lc	LC
Rodentia	*T. leucogaster*	Bushveld gerbil	Not Listed	LR/lc	DD
Rodentia	*Thallomys nigricauda*	Black-tailed tree rat	Not Listed	LC	LC
Rodentia	*T. paedulcus*	Tree rat	Not Listed	LR/nt	LC
Rodentia	*Thryonomus swinderianus*	Greater cane rat	Not Listed	LR/lc	LC
Rodentia	*Xerus inauris*	Cape ground squirrel	Not Listed	LR/lc	LC
Rodentia	*X. princeps*	Mountain ground squirrel	Not Listed	NE	NT
Rodentia	*Zelotomys woosnami*	Woosnam's desert rat	O	LR/lc	LC
Tubulidentata	*Orycteropus afer*	Aardvark	V	LR/lc	LC

APPENDIX 2: Incorporating measures of anthropogenic threat in regional conservation assessments: A case study based on South African mammals

Taxa ranked according to Combined Human Threat (CHT) averages scored as well as their respective six human variables as calculated. Of the top 25 CHT ranked taxa not listed as Threatened, taxa denoted by † are species highlighted as being NT, DD or LC, occurring in high human impacted areas, yet are most likely either "weedy taxa" and are good at surviving in human dominated landscapes, or taxa that has not been found to be negatively effected by high human impact (based on Red List information (Friedmann & Daly 2004)). Taxa denoted with ✘ are most likely NT, DD, or LC taxa occurring in high CHT areas, which are known to be highly susceptible to human impact. * indicates sub population Red List assessments. Abbreviations for column titles: regional Red List assessment (Friedmann & Daly 2004) (RRL 2004); Human Density (HD); Human growth rate Change (HC); Economy Poverty (EP); Economy Affluence (EA) (x R1 000 000); Land use Roads and Urbanization (LRU) and Land use Transformed and Degraded (LTD).

Rank	Taxon name	Common name	RRL 2004	CHT	HD	HC	EP	EA	LRU	LTD
1	*Neamblysomus julianae**	Juliana's golden mole	CR	1333.52	378.78	20.17	51.62	5279332555.32	24.24	0.42
2	*Otomops martiensseni*	Large-eared free-tailed bat	VU	1277.01	256.49	5.91	63.25	1717090988.32	11.42	0.61
3	*Neamblysomus gunningi*	Gunning's golden mole	EN	1293.09	90.25	8.48	69.18	599726174.74	8.80	0.40
4	*Dendromus nyikae*✘	Nyika climbing mouse	NT	1264.17	84.21	10.73	68.99	770825005.44	7.33	0.34
5	*Myosorex sclateri*	Sclater's forest shrew	EN	1179.51	73.53	4.69	72.62	799428309.03	6.07	0.45
6	*Cricetomys gambianus*	Giant rat	VU	1143.98	61.59	6.56	67.64	503304980.75	6.36	0.34
7	*Kerivoula argentata*	Damara woolly bat	EN	1134.50	111.82	7.14	72.08	884674386.77	6.20	0.40
8	*Myosorex cafer*✘	Dark-footed forest shrew	DD	1161.55	96.16	12.47	66.23	1119109687.80	9.06	0.36
9	*Amblysomus marleyi*	Marley's golden mole	EN	1149.44	46.82	10.79	79.95	367516195.03	4.54	0.31
10	*Mus neavei*✘	Thomas' pygmy mouse	DD	1259.39	83.00	8.54	70.19	539484322.76	7.76	0.37
11	*Cephalophus natalensis*†	Red duiker	LC	1139.40	99.04	9.80	68.59	725709383.00	6.66	0.38
12	*Rhinolophus blasii*	Peak-saddle horseshoe bat	VU	1122.29	111.68	17.62	60.23	1436189560.76	9.25	0.33
13	*Miniopterus fraterculus*✘	Lesser long-fingered bat	NT	1092.82	69.49	10.72	67.60	647746944.14	7.82	0.33
14	*Philantomba monticola*	Blue duiker	VU	1080.30	75.59	9.83	68.32	598322816.86	7.23	0.36
15	*Cercopithecus mitis labiatus*	Samango monkey	EN	1117.76	64.64	10.62	70.25	561728914.35	7.49	0.34
16	*Dendrohyrax arboreus arboreus*	Tree hyrax	VU	1085.85	93.54	8.36	70.19	602551124.99	8.53	0.36
17	*Suncus infinitesimus*†	Least dwarf shrew	DD	1071.42	74.99	12.98	64.00	1026820705.52	7.67	0.33

18	*Amblysomus hottentotus*†	Hottentot's golden mole	DD	1076.84	69.07	9.51	69.78	738397622.92	7.59	0.32
19	*Chrysospalax trevelyani*	Giant golden mole	VU	1104.06	70.14	1.89	75.87	411819583.13	8.77	0.36
20	*Neoromicia rendalli*	Rendall's serotine bat	CR	1053.24	34.07	-11.90	78.92	538330351.89	4.78	0.43
21	*Rhinolophus swinnyi*	Swinny's horseshoe bat	EN	1133.55	89.71	6.35	73.48	669932801.07	7.22	0.38
22	*Dendromus mystacalis*†	Chestnut climbing mouse	LC	1094.74	87.62	14.76	61.90	1155339510.92	7.69	0.33
23	*Ourebia ourebi*	Oribi	EN	1142.03	94.10	13.90	65.59	1336082845.01	8.65	0.35
24	*Crocidura mariquensis*†	Swamp musk shrew	DD	1078.00	69.67	14.10	61.95	1068842869.24	7.53	0.32
25	*Paraxerus palliatus ornatus*	Ongoye red squirrel	CR	1203.64	225.58	3.19	63.64	611089582.08	11.02	0.57
26	*Amblysomus septentrionalis*×	Highveld golden mole	NT	1160.94	87.55	14.68	62.45	1505311105.41	10.40	0.34
27	*Paraxerus palliatus*†	Red squirrel	NT	1134.76	90.42	5.01	74.31	557335005.16	6.02	0.42
28	*Aethomys ineptus*†	Tete veld rat	LC	1094.58	73.11	13.30	63.06	1079847551.70	7.47	0.33
29	*Paraxerus palliatus tongensis*	Tonga red squirrel	EN	1117.29	56.69	5.39	77.03	538791320.75	4.75	0.38
30	*Cercopithecus mitis*	Samango monkey	VU	1097.18	61.82	9.90	70.55	517426897.60	6.88	0.32
31	*Otolemur crassicaudatus*×	Thick-tailed bushbaby	LC	1060.99	69.58	13.50	63.89	728738098.89	5.91	0.30
32	*Pronolagus crassicaudatus*×	Natal red rock rabbit	LC	1077.43	66.02	15.31	65.38	761137764.76	6.19	0.30
33	*Epomophorus* wahlbergi†	Wahlberg's epauletted fruit bat	LC	1052.92	73.65	12.50	63.58	977821653.88	7.60	0.31
34	*Glauconycteris variegatus*†	Butterfly bat	NT	1047.33	48.95	5.88	72.77	472552180.06	4.39	0.29
35	*Grammomys dolichurus*×	Woodland mouse	DD	1053.83	70.47	11.14	65.52	704045901.93	6.56	0.31
36	*Steatomys pratensis*†	Fat mouse	LC	1071.36	60.45	10.60	66.15	1065602916.27	7.89	0.35
37	*Neamblysomus julianae*	Juliana's golden mole	VU	1140.42	178.29	29.27	51.69	2481040679.40	13.75	0.38
38	*Pipistrellus anchietae*†	Anchieta's pipistrelle	NT	1059.96	87.42	10.60	65.41	786410934.31	5.96	0.35
39	*Scotoecus albofuscus*	Thomas' house bat	VU	1284.43	248.86	2.63	65.74	2218181071.70	10.51	0.62
40	*Otomys angoniensis*†	Angoni vlei rat	LC	1048.63	65.13	13.73	62.60	979853329.74	6.91	0.30
41	*Nycteris hispida*×	Hairy slit-faced bat	NT	1036.15	31.65	-3.70	80.97	565372621.41	3.53	0.34
42	*Crocidura maquassiensis*	Maquassie musk shrew	VU	1091.04	103.96	8.86	64.06	1376351633.24	9.05	0.27
43	*Rhinolophus simulator*×	Bushveld horseshoe bat	LC	1030.43	78.17	14.18	59.75	1076904389.99	6.88	0.30
44	*Ichneumia albicauda*†	White-tailed mongoose	LC	1060.70	62.59	11.28	65.64	896181933.38	7.94	0.31
45	*Georychus capensis**	Cape mole-rat	EN	1045.74	70.06	18.02	62.59	501832570.00	7.54	0.30
46	*Myotis tricolor*	Temminck's hairy bat	NT	1015.22	71.81	13.67	58.48	1007757452.87	7.56	0.32
47	*Steatomys krebsii*	Krebs' fat mouse	LC	1031.91	68.90	14.42	59.02	1135454462.58	6.96	0.28

48	*Kerivoula lanosa*	Lesser woolly bat	NT	1051.18	77.18	9.48	66.04	749542091.32	6.96	0.30
49	*Damaliscus pygargus phillipsi*	Blesbok	LC	1032.94	47.14	11.15	65.40	896728786.24	8.20	0.27
50	*Thryonomus swinderianus*	Greater cane rat	LC	1016.02	54.06	10.87	64.34	847818282.35	7.44	0.29
51	*Rousettus aegyptiacus*	Egyptian fruit bat	LC	988.63	63.97	11.98	60.92	736294298.62	7.05	0.31
52	*Neoromicia nanus*	Banana bat	LC	1045.82	67.37	10.83	65.44	666164620.69	6.54	0.31
53	*Pipistrellus hesperidus*	African pipistrelle	LC	1041.41	56.01	13.24	63.71	741932267.85	6.21	0.29
54	*Thallomys paedulcus*	Tree rat	LC	1044.02	55.93	14.26	60.86	1009803757.35	6.84	0.29
55	*Otomys laminatus*	Laminate vlei rat	LC	1021.99	72.21	15.24	61.53	779351243.38	6.61	0.34
56	*Lemniscomys rosalia*	Single-striped mouse	DD	1053.89	71.81	13.84	61.66	1000393732.16	7.01	0.30
57	*Pronolagus randensis*	Jameson's red rock rabbit	LC	1045.58	74.85	13.88	57.39	1316977865.07	8.05	0.29
58	*Grammomys cometes*	Mozambique woodland mouse	DD	1082.66	45.76	6.58	72.60	812857062.98	4.54	0.28
59	*Connochaetes gnou*	Black wildebeest	LC	1020.45	46.83	12.14	64.70	840431856.92	7.62	0.27
60	*Chrysospalax villosus*	Rough-haired golden mole	CR	1100.42	87.31	22.05	60.94	1290575411.16	9.13	0.28
61	*Cloeotis percivali*	Short-eared trident bat	CR	975.60	69.88	15.04	57.10	1009188477.84	6.36	0.26
62	*Mastomys natalensis*	Natal multimammate mouse	LC	1020.16	63.44	11.00	66.51	758305993.76	6.97	0.28
63	*Dasymys incomtus*	Water rat	NT	1035.32	68.08	16.59	59.61	928033933.89	7.06	0.32
64	*Scotophilus dinganii*	Yellow house bat	LC	1039.53	65.92	12.07	63.97	893460640.65	7.21	0.29
65	*Crocidura flavescens*	Greater musk shrew	DD	983.04	51.34	11.74	63.30	701059921.64	7.12	0.29
66	*Chaerephon pumila*	Little free-tailed bat	LC	1045.62	68.25	13.51	63.40	732944604.36	5.78	0.30
67	*Mus orangiae*	Free state pygmy mouse	DD	1115.64	30.06	5.14	68.43	951360675.71	9.23	0.37
68	*Genetta tigrina*	Large-spotted genet	LC	1008.29	55.80	11.98	61.88	859106362.63	7.38	0.31
69	*Tragelaphus scriptus*	Bushbuck	LC	1014.99	60.48	13.87	61.15	842562523.16	6.84	0.29
70	*Mungos mungo*	Banded mongoose	LC	1057.15	71.61	14.64	60.74	1102308327.56	7.13	0.29
71	*Myosorex varius*	Forest shrew	DD	980.40	56.35	11.33	62.65	830150668.36	7.57	0.29
72	*Lutra maculicollis*	Spotted-necked otter	NT	1033.66	57.81	10.93	65.37	876145808.27	7.91	0.29
73	*Graphiurus platyops*	Rock dormouse	DD	1042.44	74.65	14.25	58.08	1326690000.18	8.23	0.28
74	*Suncus lixus*	Greater dwarf shrew	DD	1047.07	81.74	14.19	59.97	1001461762.05	6.91	0.31
75	*Mystromys albicaudatus*	White-tailed rat	EN	1010.18	55.36	10.97	64.47	808074765.88	8.30	0.31
76	*Taphozous mauritianus*	Mauritian tomb bat	LC	1014.34	73.67	12.21	61.96	899967187.15	7.21	0.30
77	*Atelerix frontalis*	South african hedgehog	NT	1016.61	47.38	9.96	63.87	940064050.81	7.94	0.28

78	*Neotragus moschatus zuluensis*	Suni	VU	996.01	33.74	3.58	77.29	437399320.00	3.28	0.30
79	*Tragelaphus angasii*	Nyala	LC	1032.84	70.90	14.67	61.69	912871090.48	6.47	0.29
80	*Graphiurus murinus*	Woodland dormouse	LC	1002.39	48.85	10.85	64.36	789162743.10	7.20	0.29
81	*Elephantulus myurus*	Rock elephant-shrew	LC	979.41	43.17	10.99	63.21	827217774.63	7.22	0.25
82	*Heterohyrax brucei*	Yellow-spotted rock hyrax	LC	962.46	47.55	16.61	56.59	639494333.74	5.38	0.27
83	*Elephantulus brachyrhynchus*	Short-snouted elephant-shrew	DD	968.57	65.90	14.45	54.96	1149853267.51	6.51	0.25
84	*Otomys irroratus*	Vlei rat	LC	934.30	44.15	9.27	62.47	723552471.17	6.91	0.26
85	*Herpestes ichneumon*	Large grey mongoose	LC	974.39	61.87	12.23	61.25	658133306.55	7.35	0.34
86	*Diceros bicornis minor*	South-central black rhino	VU	1035.88	47.18	14.79	61.27	752935494.06	5.87	0.28
87	*Dendromus mesomelas*	Brant's climbing mouse	LC	957.53	51.86	11.80	62.24	604752059.30	6.72	0.28
88	*Redunca arundinum*	Reedbuck	LC	1032.99	69.09	12.69	62.84	917540418.88	6.93	0.28
89	*Mus minutoides*	Pygmy mouse	LC	913.46	42.89	10.57	61.38	626450794.04	6.54	0.25
90	*Potamochoerus porcus koiropotamus*	Bushpig	LC	980.29	49.16	11.80	61.23	708665248.07	6.44	0.26
91	*Acomys spinosissimus*	Spiny mouse	LC	1003.78	47.07	14.22	57.51	857682079.94	5.80	0.26
92	*Scotophilus viridis*	Lesser yellow house bat	LC	1035.11	86.06	15.01	58.09	1450914210.72	7.56	0.31
93	*Crocidura silacea*	Lesser grey-brown musk shrew	DD	971.67	56.44	10.34	64.87	789173793.49	7.07	0.26
94	*Miniopterus schreibersii*	Schreibers' long-fingered bat	NT	965.46	46.88	9.53	62.54	797745175.68	6.99	0.28
95	*Aepyceros melampus*	Impala	LC	1025.48	72.50	12.32	62.12	972044129.93	6.54	0.29
96	*Tatera brantsii*	Highveld gerbil	LC	954.25	43.99	7.74	65.62	777329120.58	6.95	0.25
97	*Leptailurus serval*	Serval	NT	1013.07	59.83	12.57	63.57	849015506.07	6.84	0.28
98	*Galago moholi*	Southern lesser galago	LC	996.47	73.62	14.97	55.12	1259145221.07	7.26	0.26
99	*Equus burchellii*	Plains zebra	LC	1024.92	60.85	11.70	63.73	945453363.17	6.61	0.29
100	*Petrodromus tetradactylus*	Four-toed elephant-shrew	EN	1030.88	34.04	8.51	75.83	490118499.47	3.49	0.30
101	*Helogale parvula*	Dwarf mongoose	LC	1028.14	65.63	14.29	58.28	1181038724.87	7.11	0.28
102	*Suncus varilla*	Lesser dwarf shrew	DD	966.11	54.62	10.56	61.94	899935876.08	7.73	0.29
103	*Dendromus melanotis*	Grey climbing mouse	LC	937.97	46.82	9.66	61.71	787806598.66	6.70	0.27
104	*Myotis welwitschii*	Welwitsch's hairy bat	NT	1070.26	79.59	13.08	58.73	1323475398.21	8.63	0.31
105	*Rhinolophus fumigatus*	Rüppell's horseshoe bat	NT	923.02	51.68	11.33	58.33	848531966.71	5.12	0.21
106	*Redunca fulvorufula*	Mountain reedbuck	LC	993.49	53.48	10.63	63.70	829409166.35	7.43	0.27
107	*Poecilogale albinucha*	African weasel	DD	922.11	43.22	9.58	61.79	731601651.13	6.89	0.25

108	*Manis temminckii*	Pangolin	VU	959.25	32.88	10.20	61.92	676942954.55	5.10	0.25
109	*Crocidura fuscomurina*	Tiny musk shrew	DD	1004.34	57.08	10.40	63.66	935677430.76	7.50	0.28
110	*Crocidura hirta*	Lesser red musk shrew	DD	914.15	46.75	8.94	61.44	900707949.75	5.76	0.23
111	*Chlorotalpa duthieae*	Duthie's golden mole	LC	955.89	64.29	15.86	51.95	1503816919.64	8.38	0.36
112	*Orycteropus afer*	Aardvark	LC	826.03	33.55	5.57	61.20	660377038.11	6.12	0.20
113	*Galerella sanguinea*	Slender mongoose	LC	947.48	45.36	9.24	62.80	883250756.32	6.37	0.25
114	*Phacochoerus africanus*	Warthog	LC	1028.08	60.34	11.74	62.63	981239958.83	6.77	0.30
115	*Eptesicus hottentotus*	Long-tailed serotine bat	LC	895.37	47.12	8.71	60.71	688074152.13	6.72	0.29
116	*Georychus capensis*	Cape mole-rat	LC	842.66	32.88	12.19	52.85	710729539.41	6.98	0.27
117	*Rhinolophus landeri*	Lander's horseshoe bat	NT	1012.06	48.91	16.62	60.40	763090234.35	5.54	0.26
118	*Ceratotherium simum*	White rhinoceros	LC	1028.32	50.85	13.58	60.86	827968229.39	6.12	0.27
119	*Damaliscus lunatus lunatus*	Tsessebe	EN	960.35	46.61	15.87	56.49	896893283.82	5.59	0.24
120	*Cryptomys hottentotus*	Common mole-rat	LC	895.09	40.06	8.05	62.00	679757962.55	6.73	0.24
121	*Epomophorus gambianus crypturus*	Gambian epauletted fruit bat	DD	982.49	44.23	16.27	58.97	622607678.75	5.18	0.25
122	*Bathyergus suillus*	Cape dune mole-rat	LC	901.48	47.27	18.34	45.94	800125403.16	7.84	0.40
123	*Rhinolophus clivosus*	Geoffroy's horseshoe bat	NT	902.32	41.38	8.09	61.63	710000842.59	6.87	0.23
124	*Cercopithecus aethiops pygerythrus*	Vervet monkey	LC	941.21	51.44	10.30	61.69	774471119.25	6.75	0.24
125	*Paraxerus cepapi*	Tree squirrel	LC	977.80	52.53	14.75	55.87	964313796.34	6.03	0.26
126	*Hystrix africaeaustralis*	Porcupine	LC	825.14	33.19	5.59	61.03	659391873.95	6.09	0.20
127	*Paracynictis selousi*	Selous' mongoose	DD	916.33	44.27	11.32	59.29	586394432.72	4.42	0.23
128	*Raphicerus sharpei*	Sharp's grysbok	NT	907.43	48.33	14.57	54.21	682565339.86	4.81	0.21
129	*Hipposideros caffer*	Sundevall's leaf-nosed bat	DD	1003.18	62.86	11.05	62.15	802993659.82	5.75	0.29
130	*Myotis bocagei*	Rufous hairy bat	DD	950.56	63.18	13.46	56.84	569283851.44	5.11	0.24
131	*Amblysomus robustus*	Robust golden mole	EN	978.21	11.02	12.94	49.37	1070975563.92	9.30	0.20
132	*Crocidura cyanea*	Reddish-grey musk shrew	DD	833.40	34.24	5.58	61.17	650211426.91	6.24	0.20
133	*Pipistrellus rusticus*	Rusty bat	NT	981.11	75.71	15.62	54.94	1166650041.49	6.99	0.25
134	*Rhabdomys pumilio*	Striped mouse	LC	835.47	34.49	5.30	61.87	656691168.17	6.27	0.21
135	*Aonyx capensis*	Cape clawless otter	LC	941.53	46.27	9.87	61.67	783526387.74	7.03	0.26
136	*Cercopithecus mitis erythrarchus*	Samango monkey	VU	964.43	27.49	-0.41	84.46	121459463.28	1.72	0.27
137	*Rhynchogale melleri*	Meller's mongoose	DD	896.10	48.44	16.00	52.56	792845068.73	4.44	0.21

138	*Hippopotamus amphibius*	Hippopotamus	LC	975.77	58.72	11.58	58.61	824734082.51	5.70	0.26
139	*Rhinolophus darlingi*	Darling's horseshoe bat	NT	997.89	57.32	10.24	63.81	833863194.18	6.93	0.27
140	*Atilax paludinosus*	Water mongoose	LC	913.01	43.34	8.88	61.38	737470868.81	6.90	0.25
141	*Mus indutus*	Desert pygmy mouse	LC	891.32	30.03	4.57	64.47	876133874.67	5.18	0.24
142	*Lepus saxatilis*	Scrub / savannah hare	LC	825.14	33.19	5.59	61.03	659391873.95	6.09	0.20
143	*Pelea capreolus*	Grey rhebok	LC	925.27	50.46	11.69	59.53	786979237.91	7.33	0.25
144	*Tatera leucogaster*	Bushveld gerbil	DD	853.33	37.54	6.32	60.54	820519928.40	5.83	0.20
145	*Kobus ellipsiprymnus ellipsiprymnus*	Waterbuck	LC	997.78	46.14	14.14	59.87	756146910.01	5.51	0.27
146	*Mops condylurus*	Angolan free-tailed bat	LC	944.32	82.56	11.38	60.84	841873849.08	4.81	0.28
147	*Myomyscus verreauxi*	Verreaux's mouse	LC	825.62	36.53	16.44	47.90	650509548.82	6.98	0.33
148	*Rhinolophus hildebrandtii*	Hildebrandt's horseshoe bat	NT	941.51	38.69	15.33	55.04	720844584.31	5.13	0.24
149	*Calcochloris obtusirostris*	Yellow golden mole	VU	841.82	18.77	6.53	74.33	244435240.65	1.61	0.20
150	*Alcelaphus buselaphus*	Red hartebeest	LC	919.72	38.33	9.56	62.74	793375187.85	6.82	0.24
151	*Sylvicapra grimmia*	Common duiker	LC	825.14	33.19	5.59	61.03	659391873.95	6.09	0.20
152	*Connochaetes taurinus taurinus*	Blue wildebeest	LC	973.89	41.08	9.74	63.17	917899018.25	6.62	0.26
153	*Aethomys namaquensis*	Namaqua rock mouse	LC	815.30	30.09	5.33	60.93	650080107.52	5.98	0.19
154	*Saccostomus campestris*	Pouched mouse	LC	895.11	38.62	9.22	60.92	781424169.32	6.55	0.23
155	*Tatera afra*	Cape gerbil	LC	785.83	35.31	13.28	47.31	651736630.57	6.80	0.31
156	*Taurotragus oryx*	Eland	LC	934.25	45.55	9.61	62.96	762834932.49	6.72	0.25
157	*Syncerus caffer*	Cape buffalo	LC	973.09	45.49	11.94	60.73	724229826.70	5.80	0.24
158	*Mastomys coucha*	Multimammate mouse	LC	833.55	30.36	6.06	60.62	691268635.66	6.48	0.19
159	*Otomys sloggetti*	Sloggett's rat	DD	928.97	26.14	9.06	69.65	370841650.77	6.69	0.21
160	*Cynictis penicillata*	Yellow mongoose	LC	804.11	28.38	4.81	61.07	643809379.47	6.28	0.19
161	*Papio ursinus*	Chacma baboon	LC	869.24	41.30	8.59	61.02	731084371.87	6.17	0.22
162	*Civettictis civetta*	African civet	LC	959.09	38.67	14.20	58.12	658972511.82	5.20	0.25
163	*Neoromicia capensis*	Cape serotine bat	LC	825.14	33.19	5.59	61.03	659391873.95	6.09	0.20
164	*Nycteris thebaica*	Egyptian slit-faced bat	LC	829.79	33.51	6.32	60.47	653739362.14	6.25	0.20
165	*Hippotragus niger niger*	Sable antelope	VU	972.10	71.84	15.53	53.86	1170113896.34	6.82	0.25
166	*Xerus inauris*	Cape ground squirrel	LC	800.93	27.49	2.50	63.53	723305886.75	6.35	0.17
167	*Hyaena brunnea*	Brown hyaena	NT	921.10	37.72	8.73	62.71	794395935.94	6.65	0.22

168	*Oreotragus oreotragus*	Klipspringer	LC	809.08	28.51	5.40	60.43	657785516.55	6.00	0.19
169	*Pronolagus saundersiae*	Hewitt's red rock rabbit	LC	847.82	26.55	7.90	62.28	506580751.54	6.79	0.20
170	*Laephotis wintoni*	De winton's long-eared bat	VU	955.32	47.69	10.05	59.01	840021478.21	5.98	0.29
171	*Raphicerus melanotis*	Cape grysbok	LC	740.39	24.43	8.59	53.54	564752925.43	6.30	0.21
172	*Proteles cristatus*	Aardwolf	LC	823.89	32.25	5.56	61.32	625465898.97	6.09	0.20
173	*Tragelaphus strepsiceros*	Kudu	LC	935.00	46.30	9.50	62.71	746242120.63	6.35	0.26
174	*Aethomys chrysophilus*	Red veld rat	LC	902.55	15.96	6.77	65.72	471056453.09	4.55	0.22
175	*Ictonyx striatus*	Striped polecat	LC	825.48	33.22	5.58	61.04	659705352.84	6.09	0.20
176	*Raphicerus campestris*	Steenbok	LC	808.91	29.03	5.28	60.50	659308298.19	6.01	0.19
177	*Neoromicia zuluensis*	Aloe bat	LC	926.76	37.32	11.14	58.77	613989756.00	4.54	0.22
178	*Lepus capensis*	Cape hare / desert hare	LC	774.37	21.35	3.91	59.70	622109579.32	5.65	0.18
179	*Genetta genetta*	Small-spotted genet	LC	797.60	27.12	5.14	59.94	648344643.76	6.01	0.18
180	*Procavia capensis*	Rock hyrax	LC	825.14	33.19	5.59	61.03	659391873.95	6.09	0.20
181	*Amblysomus corriae*	Fynbos golden mole	NT	857.30	19.12	18.64	48.71	536293713.93	7.27	0.35
182	*Canis mesomelas*	Black-backed jackal	LC	823.97	33.13	5.55	61.06	656823332.07	6.07	0.20
183	*Acomys subspinosus*	Cape spiny mouse	LC	852.57	41.36	16.62	47.21	723675890.98	7.38	0.35
184	*Tadarida aegyptiaca*	Egyptian free-tailed bat	LC	825.14	33.19	5.59	61.03	659391873.95	6.09	0.20
185	*Damaliscus pygargus pygargus*	Bontebok	VU	878.01	20.02	22.22	46.28	466659009.43	7.69	0.40
186	*Pronolagus rupestris*	Smith's red rock rabbit	LC	685.53	11.31	-3.87	61.46	517708697.53	5.45	0.08
187	*Chlorotalpa sclateri*	Sclater's golden mole	DD	878.84	21.90	9.97	67.14	289247241.97	5.71	0.20
188	*Lycaon pictus*	African wild dog	EN	903.09	39.77	9.72	59.05	923938901.29	5.04	0.21
189	*Vulpes chama*	Cape fox	LC	795.76	26.44	4.62	60.72	634296602.00	6.16	0.18
190	*Acinonyx jubatus*	Cheetah	VU	914.30	33.78	10.68	60.39	779365749.21	4.73	0.23
191	*Felis silvestris*	African wild cat	LC	825.14	33.19	5.59	61.03	659391873.95	6.09	0.20
192	*Diceros bicornis bicornis*	South-western black rhino	CR	638.92	7.81	0.25	58.97	375160292.84	5.22	0.10
193	*Felis nigripes*	Black-footed cat	LC	800.54	25.86	2.41	62.10	650710182.95	6.44	0.17
194	*Otomys saundersiae*	Saunders' vlei rat	LC	782.40	24.51	8.42	58.47	480501089.18	7.11	0.19
195	*Hippotragus equinus*	Roan antelope	VU	902.35	25.50	7.03	62.12	549147796.96	4.84	0.21
196	*Cryptochloris zyli*	Van zyl's golden mole	CR	840.86	5.36	24.72	42.16	267074972.17	5.84	0.40
197	*Sauromys pETRophilus*	Flat-headed free-tail bat	LC	829.21	35.60	4.44	56.63	901271126.72	6.07	0.19

198	*Crocuta crocuta*	Spotted hyaena	NT	871.73	31.01	10.60	59.37	694580598.03	4.03	0.19
199	*Parotomys littledalei*	Littledale's whistling rat	NT	487.86	1.69	-7.15	56.14	405513086.75	3.93	0.02
200	*Pedetes capensis*	Springhare	LC	775.91	25.10	3.15	60.81	658857010.19	5.90	0.16
201	*Xerus princeps*	Mountain ground squirrel	NT	429.76	0.44	-13.22	57.20	655989000.00	0.70	0.00
202	*Caracal caracal*	Caracal	LC	811.19	29.49	5.73	60.38	650270156.89	6.05	0.19
203	*Mellivora capensis*	Honey badger	NT	816.74	35.77	5.76	60.37	652211984.64	5.95	0.20
204	*Panthera leo*	Lion	VU	864.63	31.02	9.91	58.50	702942536.48	4.32	0.18
205	*Loxodonta africana*	African elephant	LC	896.02	36.41	12.26	58.29	676451636.18	4.35	0.19
206	*Chrysochloris asiatica*	Cape golden mole	DD	664.62	20.66	5.73	50.74	530524599.67	5.54	0.19
207	*Nycticeinops schlieffeni*	Schlieffen's bat	LC	850.46	34.46	11.61	58.49	537043965.85	3.64	0.18
208	*Antidorcas marsupialis*	Springbok	LC	793.19	27.99	4.41	61.21	629831559.20	6.16	0.18
209	*Panthera pardus*	Leopard	LC	806.59	33.81	5.33	60.54	629358997.15	5.85	0.19
210	*Giraffa camelopardalis*	Giraffe	LC	848.74	35.51	7.40	60.41	814781378.05	4.91	0.19
211	*Cistugo lesueuri*	Lesueur's wing-gland bat	NT	655.64	16.26	3.20	55.24	473655615.87	5.46	0.15
212	*Galerella pulverulenta*	Small grey mongoose	LC	714.18	18.05	3.04	59.83	434712033.31	5.92	0.15
213	*Suricata suricatta*	Suricate	LC	749.07	22.01	1.47	60.95	652210393.99	6.03	0.15
214	*Rhinolophus capensis*	Cape horseshoe bat	NT	757.42	27.87	6.44	53.87	639679770.62	6.35	0.21
215	*Canis adustus*	Side-striped jackal	NT	831.87	35.54	11.96	55.01	728744630.94	3.31	0.20
216	*Laephotis botswanae*	Botswana long-eared bat	VU	835.16	19.45	18.12	51.64	608855711.54	3.39	0.15
217	*Myosorex longicaudatus*	Long-tailed forest shrew	NT	782.84	11.12	16.82	48.55	335114915.31	6.46	0.30
218	*Malacothrix typica*	Large-eared mouse	LC	668.57	10.07	-0.05	60.08	449891352.25	5.18	0.12
219	*Eremitalpa granti*	Grant's golden mole	VU	758.75	6.73	5.66	50.79	788242167.81	5.73	0.30
220	*Mops midas*	Midas free-tailed bat	LC	803.33	34.31	15.01	49.87	758723012.77	4.02	0.15
221	*Equus zebra zebra*	Cape mountain zebra	VU	751.44	8.72	15.19	53.23	281765403.17	6.02	0.23
222	*Elephantulus intufi*	Bushveld elephant-shrew	DD	698.44	11.53	4.40	58.48	733967879.62	3.07	0.11
223	*Desmodillus auricularis*	Short-tailed gerbil	LC	672.10	10.59	1.00	59.37	455636488.67	5.29	0.12
224	*Elephantulus edwardii*	Cape rock elephant-shrew	LC	642.45	16.55	3.14	54.72	448803462.56	5.55	0.14
225	*Otocyon megalotis*	Bat-eared fox	LC	738.31	14.45	2.56	60.22	491664008.96	5.49	0.15
226	*Graphiurus ocularis*	Spectacled dormouse	LC	616.97	13.76	0.12	56.03	411584347.81	5.46	0.11
227	*Gerbillurus paeba*	Hairy-footed gerbil	LC	651.11	11.85	1.27	58.11	447416668.31	4.85	0.11

228	*Chaerephon ansorgei*	Ansorge's free-tailed bat	LC	752.50	29.43	7.71	53.52	692054787.11	2.54	0.16
229	*Nycteris woodi*	Wood's slit-faced bat	NT	752.26	12.27	13.10	54.05	318529070.85	4.64	0.08
230	*Otomys unisulcatus*	Karoo bush rat	LC	617.09	13.98	-0.01	56.34	373598467.55	5.47	0.12
231	*Elephantulus rupestris*	Smith's rock elephant shrew	LC	585.31	8.24	-4.37	59.46	402715567.62	5.14	0.05
232	*Cryptochloris wintoni*	De winton's golden mole	CR	593.88	1.25	-12.26	57.20	655989000.00	2.13	0.17
233	*Zelotomys woosnami*	Woosnam's desert rat	LC	657.99	5.36	-4.56	70.16	556900602.02	1.90	0.11
234	*Rhinolophus denti*	Dent's horseshoe bat	NT	609.18	5.46	0.05	57.45	787555596.21	3.46	0.03
235	*Oryx gazella*	Gemsbok	LC	646.38	8.23	-2.05	60.26	498590631.08	4.30	0.10
236	*Aethomys granti*	Grant's rock mouse	LC	555.52	13.24	-0.93	55.11	277696201.04	5.50	0.08
237	*Cryptomys damarensis*	Damaraland mole-rat	LC	636.69	1.31	-4.50	65.53	724095999.99	2.21	0.13
238	*Bathyergus janetta*	Namaqua dune mole-rat	NT	578.60	0.94	-9.42	57.18	649946739.13	2.98	0.07
239	*Petromus typicus*	Dassie rat	NT	536.72	1.67	-1.76	55.30	592323222.74	3.56	0.02
240	*Thallomys nigricauda*	Black-tailed tree rat	LC	582.97	2.08	-2.19	61.96	643377116.11	2.43	0.08
241	*Macroscelides proboscideus*	Round-eared elephant-shrew	LC	508.08	1.89	-3.72	56.12	368042741.89	4.04	0.03
242	*Petromyscus barbouri*	Barbour's rock mouse	LC	524.28	1.44	-3.61	53.27	368342073.33	3.77	0.04
243	*Parotomys brantsii*	Brants' whistling rat	LC	487.65	1.65	-4.63	55.83	328305539.74	4.11	0.03
244	*Equus zebra hartmannae*	Hartmann's mountain zebra	EN	533.29	1.99	-2.15	55.61	631663172.69	3.08	0.02
245	*Petromyscus collinus*	Pygmy rock mouse	LC	453.24	1.11	-7.99	55.86	318913502.24	3.56	0.02
246	*Cistugo seabrai*	Angolan wing-gland bat	VU	501.40	1.09	-6.37	55.85	551370553.62	2.92	0.03
247	*Bunolagus monticularis*	Riverine rabbit	CR	444.56	1.12	-7.10	55.64	155054645.29	4.30	0.02
248	*Gerbillurus vallinus*	Brush-tailed hairy-footed gerbil	LC	448.57	1.64	-2.38	52.71	552970149.51	3.23	0.01
249	*Chrysochloris visagiei*	Visagie's golden mole	CR	384.11	0.73	-5.70	53.54	107028129.67	4.46	0.01

APPENDIX 3. Preliminary "Rare and/or Declining" listed taxa of Orange List for south African mammals. Taxa were assessed according to criteria set out in Victor & Keith 2004. All Orange Listed Near Threatened and Data Deficient taxa can be extracted from APPENDIX 1.

Taxon name	**Common name**	**Occurrence (km^2)**	**Occupancy (km^2)**	**Population size decline**	**Change noted**
Aepyceros melampus	Impala	> 20,000	> 2,001	21% to 50%	Decrease in Area
Aethomys chrysophilus	Red veld rat	> 20,000	> 2,001	< 20%	Decrease in Area and habitat quality
Aethomys ineptus	Tete veld rat	> 20,000	> 2,001	< 20%	Decrease in Area and habitat quality
Alcelaphus buselaphus	Red hartebeest	> 20,000	> 2,001	21% to 50%	Decrease in Area
Aonyx capensis	Cape clawless otter	> 20,000	501-2,000	-	Stable in Area
Arctocephalus tropicalis	Subantarctic fur seal	< 100	11-500	-	-
Bathyergus suillus	Cape dune mole-rat	> 20,000	501-2,000	-	Decrease in Area and habitat quality
Cephalophus natalensis	Red duiker	> 20,000	> 2,001	51% to 80%	Decrease in Area
Chaerephon ansorgei	Ansorge's free-tailed bat	> 20,000	11-500	-	Unknown
Chlorotalpa duthieae	Duthie's golden mole	101-5,000	501-2,000	-	Stable in Area
Connochaetes gnou	Black wildebeest	> 20,000	> 2,001	21% to 50%	Decrease in Area
Damaliscus pygargus phillipsi	Blesbok	> 20,000	> 2,001	21% to 50%	Decrease in Area
Equus burchellii	Plains zebra	> 20,000	> 2,001	< 20%	Decrease in Area and habitat quality
Felis silvestris	African wild cat	> 20,000	> 2,001	-	Unknown
Georychus capensis	Cape mole-rat	> 20,000	11-500	< 20%	Decrease in Area and habitat quality
Hippopotamus amphibius	Hippopotamus	> 20,000	> 2,001	-	Stable in Area
Lepus capensis	Cape hare / desert hare	> 20,000	> 2,001	-	Stable in Area
Lepus saxatilis	Scrub / savannah hare	> 20,000	> 2,001	sq km	Decrease in Area and habitat quality
Loxodonta africana	African elephant	> 20,000	> 2,001	sq km	Decrease in Area and habitat quality
Malacothrix typica	Large-eared mouse	> 20,000	> 2,001	< 20%	Decrease in Area and habitat quality
Otolemur crassicaudatus	Thick-tailed bushbaby	> 20,000	> 2,001	< 20%	Decrease in Area and habitat quality
Otomys angoniensis	Angoni vlei rat	> 20,000	> 2,001	< 20%	Decrease in Area and habitat quality
Otomys irroratus	Vlei rat	> 20,000	> 2,001	< 20%	Decrease in Area and habitat quality
Otomys saundersiae	Saunders' vlei rat	> 20,000	> 2,001	-	Unknown
Paraxerus cepapi	Tree squirrel	5,001 - 20,000	501-2,000	-	Stable in Area
Pelea capreolus	Grey rhebok	> 20,000	> 2,001	21% to 50%	Decrease in Area and habitat quality
Petromyscus barbouri	Barbour's rock mouse	101-5,000	11-500	-	Unknown

Poecilogale albinucha	African weasel	> 20,000	> 2,001	-	Decrease in Area and habitat quality
Potamochoerus porcus koiropotamus	Bushpig	> 20,000	> 2,001	< 20%	Decrease in Area and habitat quality
Pronolagus crassicaudatus	Natal red rock rabbit	> 20,000	> 2,001	21% to 50%	Decrease in Area and habitat quality
Pronolagus randensis	Jameson's red rock rabbit	> 20,000	> 2,001	21% to 50%	Decrease in Area and habitat quality
Pronolagus rupestris	Smith's red rock rabbit	> 20,000	> 2,001	< 20%	Decrease in Area and habitat quality
Pronolagus saundersiae	Hewitt's red rock rabbit	> 20,000	> 2,001	< 20%	Decrease in Area and habitat quality
Raphicerus campestris	Steenbok	> 20,000	> 2,001	< 20%	Decrease in Area and habitat quality
Raphicerus melanotis	Cape grysbok	> 20,000	> 2,001	< 20%	Decrease in Area and habitat quality
Redunca arundinum	Reedbuck	> 20,000	> 2,001	21% to 50%	Decrease in Area and habitat quality
Rhinolophus simulator	Bushveld horseshoe bat	> 20,000	> 2,001	-	Unknown
Sylvicapra grimmia	Common duiker	> 20,000	> 2,001	< 20%	Decrease in Area
Thallomys paedulcus	Tree rat	> 20,000	> 2,001	-	Decrease in Area and habitat quality
Tragelaphus scriptus	Bushbuck	> 20,000	> 2,001	21% to 50%	Decrease in Area and habitat quality
Xerus inauris	Cape ground squirrel	> 20,000	> 2,001	< 20%	Decrease in Area and habitat quality
Zelotomys woosnami	Woosnam's desert rat	> 20,000	501-2,000	-	Stable in Area