Towards conserving regional mammalian species diversity: a case study and data critique

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Species richness maps were derived for the Transvaal region from two different databases, namely a primary point database based on actual survey records and a generalized distribution map database. It is shown that sixteenth degree grid square (= QDS in Lombard 1995) species richness maps based on these two data sets for the region are highly disparate, which may be attributed to overestimation of species distributions by distribution maps and uneven sampling reflected in the primary point database. The limitations and problems associated with the two databases are discussed. Of the 10% most species-rich grid squares based on distribution maps and primary point data, 33,3% and 12% respectively are fully encompassed by existing conservation areas and are well represented in the sixteenth degree grid square networks selected by two iterative reserve selection algorithms.

Spesie-rykheidkaarte is vir die Transvaal-area gegenereer vanuit twee verskillende databasisse, naamlik primêre puntdata afkomstig van opnamerekords en algemene spesie-verspreidingskaarte. Daar word aangetoon dat sestiende graad ruitvierkante (= QDS in Lombard 1995) spesie-rykheidkaarte gebasseer op hierdie twee databasisse grootliks verskil. Dit kan toegeskryf word aan die neiging van verspreidingskaarte om spesieverspreidings te oorskat en die neiging van puntdata om die gevolge van oneweredige opnames te weerspieël. Die beperkings en probleme verbonde aan die twee databasisse word bespreek. Van die 10% mees spesieryke ruitvierkante vanuit die verspreidingskaarte en primêre puntdata word onderskeidelik 33,3% en 12% ingesluit in bestaande bewaringsareas, en word goed verteenwoordig in die sestiende graad ruitvierkante wat deur twee iterasie reservaat-seleksieprosedures aangewys word.

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Introduction

The term 'biodiversity' has become a buzzword in recent years and has increased awareness of the intrinsic value of the variability of living organisms. This debate emphasizes the importance of regional and national levels of action (Smith, Pressey & Smith 1994). Nevertheless, although conservation of biological diversity is internationally supported, there is no agreement on the most effective means of achieving long-term conservation goals. This is due, in part, to the various different definitions of biodiversity, and to our current limited capabilities of measuring its status and identifying trends. This process is hampered by the lack of quality regional and global data (Belbin 1993) and has highlighted the urgent need for inventory and monitoring programmes to map the world's biodiversity (Wilson 1985; Margules & Nicholls 1987; Margules & Stein 1989; ICBP 1992; Dickman, Pressey, Lim & Parnaby 1993; McNeely 1994) and make decisions on where or how it is to be permanently protected.

One measure of biodiversity is species richness (defined as number of species per unit area), an index that has been described as a 'simple but powerful' (Scott, Csuti, Jacobi & Estes 1987), 'convenient' (Usher 1986) and 'reasonable and knowable' (Erwin 1991) approach for setting conservation priorities. Species richness has been used as a base dataset for monitoring changes over time and in the identification of conservation priority areas (Kershaw, Williams & Mace 1994).

There are a number of steps involved in assigning conservation value and in prioritizing sites potentially targeted for conservation. First, conservation value must be defined; secondly, a decision must be made on what data should be used for assigning such a value. This may or may not be followed by a selection of manipulative procedures and models, and finally there is the actual selection procedure itself. The second aspect of the procedure, namely what data to use on a regional scale, is what we are primarily concerned with in this paper.

Although decisions need to be made with the very incomplete inventory of information available at present, care should be taken when evaluating the results of conservation assessments, and the inadequacies of the databases acknowledged. The reliability of the underlying database is often not described and has a vital bearing on the validity of the results of conservation evaluation and planning exercises. We thus examine and compare the implications of determining regional species richness using (i) published distribution maps to derive an 'estimated extent of occurrence' and (ii) primary point survey data to estimate 'area of occupancy'. We also examine the distribution of the existing protected areas in the Transvaal region in relation to species-rich areas.

Materials and Methods

This study is confined to the mammalian fauna of the former Transvaal Province of South Africa, which covers approximately 23% of South Africa. The former Transvaal Province now consists of the new Northern Province, Mpumalanga, Gauteng, and part of Northwest Province. This paper includes all native terrestrial mammals occurring in the Transvaal region; subspecies have been treated as separate taxa. Greater South Africa harbours some 243 species (Smithers 1986) representing approximately 6% of the world's total terrestrial mammalian fauna (Siegfried 1989), of which 201 species have been recorded within the Transvaal (194 in the primary point survey database and 189 based on distribution maps; Appendix 1).

The primary point database is based on compilations of all possible data sources for the area including museum collections, aerial censuses and simple species lists (for comprehensive source lists see Freitag, Nicholls & Van Jaarsveld in press), including those from the former Bophuthatswana Parks. This collation is an attempt to assess the current state of knowledge on the distribution of terrestrial mammals in the region and includes 34990 point records for 194 species. The dataset therefore represents confirmed presence records of species at different geographic sites only. The distribution map database represents the presence of 189 species in 474 sixteenth degree grid squares (15' × 15'; referred to as QDS by Lombard 1995) extracted from distribution maps published in Skinner & Smithers (1990).

Species richness was calculated by simply summing the number of species recorded as present in the 474 sixteenth degree grid squares for both datasets seperately. Resultant richness maps were then produced using the Geographic Information System REGIS™ (Automated Methods, Centurion, South Africa).

Distribution maps may be seen as delimiting the 'extent of occurrence' of a taxon. This may be defined as the smallest area containing all known, inferred or projected sites occupied by the taxon (excluding vagrancy) and does not take discontinuities or disjunctions in distribution into account (Mace & Stuart 1994). On the other hand, point data reflect the 'area of occupancy' within the estimated extent of occurrence. This area should preferably be measured as the number of occupied grid squares at an appropriate scale (Mace & Stuart 1994). Estimates of 'extent of occurrence' and 'area of occupancy' were thus calculated for the Transvaal as the number of sixteenth degree grid squares occupied by each species based on distribution maps and primary locality records respectively. While distribution maps tend to show historical ranges, the primary point data is far more recent, reflecting current occurrence. We therefore examined the age distribution of the records in the primary point database. In order to reduce the effects of the vast number of data records contributed by the 1985 Kruger National Park aerial census, multiple occurrences of the same species found in the same grid square by the same reference were removed and each such record only counted once.

The spatial distribution of protected areas, both public and private, in the Transvaal region was determined by estimating the percentage of each sixteenth degree grid square covered by conservation areas and mapped in REGIS™. The extent of reservation of the most species-rich grid squares was assessed, and the positions of these sites compared to those selected by the rarity-based iterative reserve selection algorithms (see Freitag *et al.*, in press) of Margules, Nicholls & Pressey (1988; unconstrained approach) and Nicholls & Margules (1993; adjacency constrained routine).

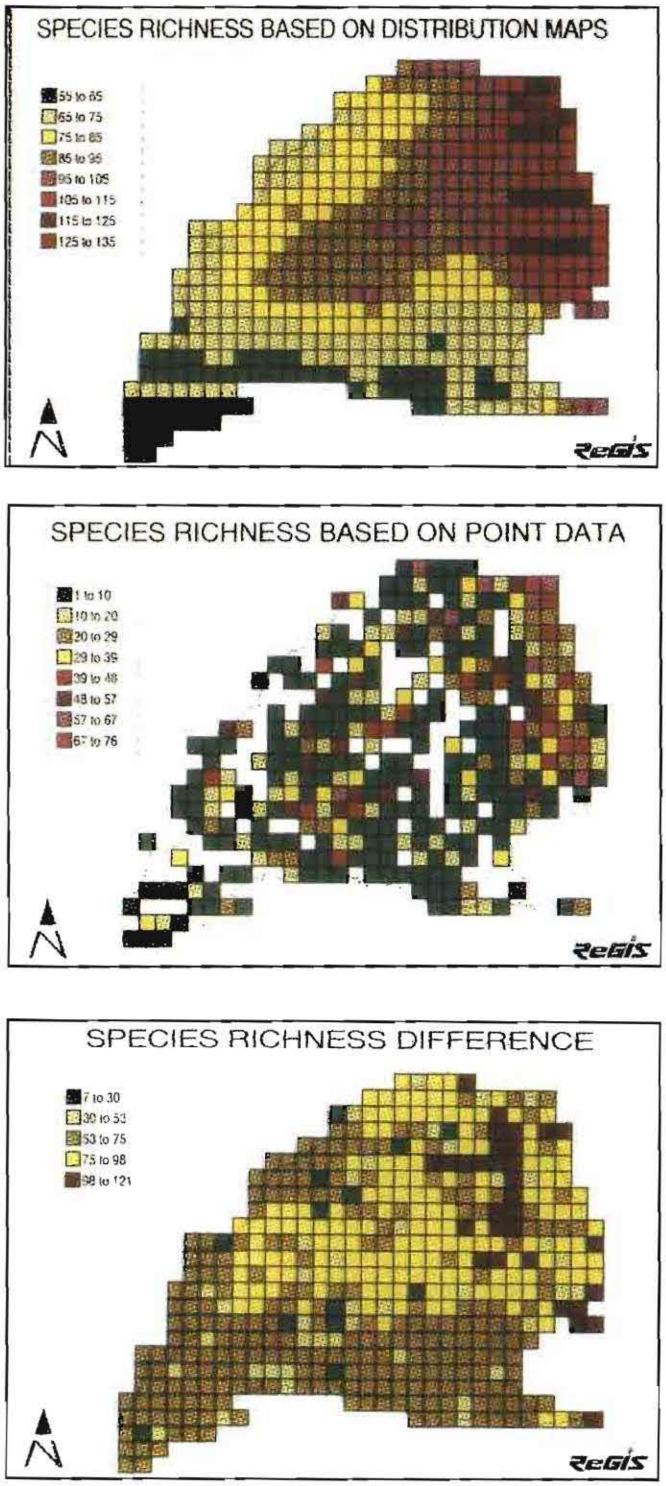

Figure 1 Simple sixteenth degree grid square mammal species richness for the Transvaal region. (Top) Species richness based on published distribution maps; (middle) species richness based on primary point data; (bottom) species richness difference (top–middle).

Results

Sixteenth degree grid square species richness based on distribution maps for the complete mammalian species complement in the Transvaal region reveals an increase in richness along a southwest–northeast gradient, with highest richness found in the northern Kruger National Park (Pafuri area; Figure 1a). In contrast, comparison of richness maps based on primary point data for the same grid squares do not show this strong southwest–northeast gradient, although there is also an area of high richness in the Pafuri region of the Kruger National Park (Figure 1b). This can be attributed in part to varying sampling effort, with some grid squares showing no, or only very limited mammal richness. It is evident that there are large discrepancies between species richness based on the two sources of data. These differences are highest in Mpumalanga (eastern Transvaal) to the west of the Kruger Park where the estimation of species richness by distribution maps is greater than that by primary point data by 98 to 121 species (Figure 1c).

Since these differences will also be influenced by the fact that distribution maps reflect historical ranges while primary point data reflect current distribution patterns, the histogram in Figure 2 shows the accumulation of primary point records in 10-year intervals from 1900 to 1995. This shows that the majority of survey data in the Transvaal region was collected in the 1980's, reflecting very recent distribution data.

Figure 3 depicts the differences in estimates of 'extent of occurrence' and 'area of occupancy' based on distribution maps and primary locality records respectively. The histogram clearly shows that a large proportion of Transvaal mammal species have relatively small 'areas of occupancy' (black shading; 0–80 grid squares), while there is a good spread of species having small to large 'extents of occurrence' (white shading).

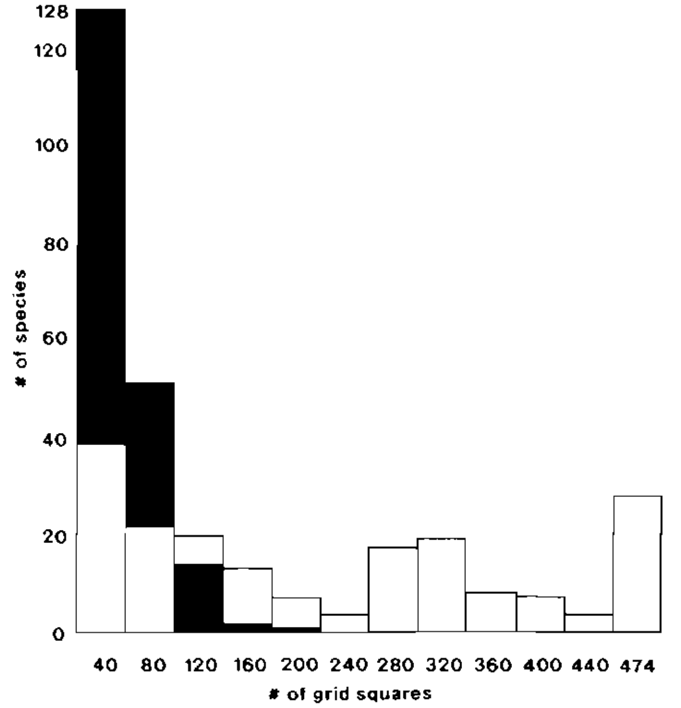

Figure 3 Bar graph illustrating the difference in 'area of occupancy' and 'extent of occurrence' for mammal species in the Transvaal region based on the number of grid squares occupied in the primary (black shading) and distribution map (white shading) databases respectively.

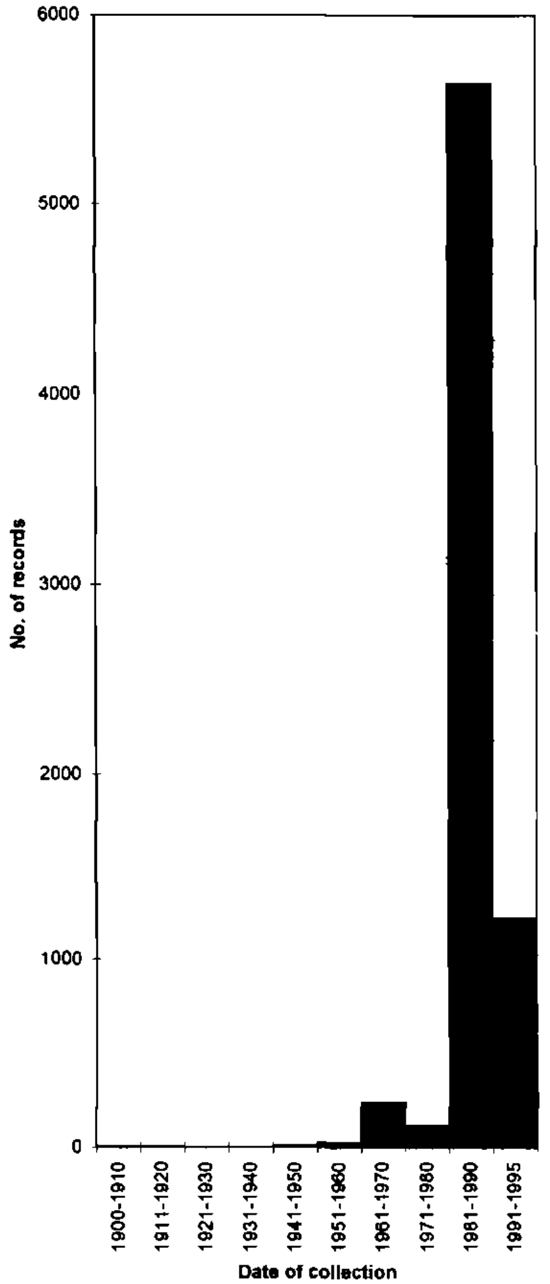

Figure 2 Histogram showing the temporal accumulation of primary point survey records in the database used in these analyses.

The percentage area per sixteenth degree grid square dedicated to conservation is graphically shown in Figure 4 where the good reserve coverage of the eastern Transvaal region (most grid squares have >26% of their areas dedicated to conservation) is primarily due to the extent of the Kruger National Park and surrounding private reserves. Table 1 shows the number of sixteenth degree grid squares in the study area falling into each of the six classes delimiting the percentage area under conservation, as well as the number and percentage areas of the most species-rich grid squares (top 10%) dedicated to conservation. Over 55% of grid squares in the Transvaal region are completely unprotected, although 18 and 12,5% of these belong to the richest sites based on primary point and distribution map data respectively. In contrast, only 4% of grid squares are completely dedicated to conservation. Twelve and 33,3% of these 19 completely protected grid squares are ranked among the richest sites based on point and map data respectively.

The amount of overlap between these grid squares with greatest species richness and the grid squares selected by the rarity-based reserve selection algorithms for the Transvaal region based on both data sets (Freitag *et al.* in press), is given in Table 2. Based on primary point data, over half of the grid squares selected by the algorithms belong to the richest sites, while grid squares selected from the distribution map dataset incorporate only 23% of the richest sites.

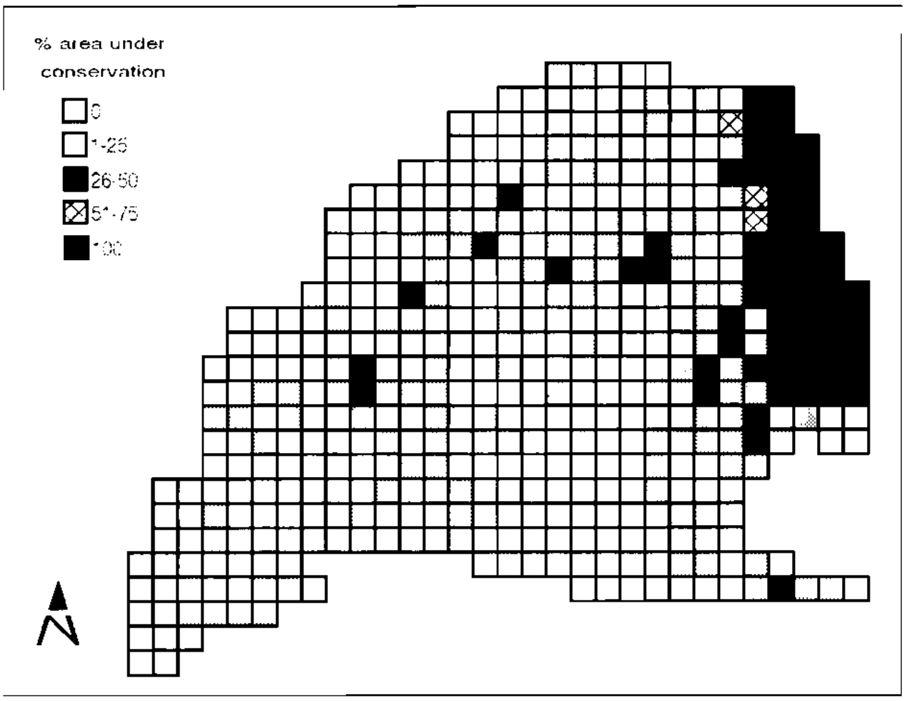

Figure 4 Map showing estimates of percentage area under conservation per sixteenth degree grid square in the Transvaal region.

Table 1 Number and percentage of sixteenth degree grid squares (GSs) with estimated percentage area under conservation, and number and percentage of the species richest grid squares (top 10%), based on distribution map and primary point data, falling within these classes

% of GS conserved	# of GSs	% of GSs	50 richest GSs Point data #	50 richest GSs Point data %	48 richest GSs Map data #	48 richest GSs Map data %
0	268	56,54	9	18	6	12,50
1–25	152	32,07	21	42	12	25,00
26–50	28	5,91	11	22	9	18,75
51–75	5	1,05	1	2	5	10,42
76–99	2	0,42	2	4	0	0
100	19	4,01	6	12	16	33,33

Table 2 Number and percentage (in parentheses) of the most species-rich sixteenth degree grid squares (GSs) selected by unconstrained (uncons) and adjacency constrained (constr) iterative reserve selection algorithms (see text)

Database	Algorithm	No. of GSs selected	Richest GSs Points	Richest GSs Maps
Points	uncons	24	14 (58,33)	
	constr	24	13 (54,17)	
Maps	uncons	13		3 (23,08)
	constr	13		3 (23,08)

Discussion

The southwest–northeast species richness gradient for mammals in the Transvaal region (Figures la and lb) is in accordance with previous findings for the Southern African subregion (vertebrates — Crowe 1990; mammals — Siegfried & Brown 1992; Rainbird 1993) and probably reflects the west-east increase in rainfall and the fact that the extreme northern Transvaal represents the southern distribution limit of species occuring more widely in Central and East Africa (Crowe 1990). Marked discrepancies in species richness based on distribution maps and primary point data, particularly in the eastern Transvaal (Figure lc), could be an artifact of uneven sampling effort. The difficulties associated with sampling the rugged escarpent terrain would lead to less intensive primary point data for this region. However, an additional possible explanation could be that this area, the mountainous Transvaal Drakensberg, represents a transition zone between the eastern Transvaal lowveld and the central Transvaal highveld (Figure 5). Distribution maps may therefore over-predict lowveld species distributions to the west while over-estimating the eastward distributions of highveld species. This is plausible since distribution maps tend to extend the range of the species relative to the point data as well as filling in the gaps between observed point locations (Mace & Stuart 1994). On the other hand, this region may be a real habitat ecotone which is utilized by species typical of both the eastern lowveld and western highveld habitats.

The majority of earlier studies have determined species richness in terms of species' range maps superimposed onto grid maps of varying sizes and thus estimating the numbers of species occuring in such quadrats (e.g. Crowe 1990; Siegfried & Brown 1992; Rainbird 1993; Turpie & Crowe 1994). Although the use of smaller quadrats may result in greater precision, this does not always provide greater accuracy as it is dependent on detailed knowledge of species distributions. Distribution maps depict broad ideal and highly generalized distributions of species, and although many species' ranges

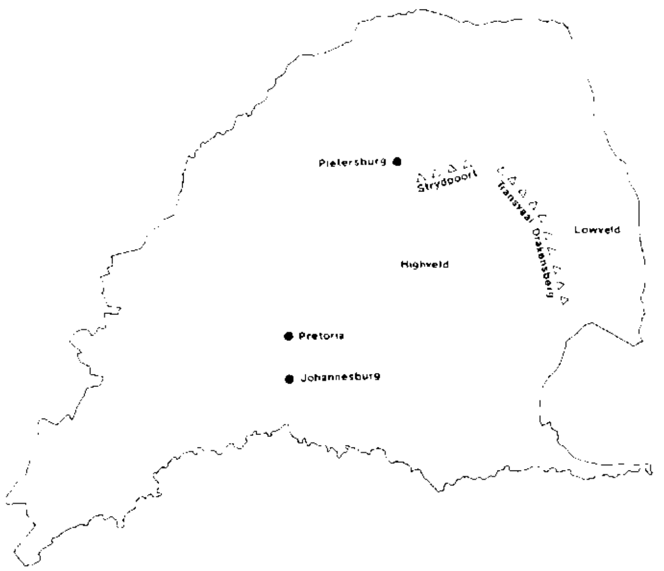

Figure 5 Map of the Transvaal region showing approximate positions of the highveld, lowveld and Transvaal Drakensberg escarpment.

have undoubtedly contracted owing to human influence, these are not taken into account in the majority of published maps. Such distribution maps, therefore, represent historic species' distributions, a factor that must be kept in mind even when making broad-scale regional recommendations, since it is the primary objective of conservation to conserve species where they occur on the ground at present. In contrast, primary survey data used in the present study is very current, having mainly been collected between 1980 and 1995 (Figure 2). This will result in greater certainty for on-the-ground conservation proposals.

Conservation evaluation is scale dependent (Kershaw *et al.* 1994), depends on the aims of the protected area network and should preferably include up-to-date information on the distributions of all species. The commonly used criterion for determining the effectiveness of a protected area network is that the most favourable one includes the maximum number of taxa in the smallest number of sites, or alternatively in the smallest area. The quality of the outputs produced by conservation planners is thus affected by the accuracy of the species' distribution maps. These in turn are further influenced by the resolution of the base data, the level of map generalization and size of the mapping unit (Stoms, Davis & Cogan 1992). Limited basic knowledge of species distribution patterns becomes particularly limiting and prejudicial (Whitehead, Bowman & Tideman 1992) when determining conservation priorities and selecting regional or national representative protected area networks. The use of distribution maps in the assigning of regional conservation priorities may boast spurious precision and carry greater authority than it should, owing to inherent inaccuracies and generalizations. While these maps may be useful for the identification of large scale global trends and priority zones (ICBP 1992), or in instances where no other data is available, great caution should be exercised when putting these ideals into practice.

Nevertheless, primary survey data is not without its limitations and potential sources of uncertainty in the point data must be noted: (i) sampling effort in the region has been uneven, resulting in underestimation of some species' distributions, particularly those that are small and inconspicuous. The effects of varying survey effort are clearly visible in the richness map produced from primary point data (Figure 1b). An example is that of the Rodentia, where greatest species diversity, based on survey data, is found in a group of four grid squares in the western Transvaal region (not shown). These grid squares in fact contain the Pilanesberg National Park which has recently been extensively surveyed for small mammals (M. Haupt, pers comm 1994). Similarly, the high species richness in the Pafuri region may be the result of extensive surveys in this region by the Transvaal Museum. Thus, centres of extreme richness may be an artifact of mere collection intensity or effort (Gentry 1992), and 'the implication of biased sampling is that it may say more about the preferences of the observers than of the wildlife' (Stoms *et al.* 1992). (ii) Some of the primary point species distribution data is dated, and as such species may no longer be present in those areas, or display large temporal variations in distribution (Pressey, Cohn & Porter 1990). (iii) Rare species distributions are often limited to areas where they are expected (Snyder & Johnson 1985) and they may not be as restricted as first thought. This may also have a bearing on the determination of centres of endemism, which could reflect intensely surveyed areas (Nelson, Ferreira, Da Silva & Kawasaki 1990). A further effect on species richness patterns has been the widespread translocation and reintroduction practices in the region. This has been predominantly aimed at the large charismatic mammals, namely the carnivores and mega-herbivores.

The status of many mammal species, particularly small mammals, varies from occurring at low densities to having restricted geographic distributions. This is reflected in the fact that 128 species (65,3%) recorded in primary surveys in the Transvaal region have been found in less than 8,4% of the entire area (Figure 3). This may in fact be an artifact of limited sampling and survey bias, and they may be commoner and more widespread than thought at present. Large areas of this region are still unsurveyed and require basic surveys (Figure 1b). To obtain reliable data on the highly mobile and ephemeral species, intense sampling is needed (McKenzie, Belbin, Margules & Keighery 1989). An important consideration is that estimates of species richness cannot be seen to be static or absolute (Williams & Gaston 1994) and ideally sampling effort should be adjusted for. However, this is not always possible, particularly in cases such as this where data is extracted from a wide variety of museum and other records. The problems of temporal and spatial variations in the natural distributions of species have not been taken into account and therefore no estimates of source and sink areas may be made (Launer & Murphy 1994). This may have far greater effects on the conservation of small terrestrial mammalian species such as rodents which often show microhabitat specificity. This real problem of limited survey data has been acknowledged by the IUCN in drawing up the new IUCN Red Data book categories (version 2.2; Mace & Stuart 1994) which has introduced the 'Data Deficient' category, in which species are to be afforded the same degree of protection as threatened taxa until their status is better evaluated.

The peak in mammalian species richness occurs in the arid savanna biome of the north-eastern Transvaal, which according to Rainbird (1993) contains 17,6% of the total number of publically protected areas in South Africa and represents 48,7% of protected land. These figures are mainly due to the contribution of the Kruger National Park which, together with the large number of private conservation areas in the eastern Transvaal lowveld, has resulted in this area being almost completely dedicated to conservation (Figure 4). This area has also been implicated by rarity-based iterative reserve selection algorithms (Freitag *et al.* in press) as being of high conservation value for a regional reserve network, and as a high priority site for the protection of 66 large mammal species in greater South Africa (Rainbird 1993) and for the South African snake fauna (Lombard, Nicholls & August, in press). In the remainder of the Transvaal, however, 94,52% of grid squares have less than 51% of their areas under conservation, (although approximately 25% of these have between 10 and 50% of their areas protected), while 56,54% of grid squares are completely unprotected (Table 1; Figure 4). Interestingly, 33,33% of the 48 richest sites based on distribution maps coincide with grid squares which are completely dedicated to conservation efforts, however only 12% of the richest point data grid squares are completely conserved (Table 1). Unfortunately though, 60% and 37,5% (based on primary and distribution map data respectively) of these grid squares have less than a quarter of their area protected. The total protection of all these sites is obviously impossible and stresses the need for a representative network. Failure to achieve this may require the design of a conservation strategy for non-protected areas.

Nature reserve selection based solely on numbers of species occuring at different sites is obviously not optimal (as this leads to unneccessary duplication of widespread common species before all rare species have been represented), and iterative selection routines combined with some form of species weighting technique is far more efficient (Kershaw *et al.* 1994). It has been suggested that the use of unweighted species richness values in comparing different sites is limited (Margules, Higgs & Rafe 1982) or is valid only when using iterative selection algorithms (Rebelo & Siegfried 1992). This may be so, but the basis of many conservation evaluation procedures and inventory efforts consists of, or is based on, species lists. The challenge facing us is the development of methods in which these species lists can be used in imaginative ways in order to ensure that sensible weightings are given to species. Nevertheless, the question arises whether species-rich areas may be completely excluded from 'optimal' reserve networks selected by iterative reserve selection algorithms. We thus compared the sixteenth degree grid square networks selected by two rarity-based algorithms (Margules *et al.* 1988; Nicholls & Margules 1993) for the Transvaal region based on both data sets (Freitag *et al.* in press) with the most species-rich grid squares for the same region. Table 2 shows that over half (58,33% and 54,17%) of the sites selected from the point database, using the unconstrained and adjacency constrained algorithms respectively for only single representations of all species, do fall within the top 50 richest sites which make up 10,55% of all sites. Although this figure is lower for selections based on the distribution map database (23,08%; Table 2), the most species-rich grid square, containing 129 species, was selected in second or third place by the unconstrained and adjacency constrained algorithms respectively. Kershaw *et al.* (1994) found that unweighted species richness offered the best option for representing maximum antelope species in minimal area when there are only a limited number of sites which may be chosen for reservation and noted that unweighted species richness coincidentally also represented a significant amount of antelope taxonomic diversity. Although it is encouraging to find such a high level of overlap between these different approaches, many rare species may be missed if using only the most species-rich sites for assigning conservation value. We agree that species richness alone is not efficient and that, ideally, estimates of species richness should be coupled to some form of rarity and/or endemicity weighting before being incorporated into conservation priority assessments and reserve selection algorithms.

The results presented here summarize patterns of species richness and distribution of a complete regional terrestrial mammalian fauna. Although there are inadequacies in the databases employed, no other comprehensive datasets exist for mammals of the region. Assessment of conservation value and prioritization of areas of particular value to the protected area network will benefit greatly from increased surveys and knowledge of the distributions of species both within and outside the borders of formal conservation areas (Dickman *et al.* 1993). Importantly these surveys should be stratified across environmental and ecological gradients, be carried out regularly to detect seasonal and long-term trends, and be able to detect the variety of species present (Dickman *et al.* 1993).

Where to from here?

Efforts to protect total overall regional biodiversity may not be entirely feasible, and many remaining pristine undisturbed habitat islands are likely to be lost. Reservation of such patches will be extremely difficult to defend in the face of the current socio-economic and political climate in South Africa. It is under these conditions that effective conservation planning must be implemented to maximize the effectiveness and usefulness of protected area networks in encompassing regional biodiversity. A prerequisite is to obtain data at a consistent level of resolution (McKenzie *et al.* 1989), and to identify and target gaps for conservation actions (Margules & Stein 1989). Importantly, biodiversity conservation does not stop at the establishment of a representative reserve network, but is dependent on management of protected areas and the surrounding lands, as well as continued monitoring (Lomolino 1994).

Increasing pressures on the maintenance of biodiversity (limited land area, competition from competing land uses, cost and time constraints) require quick decisions and are increasingly reliant on more and more detailed information which often does not yet exist, or must be compiled from scattered sources. Seemingly simple collation of such data from primary and secondary sources is not an easy task, and requires inter-institutional arrangements and agreements and good systems design for data storage and retrieval. Issues such as standardization of collection and storage mechanisms, estimates of data accuracy and age, data-sharing guidelines and the possible establishment of central databases or networks should be addressed. The possibility of identifying and using indicator taxa to reflect the general richness patterns across taxonomic groups should not be ruled out. In the face of incomplete inventory data, which may never be complete, this may represent a realistic approach towards identifying species-rich priority sites.

Although we emphasize the need to collect more detailed data relating to species distributions, this does not condemn past attempts at identifying priority conservation areas. However, we wish to highlight the basic flaws in existing available datasets, both primary survey data and particularly data using distribution maps in regional reserve selection methods.

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Appendix 1 List of mammal species occurring within the Transvaal region

Species No.	Species name	Point db	Map db
002	*Myosorex cafer*	x	x
003	*Myosorex varius*	x	x
004	*Suncus lixus*	x	x
005	*Suncus varilla*	x	x
006	*Suncus infinitesimus*	x	x
007	*Crocidura mariquensis*	x	x
008	*Crocidura fuscomurina*	x	x
009	*Crocidura maquassiensis*	x	x
010	*Crocidura cyanea*	x	x
011	*Crocidura silacea*	x	x
012	*Crocidura flavescens*	x	x
014	*Crocidura hirta*	x	x
016	*Atelerix frontalis*	x	x
018	*Chrysospalax villosus*	x	x
026	*Chlorotalpa sclateri*		x
027	*Calcochloris obtusirostris*	x	x
028	*Amblysomus gunningi*	x	x
029	*Amblysomus iris*		x
030	*Amblysomus hottentotus*	x	x
031	*Amblysomus julianae*	x	x
032	*Petrodromus tetradactylus*	x	x
035	*Elephantulus brachyrhynchus*	x	x
036	*Elephantulus rupestris*	x	
037	*Elephantulus intufi*	x	x
038	*Elephantulus myurus*	x	x
040	*Epomophorus wahlbergi*	x	x
043	*Epomophorus crypturus*	x	x
045	*Eidolon helvum*	x	x
046	*Rousettus aegyptiacus*	x	x
049	*Taphozous mauritianus*	x	x
050	*Taphozous perforatus*	x	x
052	*Sauromys petrophilus*	x	x
054	*Tadarida (Mops) midas*	x	x
055	*Tadarida (Mops) condylura*	x	x
059	*Tadarida (Chaerephon) pumila*	x	x
061	*Tadarida (Tadarida) ventralis*		x
062	*Tadarida (Tadarida) fulminans*	x	x
063	*Tadarida (Tadarida) aegyptiaca*	x	x
064	*Tadarida (Chaerephon) ansorgei*	x	x
066	*Miniopterus fraterculus*	x	x
067	*Miniopterus schreibersii*	x	x
068	*Myotis welwitschii*	x	x

Appendix 1 List of mammal species occurring within the Transvaal region (Continued)

071	*Myotis tricolor*	x	x
072	*Myotis bocagei*	x	x
073	*Pipistrellus kuhlii*	x	x
340	*Pipistrellus anchietai*	x	x
074	*Pipistrellus rusticus*	x	x
075	*Pipistrellus nanus*	x	x
076	*Pipistrellus rueppellii*	x	x
077	*Chalinolobis variegatus*	x	x
079	*Laephotis botswanae*	x	
082	*Eptesicus hottentotus*	x	x
083	*Eptesicus melckorum*	x	
085	*Eptesicus somalicus*	x	x
086	*Eptesicus capensis*	x	x
087	*Scotophilus nigrita*	x	
088	*Scotophilus dinganii*	x	x
089	*Scotophilus borbonicus*	x	x
090	*Nycticeius schlieffenii*	x	x
092	*Kerivoula argentata*	x	x
093	*Kerivoula lanosa*	x	x
096	*Nycteris woodi*	x	x
098	*Nycteris thebaica*	x	x
100	*Rhinolophus hildebrandtii*	x	x
101	*Rhinolophus fumigatus*	x	x
102	*Rhinolophus clivosus*	x	x
103	*Rhinolophus darlingi*	x	x
104	*Rhinolophus landeri*	x	x
105	*Rhinolophus blasii*	x	x
107	*Rhinolophus simulator*	x	x
109	*Rhinolophus swinnyi*	x	
110	*Hipposideros commersoni*		x
111	*Hipposideros caffer*	x	x
112	*Cloeotis percivali*	x	x
114	*Otolemur crassicaudatus*	x	x
115	*Galago moholi*	x	x
117	*Papio ursinus*	x	x
119	*Cercopithecus aethiops*	x	x
120	*Cercopithecus mitis*	x	x
121	*Manis temminckii*	x	x
122	*Lepus capensis*	x	x
123	*Lepus saxatilis*	x	x
124	*Pronolagus rupestris*	x	x
125	*Pronolagus crassicaudatus*	x	x
126	*Pronolagus randensis*	x	x
132	*Cryptomys hottentotus*	x	x
133	*Georychus capensis*	x	x
134	*Hystrix africaeaustralis*	x	x
135	*Pedetes capensis*	x	x
136	*Graphiurus (Graphiurus) ocularis*	x	x
137	*Graphiurus (Claviglis) platyops*	x	x
138	*Graphiurus (Claviglis) murinus*	x	x
140	*Xerus inauris*	x	x
145	*Paraxerus cepapi*	x	x
147	*Thryonomys swinderianus*	x	x

Appendix 1 List of mammal species occurring within the Transvaal region (Continued)

152	*Otomys laminatus*	x	x
153	*Otomys angoniensis*	x	x
156	*Otomys irroratus*	x	x
157	*Otomys sloggetti*	x	
160	*Acomys spinosissimus*	x	x
161	*Acomys subspinosus*	x	
162	*Lemniscomys rosalia*	x	x
163	*Rhabdomys pumilio*	x	x
165	*Dasymys incomtus*	x	x
166	*Grammomys cometes*	x	x
167	*Grammomys dolichuris*	x	x
171	*Mus indutus*		x
172	*Mus minutoides*	x	x
174	*Mastomys natalensis*	x	x
343	*Mastomys coucha*		x
177	*Thallomys paedulcus*	x	x
344	*Thallomys nigricauda*		x
179	*Aethomys namaquensis*	x	x
181	*Aethomys chrysophilus*	x	x
185	*Desmodillus auricularis*	x	x
186	*Desmodillus paeba*	x	x
190	*Tatera leucogaster*	x	x
192	*Tatera brantsii*	x	x
194	*Mystromys albicaudatus*	x	x
195	*Cricetomys gambianus*	x	x
196	*Saccostomus campestris*	x	x
197	*Malacothrix typica*	x	x
198	*Dendromus nyikae*	x	x
199	*Dendromus melanotis*	x	x
200	*Dendromus mesomelas*	x	x
201	*Dendromus mystacalis*	x	x
202	*Steatomys pratensis*	x	x
204	*Steatomys krebsii*	x	x
206	*Petromyscus collinus*	x	x
244	*Proteles cristatus*	x	x
245	*Hyaena brunnea*	x	x
246	*Crocuta crocuta*	x	x
247	*Acinonyx jubatus*	x	x
248	*Panthera pardus*	x	x
249	*Panthera leo*	x	x
250	*Felis caracal*	x	x
251	*Felis lybica*	x	x
252	*Felis nigripes*	x	x
253	*Felis serval*	x	x
255	*Otocyon megalotis*	x	x
256	*Lycaon pictus*	x	x
257	*Vulpes chama*	x	x
258	*Canis adustus*	x	x
259	*Canis mesomelas*	x	x
260	*Aonyx capensis*	x	x
261	*Lutra maculicollis*	x	x
262	*Mellivora capensis*	x	x
263	*Poecilogale albinucha*	x	x

Appendix 1 List of mammal species occurring within the Transvaal region (Continued)

264	*Ictonyx striatus*	x	x
266	*Civettictis civetta*	x	x
267	*Genetta genetta*	x	x
268	*Genetta tigrina*	x	x
269	*Suricata suricatta*	x	x
270	*Paracynictis selousi*	x	x
272	*Cynictis penicillata*	x	x
273	*Herpestes ichneumon*	x	x
274	*Galerella sanguinea*	x	x
275	*Galerella pulverulenta*	x	
276	*Rhynchogale melleri*	x	x
277	*Ichneumia albicauda*	x	x
278	*Atilax paludinosus*	x	x
279	*Mungos mungo*	x	x
280	*Helogale parvula*	x	x
288	*Orycteropus afer*	x	x
289	*Loxodonta africana*	x	x
290	*Procavia capensis*	x	x
292	*Heterohyrax brucei*	x	x
295	*Ceratotherium simum*	x	x
296	*Diceros bicornis*	x	x
298	*Equus burchelli*	x	x
299	*Potamochoerus porcus*	x	x
300	*Phacochoerus aethiopicus*	x	x
302	*Hippopotamus amphibius*	x	x
303	*Giraffa camelopardalis*	x	x
305	*Connochaetes gnou*	x	x
306	*Connochaetes taurinus*	x	x
308	*Alcelaphus buselaphus*	x	
309	*Damaliscus dorcas dorcas*	x	
341	*Damaliscus dorcas phillipsi*	x	x
310	*Damaliscus lunatus*	x	x
312	*Cephalophus natalensis*	x	x
313	*Sylvicapra grimmia*	x	x
314	*Antidorcas marsupialis*	x	
315	*Oreotragus oreotragus*	x	x
317	*Ourebia ourebi*	x	x
318	*Raphicerus campestris*	x	x
320	*Raphicerus sharpei*	x	x
321	*Neotragus moschatus*	x	x
322	*Aepyceros melampus*	x	x
324	*Pelea capreolus*	x	x
325	*Hippotragus equinus*	x	x
326	*Hippotragus niger*	x	x
327	*Oryx gazella*	x	
328	*Syncerus caffer*	x	x
329	*Tragelaphus strepsiceros*	x	x
331	*Tragelaphus angasii*	x	x
332	*Tragelaphus scriptus*	x	x
333	*Taurotragus oryx*	x	x
334	*Redunca arundinum*	x	x
335	*Redunca fulvorufula*	x	x
336	*Kobus ellipsiprymnus*	x	x