Patterns of distribution and protection status of the endemic mammals in South Africa

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South Africa contains the majority of southern Africa's endemic mammals and hence is an important area for mammal conservation. Moreover, there is an increase in endemism, as determined by range maps, from the northern borders of the country towards the Western Cape Province. Within this area, the Cape fold mountains have a high number of endemics, particularly those which have very restricted ranges. These mountains are at the transition of the Karoo and fynbos biomes and may be a region of high species turnover. The numerous fynbos protected areas and mountain catchments, which incorporate over 30% of the Cape fold mountains, thus protect many of the endemic mammals of this area. The majority of these endemics are small mammals and many are listed in the Red Data Book, especially those restricted to the Nama- and Succulent Karoo. This is of concern, as both areas are inadequately protected by the existing protected areas. The coastal forests also contain many Red Data Book species, particularly Insectivora. These forests are, however, inadequately protected in the Port St Johns region. In this analysis data for the Insectivora were used to compare point and range data. The results indicate that patterns emerging from range maps provide a broad picture which can then be focused with the use of higher resolution data.

Die oorgrote meerderheid van Suider-Afrika se endemiese soogdiere kom in Suid-Afrika voor. Dit spreek dus vanself dat die land belangrik is vir soogdierbeskerming. Wat meer is, volgens verspreidingskaarte neem endemisme toe vanaf die land se noordgrens in die rigting van Wes Kaap Provinsie. Binne hierdie gebied, het die Kaapse Plooiberge besonder baie endemiese spesies — veral spesies met 'n bale klein verspreidingsgebied. Die berge in hierdie streek dien as die oorgangsone tussen die Karoo en die fynbosbioom, 'n gebied wat moontlik 'n hoë omset van spesies het. Meer as 30% van die Kaapse Plooiberge en baie van die gebied se endemiese spesies word dus beskerm binne die streek se talle fynbosreservate en bergopvanggebiede. Die oorgrote meerderheid van hierdie endemiese spesies is klein soogdiere waarvan talle reeds in die Rooi Databoek gelys word, veral die wat beperk is tot die Nama- en die Sukkulente Karoo: 'n kommerwekkende toedrag van sake omdat albei hierdie gebiede onder-beskerm word in bestaande beskermde gebiede. Talle Rooi Data-spesies kom ook in die kuswoude voor, veral insekvreters. Hierdie woudgebiede is veral onder-beskerm in die omgewing van Port St Johns. In hierdie ontleding is data vir insekvreters gebruik om punt- en verspreidingsdata met mekaar te vergelyk. Die resultate dui daarop dat verspreidingskaarte 'n oorsig van die breë beeld gee, en dat 'n duideliker beeld van die patroon verkry kan word uit die verwerking van puntdata.

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Introduction

The rapid rate of extinction which we are currently experiencing represents a loss of resources we can ill afford. In recognition of the seriousness of this situation, one of the key agreements emerging from the Earth Summit in Rio was the Convention on Biodiversity (UNCED, Rio de Janeiro, 1992). By signing this convention, South Africa has recognized the importance of protecting the biodiversity within its borders. Endemic species are a particular responsibility and, as they have restricted distributions, they are inherently vulnerable. This analysis focuses on the endemic mammals of South Africa, which are defined as all terrestrial mammals having over 75% of their distribution within the country. In this study, South Africa is defined to include Lesotho and Swaziland, as these countries form a geographically continuous unit.

Endemics may be the product of local species radiation, or the remnants of species with previously wider distributions. The numerous endemic chrysochlorids (golden moles) are an example of an archaic fauna that has undergone local radiation, whereas species such as the bontebok (*Damaliscus dorcas*) may well have had much wider distributions in the past (Meester 1965; Coe & Skinner 1993). Whether endemics are new species or archaic relicts, they require special protection.

The conservation of endemic mammals in South Africa is particularly important, as this country is a centre of endemism within southern Africa. There are nearly 300 terrestrial mammal species in southern Africa, of which approximately 33% are endemic to the subregion. Forty-one of these sub-regional endemics are restricted to South Africa, whereas very few are restricted to the other southern African countries. For example, Namibia, which follows South Africa in mammal endemism, has only five endemics. Conservation of southern Africa's endemic mammals must, therefore, be effected largely in South Africa.

Although endemism is politically defined, one could argue that it is better to focus on species with restricted ranges. For example, there are four species in southern Africa which have ranges < 300 km^2, but which are not classified as endemic as a result of their distribution falling on the boundaries of two countries. These species include two chrysochlorids and two murids, and like the majority of South Africa's endemic mammals, are small. Indeed, only six of South Africa's endemic

mammals are large mammals, and all of these are ungulates. The remaining 85% comprise small mammals with a mass less than 5 kg. If one regresses body size against endemism for the non-volant mammals, there is a statistically significant negative relationship between the level of endemism in a family and the average size of its members (Gelderblom 1993). The less vagile species, such as the subterranean families Chrysochloridae and Bathyergidae, show particularly high levels of endemism.

The main objectives of this study were to determine: (i) centres of endemism; (ii) centres of high richness of restricted-range species; and (iii) centres of Red Data Book species richness. These 'hotspots' were compared with the existing protected area network to determine how well they are protected spatially. Our analysis highlights gaps in the existing protected area system and discusses their implications for the protection of our endemic mammals.

As a result of the cryptic nature of small mammals, they are frequently poorly sampled, thus range maps were used to determine broad distributional patterns. The results from this work are compared with those obtained with point data to evaluate the efficacy of each approach.

Methods

Two types of data were used for this analysis: range maps and point data. Used together, they are perhaps the most effective way of mapping our biodiversity, given the constraints of current data availability. The ideal situation would be to have up-to-date, fine scale locality data for all species in South Africa. However, up-to-date surveys of all species, even on a quarter degree scale, are not available, and would require considerable financial outlay. Furthermore, many species are cryptic or difficult to trap, and consequently there are very few confirmed records of their existence. In extreme cases, there is only one known locality where a species has been confirmed as present.

Point data are more accurate, and if the data set is kept up to date, do not result in inclusion of sites which are no longer suitable for the species concerned. Some locality records are over 100 years old, and changing land-use practices may have resulted in extinctions at sites where species were previously present. This affects carnivore distributions more than that of small mammals, since large predators are often actively eradicated by man, whereas the smaller species (such as bats and insectivores) are frequently able to persist in relatively small remnants of natural vegetation. Furthermore, as many sites have not been surveyed, there are many errors of omission: exclusion of sites which do in fact contain a species but which have not been surveyed. This is a problem particularly in the arid interior of the country, and this region should therefore be a priority in any future attempts to inventory the country's biodiversity.

Range maps frequently contain coarse scale data and rely on extrapolations based on vegetation type boundaries. This approach may, however, result in errors of commission as, unless the correlation of distribution with vegetation types is confirmed in the field, much of the extrapolation may be spurious. In addition, local extinctions may result in the absence of a species from an area within its range. As many species have very specific requirements and hence naturally patchy distributions, range maps represent potential distributions, and should not be confused with confirmation of occurrence in the field. Analyses using range maps thus provide broad distributional patterns which can be focused with point data. Subsequent ground-truthing of the validity of species distributions is then vital.

Range maps were digitized from Skinner & Smithers (1990). The data were subsequently analysed using the geographical information system (GIS) ARC/INFO (version 6. 1. 1). The list of species used is given in Appendix 1. Range map data were analysed at the quarter degree square 15' × 15' (QDS) level of resolution. As extreme caution must be exercised during the breakdown of data to a finer scale of resolution (Turner, Dale & Gardner 1989), we were conservative in interpreting the results, and confirmed these by comparison with the point data. Indeed, as the data were of coarse resolution, species richness was regarded as potential species richness rather than the actual number of species occurring in the QDS. In addition, the endemic Insectivora (insectivores) were analysed separately to facilitate comparison with results obtained from the point data.

The size of each species' range was determined and the lower 50% were taken to be restricted range species. For effective conservation, not all species should be ranked equally. As ubiquitous species require less protection than rare species which are extremely localized or sensitive to disturbance, regions of high Red Data Book richness were also determined.

Results

Patterns of endemic mammal species richness

Endemism increases as one moves away from the northern boundaries of South Africa towards the Western Cape Province (Figure 1). Within the Western Cape Province, there appears to be a concentration of endemics along the fold mountains (Figure 2). Indeed, the area of highest endemism is found in the region of the Cederberg complex (or western fold mountains), which lie at the transition between the fynbos and Karoo. This area includes the Cederberg, the Warm and Koue Bokkeveld, the Winterberg, the Skurweberg, the Swartruggens and surroundings.

A high proportion (36%) of endemic mammal species are found in predominantly montane habitat [for example: *Elephantulus edwardii* (the Cape rock elephant shrew), *Aethomys granti* (Grant's rock mouse), *Equus zebra* (the Cape mountain zebra) and *Petromyscus barbouri* (Barbour's rock mouse)]. This is of particular importance when one considers the small percentage of South Africa's total land area covered by montane habitat.

The area which potentially contains 10–14 endemic species (Figure 1) stretches along the southern coast, extending up slightly into the Nama-Karoo. This area includes parts of the Succulent Karoo, fynbos and Knysna-Tsitsikamma forests. Seventy-six per cent of the QDSs in fynbos potentially contain at least 15 endemics, as do 30% of the Succulent Karoo QDSs. In contrast, the extensive savanna, grasslands and Nama-Karoo contain relatively few endemic species with under 2% of their surface area potentially containing 15 endemics.

Figure 1 Species richness of South African endemic mammals. The key indicates potential number of endemic mammal species per QDS.

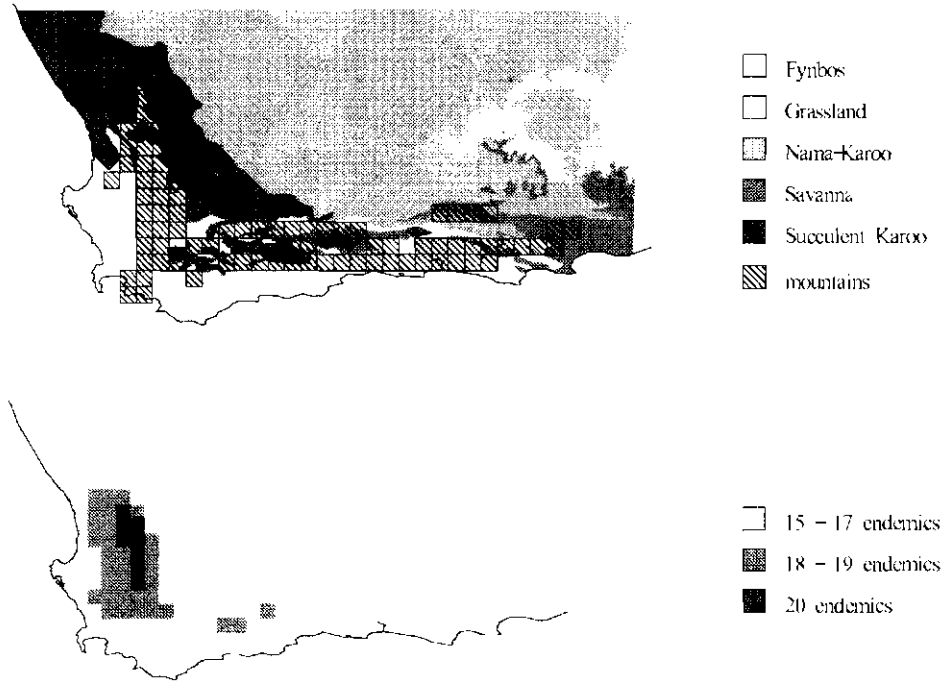

Figure 2 The positions of areas of high endemic mammal species richness in relation to some of the biomes, and the southern Cape fold mountains.

Patterns of restricted-range species richness

The pattern of restricted-range species richness is similar to that emerging from analysis of the species richness of endemic mammals (Figure 3). The region which scores the highest is the western fold mountains of the Cederberg complex. However, several coastal areas also emerge as important centres. This is a consequence of the restriction of several species, such as *Cryptochloris wintoni, Cryptochloris zyli* and *Bathyergus janetta*, to small areas on the Namaqualand coastal plain. In view of the Red Data Book status of these species, future protection of this area is important. In addition, the forests of the south and east coast are also important as a result of the occurrence of restricted range species, such as the vulnerable giant golden mole *Chrysospalax trevelyani*.

Figure 3 Species richness of restricted range endemics in greater South Africa. The key indicates the potential number of restricted range endemics per QDS.

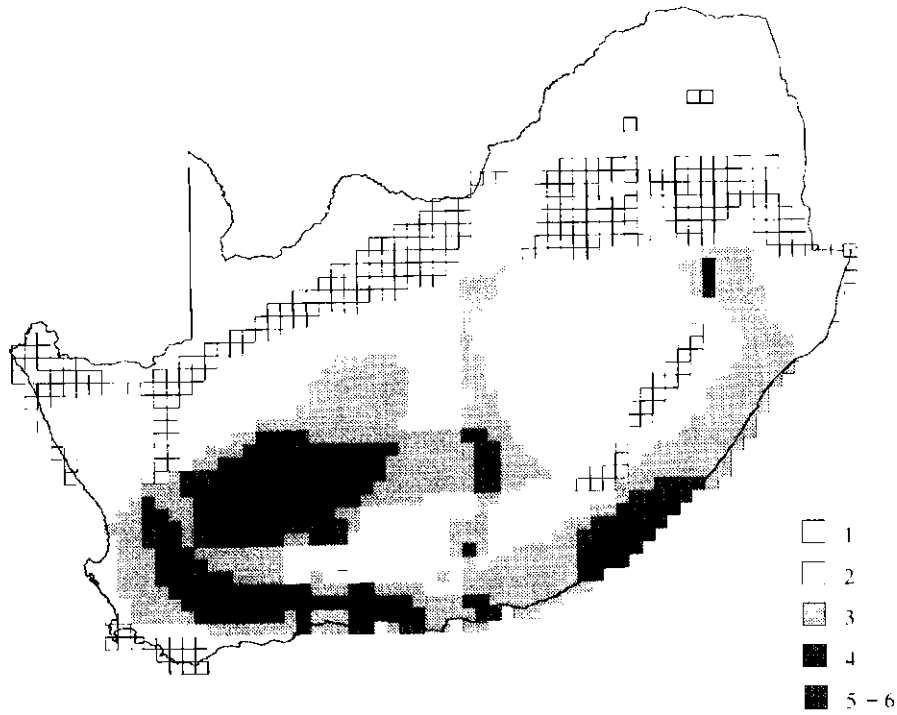

Figure 4 Map indicating regions of high species richness of South African endemic mammals which are listed in the Red Data Book. The key indicates the potential number of endemic mammal species in the Red Data Book per QDS.

Patterns of high species richness of Red Data Book endemic mammals

The area of highest Red Data Book species richness is the inland fold mountains of the Little Karoo (Figure 4), which are protected by protected areas such as Anysberg Nature Reserve. The central Nama-Karoo also emerges as an the important area in terms of Red Data Book richness. Indeed, the riverine rabbit, South Africa's only endangered endemic, is restricted to this biome, which is poorly protected in some areas. Other areas of high Red Data Book species richness include the forests of the Eastern Cape coast, and the coastal forests of the Knysna-Tsitsikamma region. The coastal forests of the Eastern Cape are not well protected, and experience considerable pressure from the large, local human population.

There is, however, reasonable protection of the coastal forests in the Knysna-Tsitsikamma region.

How well are the endemic mammals protected?

Of the 40 endemic mammals in South Africa, 20 are listed in the Red Data Book. They are predominantly small mammals (Table 1). Admittedly, the status of 14 small mammal species is listed as indeterminate as a result of a lack of knowledge of their conservation status. This indicates a pressing need for further research on small mammals.

The populations of the two large mammals which are listed in the Red Data Book, the Cape mountain zebra and the bontebok, have increased as a result of the establishment of protected areas specifically to protect them (Smithers 1986).

Comparison of the use of point and range map data

Patterns of endemic Insectivora species richness

Both point and range map data indicate that the coastal regions are most important for the endemic Insectivora (Figure 5). Moreover, the hotspots in the northern Transvaal and in the Knysna-Tsitsikamma forests are found in both data sets. In addition, the species overlap between the two data sets

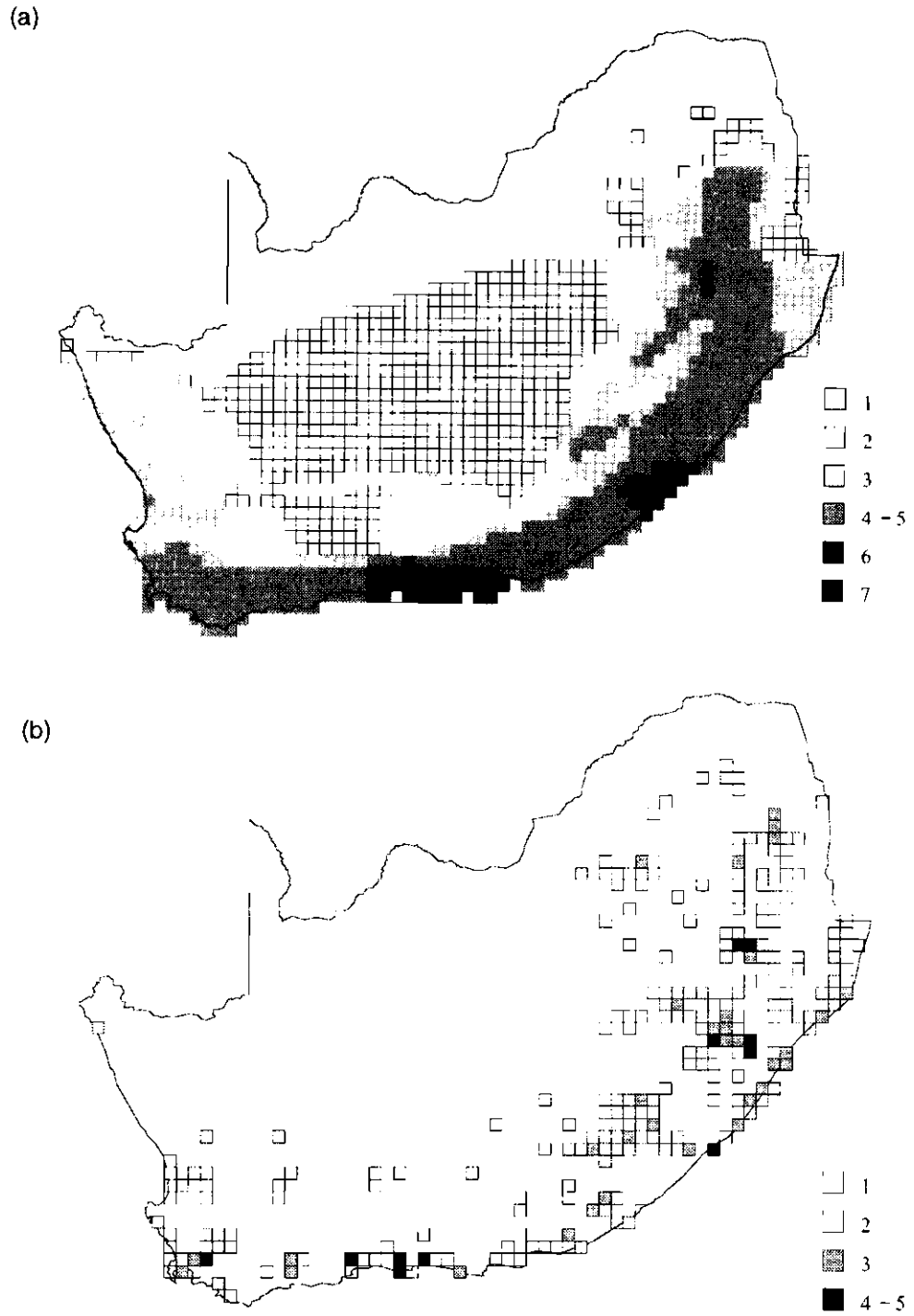

Figure 5 Comparison of patterns of South African endemic insectivore distributions, using (a) range and (b) point data. The keys indicate the potential number of endemic Insectivora species per QDS.

Table 1 Small mammals listed in the most recent Red Data Book on terrestrial mammals in South Africa. (Data from Smithers 1986)

RDB rating	Scientific name	Common name
Endangered	*Bunolagus monticularis*	Riverine rabbit
Vulnerable	*Chrysospalax villosus*	Rough-haired golden mole
	Chrysospalax trevelyani	Giant golden mole
	Mystromys albicaudatus	White-tailed mouse
Rare	*Graphiurus ocularis*	Spectacled dormouse
	Bathyergus janetta	Namaqua dune mole-rat

Table 2 Comparison of species lists in range map and point data analyses for two quarter degree squares

Range map	Point data
Tsitsikamma — QDS 3422AA	
Myosorex longicaudatus	*Myosorex longicaudatus*
Myosorex varius	*Myosorex varius*
Crocidura flavescens	*Crocidura flavescens*
Chlorotalpa duthieae	*Chlorotalpa duthieae*
Amblysomus iris	*Amblysomus corriae*
Amblysomus hottentotus	
Northern Transvaal — QDS 2730AC	
Myosorex longicaudatus	*Myosorex longicaudatus*
Myosorex varius	*Myosorex varius*
Crocidura flavescens	*Crocidura flavescens*
Chlorotalpa sclateri	*Chlorotalpa duthieae*
Amblysomus hottentotus	*Amblysomus septentrionalis*

is considerable (Table 2).

The range map data do, however, indicate an additional hotspot in the Eastern Cape Province. The actual number of species recorded in the range map analysis is higher and, as discussed earlier, should be regarded as the suite of species potentially found in each QDS. There is also an additional hotspot in the point data in Gauteng.

Centres of high species richness of Red Data Book endemic Insectivora

The same hotspot is seen in the analysis of the point data for Red Data Book endemic insectivores. The small hotspot in the Northern Transvaal, and a larger area in the Knysna-Tsitsikamma region, are also highlighted as important for Red Data Book Insectivora (Figure 6). Again, the actual numbers of species in the polygon analysis are higher and the Port St Johns region in the Eastern Cape Province emerges as an additional important area. Indeed, it is the highest scoring area when one considers the actual level of threat experienced by the species concerned.

Discussion

Southern Africa is a centre of endemism for arid-adapted species (Mackinnon & Mackinnon 1986). Moreover, within southern Africa, South Africa has by far the highest number of endemic mammals, probably as a result of its isolated position at the end of the continent, together with the complexity of its vegetation and topography. The extensive biogeographical zones in the north of the country such as the savannas, grasslands and Nama-Karoo extend beyond the country's borders into tropical Africa and, unlike the more isolated vegetation types in the south, do not contain many endemics (Crowe 1990).

Patterns of endemism and high restricted range richness

In view of its isolated position at the end of the continent, the winter-rainfall shrubland of the Western Cape Province might be predicted to be a centre of endemism. Indeed, the richness of the endemic flora of this region is renowned (Cowling, Gibbs Russel, Hoffman, & Hilton-Talyor 1989). The importance of the Western Cape Province for endemic mammals has been recognized in earlier studies (Bigalke 1972; Siegfried & Brown 1992). The present analysis reveals finer scale patterns than have previously been recorded, and indicates that the fold mountains of the Western Cape Province are centres of endemic mammal richness. Moreover, this is also the area of highest restricted range species richness.

High endemism in montane regions may be a widespread pattern, as mountains are by nature isolated, which facilitates speciation (Coe & Skinner 1993). The slopes of different aspect and altitude found in montane areas provide a wide variety of microhabitats, which may allow species at the extremes of their ranges to persist. Mountains may thus act as refugia which promote the protection of biodiversity under conditions of climatic change (Sprugel 1991).

Caution is, however, essential when interpreting the results of this analysis, as the level of resolution of the distribution maps from which the data were obtained is coarse. Thus, the concentration of endemics in the mountains may be partly a consequence of apparent overlap of ranges which are in reality allopatric. In such cases, mountains may function as a barrier to dispersal, and may be a region of high biological turnover rather than high species richness at any one location. Moreover, high turnover of species (beta diversity) is also a characteristic of transition zones between habitats. This phenomenon potentially contributes to the high endemic mammal richness in the Cederberg complex, which lies between Karoo and fynbos biomes. Caution should be employed when selecting areas of high species turnover for conservation as this may result in the preservation of marginal populations which exist in transitional habitat at the extremes of the species' environmental tolerance. The final decision of where to best conserve must therefore be based on assessment of viability of the populations on the ground rather than a species checklist (Gilpin 1987).

Protection of areas of high endemic mammal richness and high Red Data Book richness

The area of highest mammal endemism, the Cederberg (Figure 1), is protected by the Cederberg Wilderness Area. Indeed, the conservation status of many endemics is improved by their location in the mountain fynbos of the Western Cape Province, which contains numerous protected areas. Furthermore, many of the mountains also receive protection as catch-

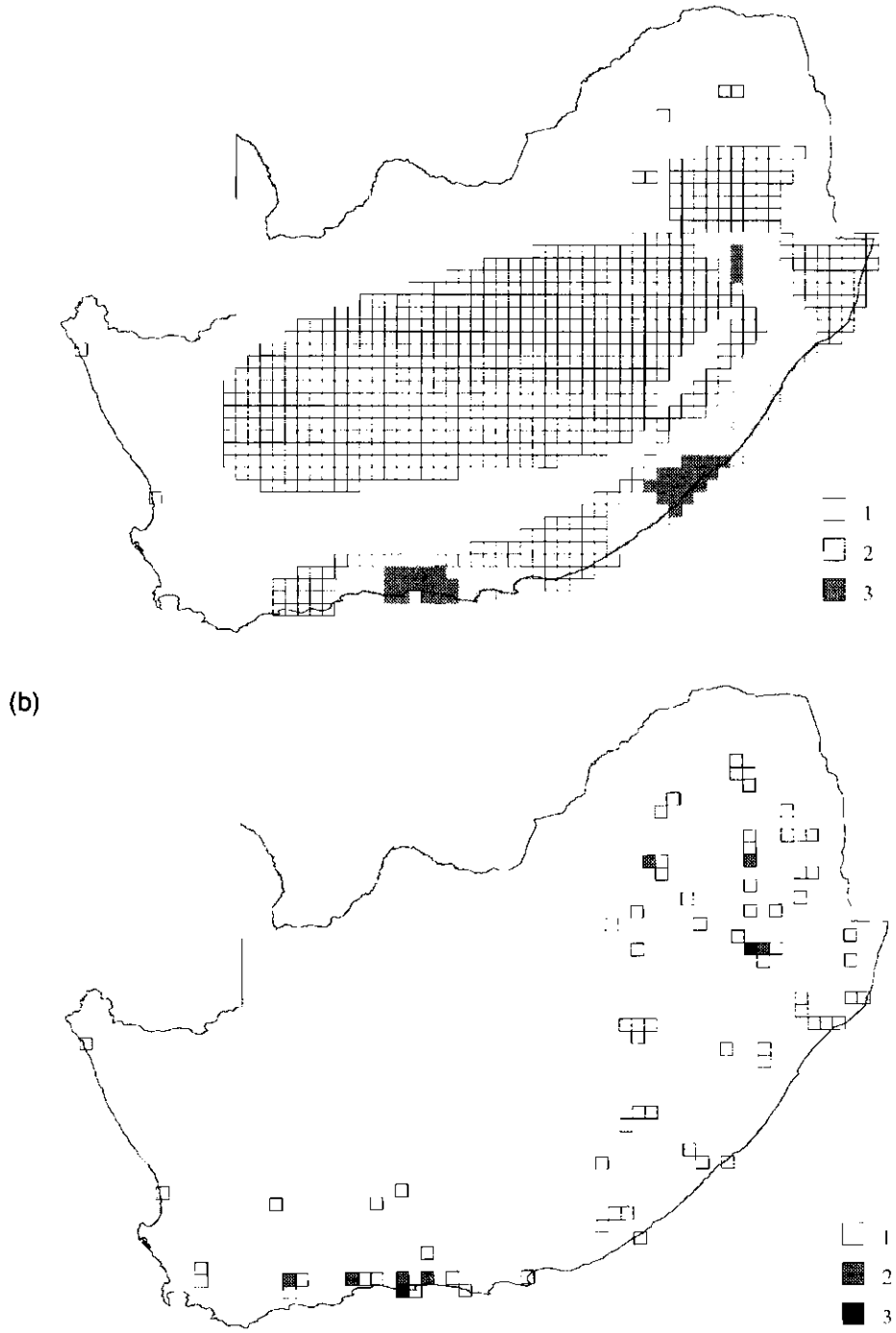

Figure 6 Comparison of patterns of South African endemic, Red Data Book listed insectivore distributions, using (a) range and (b) point data. The keys indicate the potential number of endemic, Red Data Book Insectivora species per QDS.

ment areas.

The two biomes which are inadequately protected are the Nama- and Succulent Karoo (Hilton-Talyor & Le Roux 1989). The threatened status of the endemic mammals restricted to these regions is of concern. Moreover, as both of these regions are arid zones, their fauna may become increasingly important with predicted global climatic changes (Stock 1992; van der Hammon 1992).

Two endemic and threatened mammals are restricted entirely to the Nama-Karoo: Grant's rock mouse, *Aethomys granti* (Indeterminate) and the riverine rabbit, *Bunolagus monticularis* (Endangered). The latter is not well protected and is threatened by veld degradation and agricultural development of the riverine fringes (Duthie, Skinner & Robinson 1989).

In addition, the three species restricted to the Succulent Karoo are also listed in the Red Data Book. They include the Namaqua dune mole rat, *Bathyergus janetta*, which is potentially threatened by strip mining in this region (Smithers 1986), and two other indeterminate species: *Cryptochloris wintoni* and *Cryptochloris zyli*, both of which are only known from single localities.

The area of high endemic mammal Red Data Book species richness in the broken terrain of the Little Karoo is protected by the existing protected area system; as are the Knysna-Tsitsikamma forests which also contain many endemic mammals

listed in the Red Data Book. However, the coastal forests in the Port St Johns region, which are particularly important for endemic, Red Data Book Insectivora (particularly golden moles) are currently under-protected.

Comparison of range and point analyses

The results of the analyses using range maps and point data are generally complementary, a finding that we expected since the range maps in Skinner & Smithers (1990) were plotted from point data associated with museum specimens. The range maps indicate broader scale patterns and suites of species which may potentially occur in a particular area. Whether or not the species concerned actually occur in a particular location can be confirmed with up-to-date point data. The region of high Red Data Book Insectivora richness in the Eastern Cape is not highlighted by the point data. While this may be an artefact of poor point data sampling, it may also be an error of commission. This illustrates the inadvisability of using range maps to infer the presence of species in an area on the basis of broad distribution patterns and superficial habitat tolerances, particularly if dealing with stenoecious species such as golden moles. Moreover, local extinction of some species may have occurred in response to widespread overgrazing and disturbance associated with over-population. Further field work in this area is therefore recommended.

The additional hotspot in Gauteng, which was evident from the point data, should also be investigated on the ground. This is likely to be a result of more intensive sampling by staff from the Transvaal Museum and universities in this region. The high human densities in this province may, however, have resulted in some local extinctions which would render old distributional records obsolete.

Conclusions

The importance of effective conservation of our endemic mammals is emphasized by the loss of two endemic species, the quagga (*Equus quagga*) and the blue antelope (*Hippotragus leucophaeus*) (Skinner & Smithers 1990). As the majority of our endemics are small mammals, it is this component of mammalian biodiversity that needs priority attention, especially in view of the threatened status of many species. The centre of endemism is in the fynbos, particularly in the western fold mountains which include several protected areas. This area together with the coastal plain also appears to be important for restricted range species. The inadequately protected Nama-Karoo is, however, of particular concern as it contains many Red Data Book species including our only endangered endemic, the riverine rabbit. In addition, range maps indicate that the inadequately protected coastal forests of the Eastern Cape are also important for threatened endemics, particularly the Insectivora.

The results of analyses using range maps and point data are generally complementary. Indeed, there are two advantages to analysing both data suites. First, by analysing point data, one can identify 'gaps' or areas that have not been adequately sampled before. Given the tremendous cost involved with large biological surveys, this ability to identify areas requiring priority attention is invaluable. Second, from range map data, one can identify suites of species that may potentially occur in inadequately sampled areas, and thus formulate hypotheses to be tested subsequently by ground-truthing expeditions. Such a dualistic approach is preferable to *ad hoc* surveying on an uncoordinated basis.

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Appendix 1 Species included in the analysis of the distribution of the endemic mammals of South Africa and their Red Data Book status

Species common name	Scientific name	Red Data Book status
Long-tailed forest shrew	*Myosorex longicaudatus*	indeterminate
Forest shrew	*Myosorex varius*	none
Least dwarf shrew	*Suncus infinitesimus*	indeterminate
Greater musk shrew	*Crocidura flavescens*	none
Giant golden mole	*Chrysospalax trevelyani*	vulnerable
Rough-haired golden mole	*Chrysospalax villosus*	vulnerable
De Winton's golden mole	*Cryptochloris wintoni*	indeterminate
Van Zyl's golden mole	*Cryptochloris zyli*	indeterminate
Cape golden mole	*Chrysochloris asiatica*	none
Duthie's golden mole	*Chlorotalpa duthieae*	indeterminate
Sclater's golden mole	*Chlorotalpa sclateri*	indeterminate
Gunning's golden mole	*Amblysomus gunningi*	indeterminate
Zulu golden mole	*Amblysomus iris*	indeterminate
Hottentot golden mole	*Amblysomus hottentotus*	none
Juliana's golden mole	*Amblysomus julianae*	indeterminate
Cape rock elephant-shrew	*Elephantulus edwardii*	none
Lesueur's hairy bat	*Myotis lesueuri*	indeterminate
Cape horseshoe bat	*Rhinolophus capensis*	none
Natal red rock rabbit	*Pronolagus crassicaudatus*	none
Riverine rabbit	*Bunolagus monticularis*	endangered
Cape dune mole-rat	*Bathyergus suillus*	none
Namaqua dune mole-rat	*Bathyergus janetta*	rare
Cape mole-rat	*Georychus capensis*	none
Spectacled dormouse	*Graphiurus ocularis*	rare
Brant's whistling rat	*Parotomys brantsii*	none
Laminate vlei rat	*Otomys laminatus*	none
Saunders' vlei rat	*Otomys karoensis**	none
Sloggett's vlei rat	*Otomys sloggetti*	none
Karoo bush rat	*Otomys unisulcatus*	none
Cape spiny mouse	*Acomys subspinosis*	none
Verraux's mouse	*Myomyscus verreauxii*	none
Gran"s rock mouse	*Aethomys granti*	indeterminate
Cape gerbil	*Tatera afra*	none
White-tailed mouse	*Mystromys albicaudatus*	vulnerable
Barbour's rock mouse	*Petromyscus barbouri*	none
Cape mountain zebra	*Equus zebra*	vulnerable
Black wildebeest	*Connochaetes gnou*	none
Blesbok/bontebok	*Damaliscus dorcas*	rare
Cape grysbok	*Raphicerus melanotis*	none
Grey rhebok	*Pelea capreolus*	none

(Taylor, Meester & Kearney 1993)