Anuran distribution, diversity and conservation in South Africa, Lesotho and Swaziland

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The distributions of 96 anuran species in South Africa were mapped using published locality records, and the collections of the South African and Port Elizabeth museums. Centres of richness, endemism and Red Data Book (RDB) richness were identified, and compared with currently protected areas, using a geographical information system (GIS). Maputaland and the Kwazulu/Natal coast were identified as centres of species richness. Endemic 'hotspots' occur in the vicinity of Pietermaritzburg, Durban and the fynbos region of the Western Cape. The Western Cape was also identified as a centre of RDB species richness. A large portion (95,8%) of South African anuran species are found in protected areas. The effective long-term viability of populations of many of these species within these areas, must be assessed. Currently four South African frog species are not found within protected areas. The Karoo biomes were identified as being under-represented, both in the species database and in the proportion of conserved areas. While a large proportion of the fynbos biome is contained in reserve areas, the low-lying fynbos habitats have almost disappeared as a result of urbanization and agriculture. Remnants of the sandy coastal fynbos and renosterveld veld types require urgent conservation. Several areas in the Western and Eastern Cape were identified as requiring additional research and conservation measures. A GIS proves a useful tool in the analysis of species distributions and the prioritization of areas and species for conservation. The importance of accurate collection data, for incorporation into species databases, and the regular publication of reserve species lists is emphasized.

Die verspreidings van 96 Anura-soorte in Suid-Afrika is gekarteer met behulp van gepubliseerde verspreidingsrekords en die versamelings van die Suid-Afrikaanse en die Port Elizabeth-Museums. Kerngbiede van spesierykheid, endemisme en Rooi Databoek- (RDB) rykheid is geïdentifiseer en met behulp van 'n geografiese inligtingstelsel (GIS) vergelyk met huidige bewaarde gebiede. Maputaland en die Kwazulu/Natal-kus is geïdentifiseer as gebiede met 'n besondere rykheid aan spesies. Endemiese kerngebiede kom voor in die omgewing van Pietermaritzburg, Durban en in die fynbosgebied van die Wes-Kaap. Die Wes-Kaap is ook aangewys as ryk aan RDB-spesies. 'n Groot gedeelte (95,8%) van Suid-Afrikaanse Anura-soorte kom voor in bewaarde gebiede. Dit is nodig dat die langtermyn-lewensvatbaarheid van baie van die soorte in hierdie gebiede bepaal word. Tans word vier Suid-Afrikaanse paddasoorte nie in bewaringsgebiede aangetref nie. Die Karoo-bioom is onder-verteenwoordig in terme van die spesie-databasis en bewaringsgebiede. Hoewel 'n groot deel van die fynbosbioom binne reservate gelee is, het laagliggende fynboshabitats feitlik verdwyn as gevolg van verstedeliking en landbou. Oorblyfsels van die sanderige kusfynbos en renosterveld verg dringende bewaring. Daar is verskeie gebiede in die Wes- en Oos-Kaap waar verdere navorsing en bewaring nodig is. 'n GIS is baie geskik vir die ontleding van spesie-verspreidingspatrone en die uitwys van gebiede en spesies vir bewaring. Die belangrikheid van akkurate ingesamelde data vir toevoeging tot spesie-databasisse en die gereelde publikasie van reservaatoorsiglyste word beklemtoon.

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Introduction

The biodiversity crisis has rapidly attained priority status within the global environmental community, focusing attention on the urgent need to inventory all living species and assess their conservation status. An associated requirement is an investigation of the efficiency of currently protected areas in ensuring the long-term preservation of biological diversity. South Africa contains six major terrestrial biomes: fynbos, forest, Nama-Karoo, Succulent Karoo, grassland and savanna (Rutherford & Westfall 1986). Collectively these contain a rich and diverse flora and fauna, a large portion of which is endangered or threatened. Southern African amphibian species constitute approximately 2% of the world's total for this group (Siegfried 1989). The relative richness and high level of endemism (44%) is indicated by the fact that southern Africa has 0,07 amphibian species/100 km^2 compared to the global average of 0,03 amphibian species/100 km^2 and an African average of 0,02 amphibian species/100 km^2 (Siegfried 1989). The origin and proliferation of so many amphibian genera within South Africa indicate a high level of evolutionary activity (Poynton 1989). The precise number of amphibian species in South Africa is unknown, with taxonomic disputes leading to different national totals of described species. In addition, there are species that have yet to be collected and described. Over 12 new amphibians have been described since 1975 and at least five others are currently being named (Branch 1994).

Historically, the South African system of protected areas was developed with a pronounced bias towards areas with either large mammal faunas or mountain catchments, or, to a lesser degree, forest resources (Rebelo 1994; Siegfried 1989). There was no national conservation strategy maximizing the preservation of overall biological diversity. The taxonomic and geographic databases for all South African vertebrate groups (except for fish) are poorly or inadequately developed

(Drinkrow, Cherry & Siegfried 1994), and more than half of the protected areas lack accurate or complete species lists for these groups (Siegfried 1989). Less than 40% of the amphibian holdings of South African natural history museums are included in accessible computerized databases (Drinkrow *et al.* 1994).

Lombard, August and Siegfried (1992) have stressed the need for a national plan to maximize the preservation of South Africa's biodiversity in protected areas. Biodiversity is not uniformly distributed over South Africa and some areas are definitely more species-rich than others. These 'hotspots' consist of different environments and vegetation types. Fundamental to the formulation of a conservation programme is the consideration of all elements interacting in the environment. This requires up-to-date taxonomies and accurate species distribution maps (historical and modern) for as many groups as possible. In a preliminary attempt to assess the overall conservation status of South African anurans, this paper aims (i) to identify centres of amphibian species richness, endemism and Red Data Book (RDB) richness in South Africa; (ii) to compare the locality of identified 'hot-spots' within South African biomes and protected areas; (iii) to assess the conservation status of South African anurans; and (iv) to consider the major threats to the preservation of the South African amphibian fauna, particularly within 'hotspots', and to make recommendations for its effective conservation.

Methods

The philosophy and methodology used in this analysis is discussed by Lombard (1995). Methods specific to the anuran analysis are described in the section below. The analysis was conducted at the species level and all South African species listed in the most recent South African amphibian checklist (Branch, Baard, Haacke, Jacobsen, Poynton & Broadley 1988) were recognized. Species described subsequently have been deliberately excluded from this analysis, as sufficient time has not yet elapsed for judgement to have been passed on their validity. The South African, Lesotho and Swaziland distributions of 96 anuran species (Appendix 1) were mapped at the quarter degree square scale (QDS) using the published locality records of Bates (1992 & 1993), Boycott (1982 & 1992), Branch (1988), Burger (1993), Channing (1986), Comrie Greig, Boycott & De Villiers (1979), Jacobsen (1989), Lambiris (1988), Picker & De Villiers (1989), Pickersgill (1984) and Poynton (1964) as well as the localities recorded in the computerized data of the South African and Port Elizabeth Museums. Using a Geographic Information System (GIS), ARC/INFO version 6. 1. 1. (Environmental Systems Research Institute, Redlands, California), a spatial analysis was performed on the distributions of each anuran species with a recorded distribution within South Africa, Swaziland and Lesotho. The top 5% of the QDSs containing data were compared individually in terms of species richness, endemic richness and RDB richness with the configuration of the existing protected area network in South Africa. The protected areas include national, provincial, municipal, and other reserves administered by local authorities, as well as forestry areas owned by the state. Some private nature reserves have also been included (Lombard 1995).

Results

Species richness

Centres of exceptionally high species richness (28 to 37 species) are found along the coast of KwaZulu/Natal north of Durban, particularly in Maputaland (Figure 1). These centres include both coastal dune forest and moist savanna biomes. Areas that were identified as regions of high (19–27 species) species richness include: the arid savanna of the eastern regions of the Northern and Eastern Transvaal; the arid and moist savanna biomes in central and southern Northern Transvaal; the grassland biome in the vicinity of Pietermaritzburg; the afromontane forest and montane grasslands of the Natal Drakensberg escarpment; the southern coastal regions of Kwazulu/Natal; the Eastern Cape coast (including coastal forest in the vicinity of Port St Johns), and the fynbos of the south-western Cape. The 'hotspots' and areas of high species richness have peripheral areas of intermediate species richness (10–18 species). The region between Durban and the Drakensberg protected areas, as well as the areas surrounding Port Elizabeth and East London, also fall into the intermediate category. Swaziland contains areas of average species richness, with the exception of the arid central interior of the country, which was shown to be an area of relatively low species richness. The Succulent Karoo biome is identified as an area of low species richness (1 to 9 species) while the Nama-Karoo is characterized by an apparent absence of amphibian species.

Endemic species richness

'Hotspots' of exceptionally high endemic species richness (13 to 16 species) occur in the vicinities of Pietermaritzburg and Durban in KwaZulu/Natal and in the fynbos surrounding Cape Town in the Western Cape (Figure 2). A high degree of anuran endemism is found in the latter fynbos 'hotspot' with QDSs containing 13 to 16 national and local endemics. Several areas have high endemic species richness (9 to 12 endemic species), including the Eastern Transvaal, the moist savanna of southern Kwazulu/Natal, the Lesotho-Kwazulu/Natal border along the Drakensberg escarpment, on the Eastern Cape coast and the Western Cape. The Eastern Cape, contains three areas of relatively high endemism; one in coastal forest near Port St Johns (which is also an area of species richness); the second, bordering on coastal savanna and grassland biomes, includes the Katberg and Amatola Mountains; and the third is the Elandsberg, which falls within the fynbos biome. The southern region of the Western Cape, in addition to possessing a 'hotspot', is indicated as an area of concentrated endemic richness. Areas of average endemic species richness (5 to 8 endemic species) occur: in the Northern Transvaal, on the Eastern Transvaal/Swaziland border, in the grasslands along the border between the Eastern Transvaal and Kwazulu/Natal, throughout the central and southern regions of KwaZulu/Natal and along the coastal areas of the Eastern and Western Cape. The Northern Cape Province (with the exception of one intermediate area of endemic species richness), Lesotho, Swaziland, and the Karoo biomes are represented by a paucity of endemic species (1 to 4 endemic species).

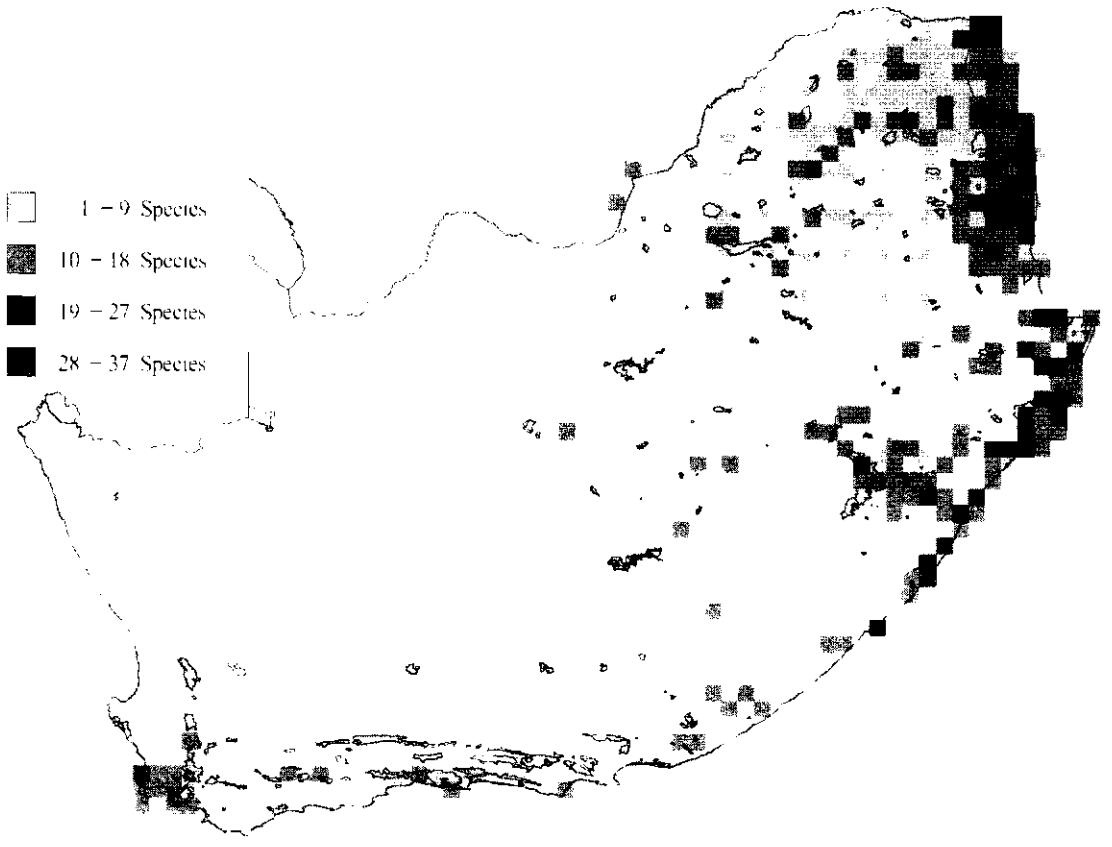

Figure 1 Map of South Africa indicating distribution of conservation areas and shaded QDSs indicating anuran species richness.

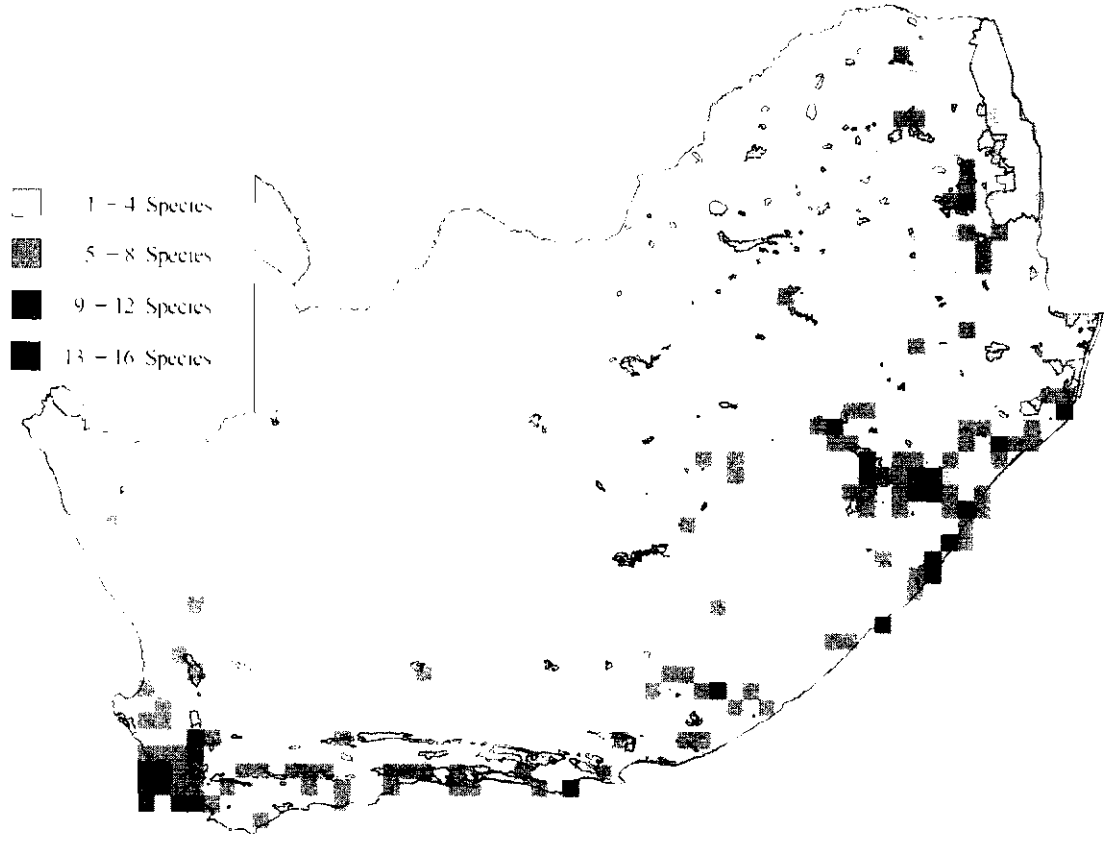

Figure 2 Map of South Africa indicating distribution of conservation areas and shaded QDSs indicating species richness of endemic anurans.

Red Data Book richness

The Cape Peninsula, together with the adjacent Cape Flats, and the Grootwinterhoek mountains are indicated as centres of RDB richness with between 3 and 5 species per QDS (Figure 3). QDSs adjacent to the Cape 'hotspots' are identified as additional areas of high RDB richness. The Drakensberg and the St Lucia regions each contain two RDB species. Areas in Kwazulu/Natal, the Eastern and Northern Transvaal, Swaziland, the Northern and Eastern Cape and the Western Cape contain a single RDB species.

Protected areas

The existing reserve system in South Africa is compared with the top 5% of all the QDSs containing data in each category. The top 5% of species richness QDSs contain 19 to 37 species (i.e. classes 3 and 4 in Figure 1). The top 5% of endemic richness QDSs contain 9 to 16 species (i.e. classes 3 and 4 in Figure 2). The top 5% of RDB richness is represented by class 4 which contains 4 to 5 species (Figure 3).

All QDSs showing high species richness (over 18 species/QDS) intersect with at least one protected area (Figure 1). However, some protected areas in the Northern Transvaal, Kwazulu/Natal, Eastern and Western Cape are very small fragments. Of the relatively extensive reserve system in the southern portion of the Eastern Cape and Western Cape provinces, protected areas on the Cape Peninsula are indicated as being of primary importance in the protection of anuran species richness.

A comparison of areas of endemic species richness and protected areas reveals all endemic 'hotspots' or areas of high endemism are associated with protected areas (Figure 2). The majority of areas of high endemic richness in the Northern and Eastern Transvaal, and Kwazulu/Natal, either intersect with or contain protected areas, but several of these are very small and isolated or the area of overlap is small. The Drakensberg reserves are well situated to protect the endemics occurring in this mountainous region. The Eastern Cape coast has three areas prioritized, all of which have associated protected areas, which are either forest areas or small reserves administered by local authorities. One of these areas, in the vicinity of Port St Johns, is also recognized as an area of high species richness. In the Western Cape, the mountain fynbos of the Cape Peninsula is well protected but the Cape Flats region has only a few protected areas, which are small and isolated. The majority of QDSs identified as 'hotspots' of anuran endemism either have or include one or more protected areas. Although this may be regarded as providing some form of protection, this does not necessarily imply that all species are adequately protected (Figure 2).

The top 5% of QDSs containing anuran RDB species occur solely in the Western Cape, and comprise mainly the Cape Peninsula and the lower lying Cape Flats habitat (Figure 3). Two of the seven QDSs selected as RDB 'hotspots' or areas of high RDB richness (3 to 5 RDB species) contain no large protected areas.

All six South African biomes are represented by measures of species and endemic richness. As only the fynbos biome is prioritized in terms of RDB richness, only one QDS, in the immediate vicinity of Cape Town, is common to the higher

Figure 3 Map of South Africa indicating distribution of conservation areas and shaded QDSs indicating the richness of South African Red Data Book anuran species.

Table I List of anuran species not recorded in South African protected areas and their Red Data Book (RDB) conservation status (Branch 1988)

Species	RDB status
Breviceps macrops	Restricted
Cacosternum poyntoni	Indeterminate
Leptopelis bocagii	Not listed
Strongylopus springbokensis	Not listed

categories of all three measures. The Nama-Karoo and Succulent Karoo biomes are represented by the lowest measures of all three categories.

Four anuran species (4,2%) of the 96 examined in this analysis, have not been recorded in conservation areas in South Africa (Table 1). Two of these species are listed in the RDB (Branch 1988). *Breviceps macrops*, previously regarded as a national endemic, occurs in the sandy coastal dune belt between Port Nolloth and the Groen River mouth. It has recently been established that this species and *Cacosternum namaquense* occur extralimitally with a distribution that extends into southern Namibia (Channing & Griffin 1993). *Bufo amatolicus* and *Anhydrophryne rattrayi* are endemic to the forests of the Amatola Mountains of the Eastern Cape. *Cacosternum poyntoni*, known from a single specimen collected in 1954, is now considered extinct (Branch 1994). Subsequent searches at the type locality since disturbed by urban development and bush encroachment have failed to find examples of the species. *Leptopelis bocagii* is widely distributed north of South Africa, but has only a single locality record within the Northern Transvaal (Poynton & Broadley 1991). *Strongylopus springbokensis* appears to be restricted to the mountainous area of Namaqualand, north of the Knersvlakte and south of the Orange River (Channing 1986), no locality within a protected area has been recorded for this species. *Breviceps acutirostris* and *Cacosternum namaquense* have each been recorded from only one protected area, Grootvadersbos and the Karoo National Park, respectively.

Microbatrachella capensis, a Western Cape lowland fynbos endemic has not been reported from the Cape Flats since the mid-1960s, and is listed as endangered in the RDB (Branch 1988). *M. capensis* has been recorded near Betty's Bay, Kleinmond and between Gansbaai and Agulhas (De Villiers 1988) and recently the presence of a population in the Kleinmond Coastal Reserve has been confirmed (De Villiers, pers comm).

Discussion

The conservation strategy that is developed must be specific to a clearly defined goal, because different criteria (e.g. species richness and endemic species richness) may identify different areas as important. The accuracy of the final spatial analysis is determined by three factors: the completeness and accuracy of the data; the evenness of the coverage, which reflects collecting effort, and the inherent limitations of the initial database (Rebelo 1994).

In terms of the present analysis, it is important to assess the completeness of the database. Poynton's (1964) revision incorporated all specimens deposited in South African museums, as well as some overseas institutions, at that time. With regard to subsequent collecting effort, distribution records for the former Transvaal Province have been updated by Jacobsen (1989), those for the Free State by Bates (1992), those for Kwazulu/Natal by Lambiris (1988) and those for Swaziland by Boycott (1992). This leaves both Lesotho and the former Cape Province uncovered. By utilizing the computerized databases of the collections of the South African and Port Elizabeth Museums, we believe that we have incorporated the vast majority of species localities in the former Cape Province which have been recorded over the past thirty years. An updated checklist, with distribution records, of the amphibians of Lesotho is urgently required and is in the process of being prepared (Bates, pers. comm.). Although we are unaware of any major collecting efforts conducted in Lesotho, we acknowledge that a weakness of this study is that any recent records for this country have not been incorporated in our analysis.

The problems of presence/absence data, abundance and scale are discussed by Lombard (1995). 'Hotspots' identified by the analysis may be biased by concerted collection efforts in protected areas, and in close proximity to major towns or cities and research institutions, for example Durban, Pietermaritzburg and Cape Town (Figure 1). Other areas may appear less important because they have not been extensively sampled. Under-sampling and remoteness are almost certainly important factors in the representation of the Karoo biome species measures. The Nama-Karoo, areas of the Eastern Cape and the savanna regions of the Northern Cape require careful assessment in terms of presence/absence data to represent species richness accurately (Figure 1).

Since locality databases from both museum collections and distribution publications were used, no temporal distinctions between the distribution records of species are provided. Thus extinct populations will feature in a historical database, necessitating the ground-truthing of the data before finalizing protected area choices. For example such an exercise has been successfully completed by Picker & DeVilliers (1989) for *Xenopus gilli*. However, as a foundation for further research, the results of this type of spatial analysis can provide: (i) standards for future assessments and studies; (ii) information identifying shortcomings in data collection and (iii) good indications of areas that merit consideration for conservation. The effective preservation of species and accurate design of protected areas require careful assessments of distribution records to determine the occurrence of species within the area concerned.

Species richness

All the identified 'hotspots' of species richness are protected to some degree within existing protected areas (Figure 1). The Wolksberg region of the north-eastern Transvaal escarpment, also recognized as a floral 'hotspot', has 13,3% of its area conserved (Cowling & Hilton-Taylor 1994). The Kruger National Park and Maputaland reserves appear as centres of species richness largely as a result of their position as transitional areas between tropical and more temperate habitats, and intensive collecting within these reserve areas. The species-rich northern coastal region of Kwazulu/Natal, similarly

recognized as a transition zone between tropical and temperate herpetofaunas (Bruton & Haacke 1975), has 10% of its area protected (Cowling & Hilton-Taylor 1994). This region falls within the southern-most distributional limits of the species-rich East African lowland group and includes the southerly limits of numerous reptile and amphibian species (Haagner 1994; Poynton & Broadley 1991). Currently there is little urban development in this region and species are relatively well-protected within existing protected areas. However, both the burgeoning population and agricultural pressures present potential for conflict between conservation and development interests in the region. Other potential threats to the Maputaland environment include afforestation, overgrazing, mining, tourism and subsistence, and commercial harvesting of indigenous plants (Cowling & Hilton-Taylor 1994). The precise extent of the overlap of species ranges and nature reserves needs to be assessed directly and at a finer scale of resolution than this data set allows.

Of the 84 South African anuran species considered by Siegfried (1989), the Succulent Karoo biome has the lowest percentage occurrence of amphibians in protected areas (8 of 11 species, or 72,7%). The current analysis identified only Succulent Karoo frog species, *Breviceps macrops*, as absent from protected areas and did not identify the single species in the Nama-Karoo listed as unprotected by Siegfried (1989). The forested habitat of the Amatola Mountains contains two protected species. This area now belongs to the state and the South African Forestry Company Limited (SAFCOL), so assurances are required with regard to their conservation status in the event of privatization. The discrepancies between our and Siegfried's (1989) figures may be attributed to the relatively poor representation of Karoo biome amphibians and to the lack of accurate species lists for conservation areas acknowledged in the earlier study. The remaining biomes have 88 to 100% of species present in protected areas (Siegfried 1989). A large proportion (95,8%) of the 96 South African anuran species distributions on which this analysis is based, fall within, or in close proximity to, existing protected areas. This is surprisingly high considering that the South African reserve system constitutes approximately 6 to 8% of the area of the country (Siegfried 1989), and was not developed to preserve anuran diversity.

A locality record in a protected area, however, does not guarantee either the short- or long-term preservation of a species. For example, *Breviceps gibbosus*, *Heleophryne hewitti*, *Hyperolius pickersgilli* and *Xenopus gilli*, are all listed as RDB species occurring within protected areas, but this does not necessarily imply that these species are adequately protected (Branch 1988). Habitat fragmentation is a problem for many protected areas owing to their small size and isolation within a landscape transformed by agricultural use or urbanization, and very few protected areas have corridors of suitable habitat to function as bridges between them. The process of fragmentation may also lead to the concentration of surviving endemic or threatened species in natural remnants (Wood, Low, Donaldson & Rebelo 1994). While offering protection in the short term, this may not ensure the long-term viability of a species. Furthermore, isolation in small pockets of habitat can increase the vulnerability of a species to habitat alteration or natural disasters, such as floods and fires. Apart from habitat destruction, the individual or combined effects of urbanization, agriculture and industry, often include chemical pollution and alteration of water availability. Pollution effects may extend into the natural protected habitat, and anurans with their wet, absorptive skins and dual life-cycle are particularly susceptible to water and ground pollution, as well as air-borne contaminants in the environment. The establishment of buffer zones around areas conserving anuran diversity should be considered, as these could considerably increase the effective core reserve size,

Endemism

Local endemics are the prime focus of conservation actions, despite the fact that endemism is determined according to political boundaries which are not always appropriate for effective conservation management. It is essential that effective areas for the protection and conservation of endemic species should be recognized and established. 'Hotspots' of species richness (Figure 1) are completely different 'hotspots' to those for endemic species richness (Figure 2). The Maputaland region and the Kruger National Park, for example, in spite of being centres of species richness, are not recognized as centres of endemism. The distribution of South African protected areas appears to favour the conservation of overall species richness, but it does not seem adequate to conserve endemics.

The Cape Peninsula with the adjacent lowlands and surrounding mountain ranges is regarded as a centre of endemism (Poynton 1989). It contains 16 South African endemics, of which six are endemic to the Western Cape fynbos. In addition to intensive specimen collection in this area, this high level of endemism is thought to reflect recent sea-level changes resulting in the intermittent isolation of Table Mountain and the climatic isolation of the region. It is clear that the concentration of endemic and rare taxa within the Cape Metropolitan area (Figures 2 & 3) combined with rapid urbanization, emphasizes the need for a strategy to preserve the biotic diversity within this region. The precarious conservation status of this area has been widely acknowledged (Branch 1988; Wood *et al.* 1994; Cowling & Hilton-Taylor 1994). The habitats comprising poor sandy soils and ephemeral pools of the Cape Flats, are under increasing pressure for low-cost housing, while the low-lying fertile renosterveld has been almost completely converted to agricultural use. These factors have combined with alien infestations to almost totally destroy the natural vegetation of the Cape Flats and other lowlands adjacent to Cape Town, so that identification and conservation of remaining viable undisturbed patches is a matter of urgency (Wood *et al.* 1994).

The Pondoland protected areas conserve 7% of the southern KwaZulu/Natal area and northern Eastern Cape coast (Cowling & Hilton-Taylor 1994). This is not adequate to protect those areas identified as important for the conservation of endemic species in the region (Figure 2). The major environmental threats in this region include population growth, land transformation for agriculture, and overgrazing (Cowling & Hilton-Taylor 1994). The vicinity of Port St Johns, identified as one of both species richness and endemism, should be surveyed.

The Amatola Mountains in the Eastern Cape contain two

locally endemic frog species. While this area currently enjoys protected status under a conservation authority this would not be guaranteed if SAFCOL were to be privatized. Further development of exotic tree plantations would pose a serious threat as monocultures destroy habitats suitable for amphibians. The Elandsberg, near Port Elizabeth, which is utilized extensively for pine plantations, contains the most easterly patch of true fynbos vegetation and the endemic frog, *Heleophryne hewitti* (Boycott & Branch 1988). While a portion of its restricted distributional range is within a protected area, the species is threatened by habitat loss as a direct consequence of forestation and the introduction of alien fish which pose a threat to recruitment (Boycott & Branch 1988). Opencast diamond mining activities in the dunefields of the northern Namaqualand coast potentially threaten *Breviceps macrops* with habitat destruction. It is important that the extent of this species range into Namibia is determined, and a full assessment of its conservation status must be made. Mining management could be approached to develop a conservation policy that leaves sufficient adjacent habitat undisturbed to allow for migration and recruitment to previously-mined sites.

Biomes

The major terrestrial biomes occurring in South Africa (Acocks 1953) are all represented in the protected area system. It has been previously recognized that the Karoo (particularly the Succulent Karoo), grassland, and lowland fynbos biomes are under-represented (Siegfried 1989). Only 2% of the Succulent Karoo is conserved and the absence of representative data from the Nama-Karoo has been discussed earlier. Grasslands appear to have been widely sampled (Figure 1), and with the exception of the KwaZulu/Natal Drakensberg reserves and those in the vicinity of Pietermaritzburg, do not appear to be rich in anuran species (1–9 species). With 53% of the biome conserved, the fynbos appears to be well protected (Cowling & Hilton-Taylor 1994). Although listed as RDB species, *Capensibufo rosei* and *Heleophryne rosei* are regarded as adequately protected within the mountain fynbos habitats (Branch 1988). Coastal fynbos, however, which includes the critically endangered renosterveld, and other lowland vegetation types is represented in only 10% of the reserves and constitutes a meagre 3% of total fynbos reserve area (Siegfried 1989). Two of the endemic frog species in the Western Cape which require sandy low-lying habitat with shallow vleis and pans are listed as endangered in the RDB (Branch 1988): *M. capensis* (Table 1), and *Xenopus gilli*. Several other Western Cape endemics are listed as RDB species that require low-lying coastal fynbos habitat, including *Breviceps gibbosus* and *Cacosternum capense*. The protection of appropriate indigenous habitats in the lowlands of the Western Cape is imperative, but in many cases the opportunities have already been lost. Therefore areas of coastal fynbos, identified as areas of average endemic species richness and containing RDB species (Figure 2 & 3), are of significance for conservation action and should be assessed in the immediate future.

Recommendations

The conservation of biodiversity requires that specimens are identified correctly and that accurate species distributions and abundance over time are recorded. Accurate determinations of the degree of protection a species requires are possible only if the population size, distribution, ecological aspects and reproductive biology of the species in question have been studied. Thus it is important that threatened or vulnerable species should be carefully monitored, particularly those with small populations or restricted distributions. Similarly the conservation status of recently described species should be assessed as a matter of urgency, particularly those that exhibit restricted distributions and have not been recorded from a reserve area.

A GIS is a useful and efficient tool for identifying and directing research to areas and species important in the conservation of biodiversity. It has the potential to assist in the selection of either a single or a network of suitable protected areas. Several centres of South African anuran species richness, endemism and RDB richness have been identified using the data currently available. In South Africa there are extensive areas where no distribution records exist, and a concerted collecting effort is therefore required. In other areas, the accuracy of the locality data recorded needs to be improved. The under-representation of the Karoo biomes and the necessity for the compilation of a checklist with distribution records for Lesotho, have been acknowledged.

A uniform national policy for the protection of all amphibian species is required. The protected status of all areas that contain local endemics should be ensured. In areas where declaration of large reserves is impractical, protection on private land should be encouraged by public education supporting management practices which maintain or benefit the survival of populations. But the declaration of core reserves, at least, would be an important catalyst in the conservation of these endemics which still require formal protection. The precise location and design of such reserves will have to be preceded by careful fieldwork to determine which areas retain viable populations of threatened species, if their conservation status is to be optimized.

With regard to existing protected areas, conservation officers should be encouraged to maintain and publish accurate species lists of protected areas at regular intervals. Research specimens should be well documented and preserved, and lodged as voucher specimens with an appropriate institution. Accurate specimen localities (point data) and collection dates are essential for precise spatial analyses, and combined with accessible and compatible databases, these could reduce the need to collect more specimens for future research. In addition, the establishment of specialized, networked databases allows for local, regional and national analyses by conservation-orientated researchers and planners.

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Appendix 1 List of South African anuran species used in the spatial analysis

Genus	Species
Xenopus	*gilli*
Xenopus	*laevis*
Xenopus	*muelleri*
Heleophryne	*hewitti*
Heleophryne	*natalensis*
Heleophryne	*purcelli*
Heleophryne	*regis*
Heleophryne	*rosei*
Bufo	*amatolicus*
Bufo	*angusticeps*
Bufo	*fenoulheti*
Bufo	*gariepensis*
Bufo	*garmani*
Bufo	*gutturalis*
Bufo	*maculatus*
Bufo	*pardalis*
Bufo	*rangeri*
Bufo	*vertebralis*
Capensibufo	*rosei*
Capensibufo	*tradouwi*
Schismaderma	*carens*
Breviceps	*acutirostris*

Appendix 1 List of South African anuran species used in the spatial analysis (Continued)

Breviceps	*adspersus*
Breviceps	*fuscus*
Breviceps	*gibbosus*
Breviceps	*macrops*
Breviceps	*montanus*
Breviceps	*mossambicus*
Breviceps	*namaquensis*
Breviceps	*rosei*
Breviceps	*sylvestris*
Breviceps	*verrucosus*
Phrynomerus	*annectens*
Phrynomerus	*bifasciatus*
Anhydrophryne	*rattrayi*
Arthroleptella	*hewitti*
Arthroleptella	*lightfooti*
Cacosternum	*boettgeri*
Cacosternum	*capense*
Cacosternum	*namaquense*
Cacosternum	*nanum*
Cacosternum	*poyntoni*
Cacosternum	*striatus*
Microbatrachella	*capensis*
Natalobatrachus	*bonebergi*
Phrynobatrachus	*acridoides*
Phrynobatrachus	*mababiensis*
Phrynobatrachus	*natalensis*
Hildebrantia	*ornata*
Ptychadena	*anchietae*
Ptychadena	*mascareniensis*
Ptychadena	*mossambica*
Ptychadena	*oxyrhychus*
Ptychadena	*porosissima*
Ptychadena	*taenioscelis*
Pyxicephalus	*adspersus*
Rana	*fuscigula*
Rana	*angolensis*
Rana	*dracomontana*

Appendix 1 List of South African anuran species used in the spatial analysis (Continued)

Rana	*vertebralis*
Strongylopus	*bonaespei*
Strongylopus	*fasciatus*
Strongylopus	*grayii*
Strongylopus	*hymenopus*
Strongylopus	*springbokensis*
Strongylopus	*wageri*
Tomopterna	*cryptotis*
Tomopterna	*delalandei*
Tomopterna	*krugerensis*
Tomopterna	*marmorata*
Tomopterna	*natalensis*
Chiromantis	*xerampelina*
Afrixalus	*aureus*
Afrixalus	*delicatus*
Afrixalus	*fornasinii*
Afrixalus	*knysnae*
Afrixalus	*spinifrons*
Hyperolius	*argus*
Hyperolius	*horstockii*
Hyperolius	*marmoratus*
Hyperolius	*pickersgilli*
Hyperolius	*poweri*
Hyperolius	*pusillus*
Hyperolius	*semidiscus*
Hyperolius	*tuberilinguis*
Kassina	*maculata*
Kassina	*senegalensis*
Semnodactylus	*wealii*
Leptopelis	*bocagii*
Leptopelis	*mossambicus*
Leptopelis	*natalensis*
Leptopelis	*xenodactylus*
Arthroleptis	*stenodactylus*
Arthroleptis	*wahlbergi*
Hemisus	*guttatus*
Hemisus	*marmoratus*