Introduction to an evaluation of the protection status of South Africa's vertebrates

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During the Zoological Society of Southern Africa's 1994 Symposium in Pietermaritzburg, a theme session was convened to evaluate the protection status of selected groups of South African vertebrates (*viz.* freshwater fish, frogs, tortoises and terrapins, snakes, birds, and various mammal orders). The research papers presented during that session are reported in this number of the South African Journal of Zoology. The rationale behind the research, and the data and methods used, are described in this introductory paper. South Africa's national and international contractual obligations to conserve its biodiversity, and the urgent need for a national conservation strategy and national conservation information networks and databases, are also discussed.

Gedurende die 1994 Simposium van die Dierkundige Vereniging van Suidelike Afrika in Pietermaritzburg, is 'n temasessie gehou om die beskermingstatus van 'n gekose groep Suid-Afrikaanse gewerwelde diere te evalueer (te wete varswater visse, paddas, skilpaaie en varswaterskilpaaie, slange, voëls, en verskeie soogdierordes). Die navorsingsreferate wat gedurende hierdie sessie gelewer is, word in hierdie nommer van die Suid-Afrikaanse Tydskrif vir Dierkunde aangebied. Die beredenering agter die navorsing, en die data en metodes wat gebruik is, word in hierdie inleidingsreferaat beskryf. In die referaat word Suid-Afrika se nasionale, en internasionale kontraktuele verpligtinge om sy biodiversiteit te bewaar, bespreek, asook die dringende noodsaaklikheid vir 'n nasionale bewaringstrategie en nasionale bewaringsinformasienetwerke en -databasisse.

A rich heritage

The World Conservation Monitoring Centre recently recognized South Africa as the third most biologically rich country in the world (after Brazil and Indonesia, WCMC 1992). The country's rich biological heritage has been well described in both the popular and scientific literature (Goldblatt 1978; Werger 1978; Cowling, Gibbs Russell, Hoffman & Hilton-Taylor 1989; Siegfried 1989; Huntley 1995; Siegfried & Brooke 1994). Although South Africa occupies only 0,8% of the world's total land area, it contains 8% of the world's vascular plants, 2% of the world's amphibians, and between 6 and 7% of the world's reptile, bird and terrestrial mammal species (Siegfried 1989; Huntley 1995; Siegfried & Brooke 1994). Not only is the area rich in species, but high levels of endemism are characteristic of many plant and animal taxa. The Cape Floristic Region (CFR) deserves a special mention with *ca* 8600 species, of which 68% are endemic to the region (Huntley 1995). Consequently, Myers (1990) recognized the CFR as the world's 'hottest hotspot', not only because of the its high levels of richness and endemism, but also because the region is subject to increasing threats from agriculture, alien plant invasion and urban development.

Contractual obligations

Given this exceptional biological wealth, South Africa has recently ratified the Convention on Biological Diversity (CBD), which emanated from the United Nations Conference on Environment and Development (UNCED, Rio de Janeiro, 1992). The country is already a signatory to many other international conventions, for example, the Convention on International Trade in Endangered Species (CITES), and the Convention for the Conservation of Wetlands of International Importance (Ramsar).

South Africa is also committed to internal conservation legislation, as evidenced by the National Parks Act No. 57 of 1976, and the Environment Conservation Act No. 73 of 1989. In addition, with South Africa's transition to a new democracy, the country is seen as a centre of biological, technical and electronic expertise, to be shared with neighbouring countries. Can South Africa succeed in this role, as well as fulfil its national and international obligations?

The need for national strategies

The CBD calls for signatory countries to 'develop national strategies, plans or programmes for the conservation and sustainable use of biological diversity'. The need for national co-ordination of conservation planning has also been emphasized by Noss (1983, 1992), Belbin (1993), and Scott, Davis, Csuti, Noss, Butterfield, Groves, Anderson, Caicco, D'Erchia, Edwards, Ulliman & Wright (1993). Many countries have already developed national conservation strategies, for example, the Biological Diversity Advisory Committee of Australia has formulated a National Strategy for the Conservation of Australia's Biodiversity, and the United Kingdom has published a Biodiversity Action Plan (UK 1994). The National Biological Survey of the United States has already initiated a national Gap Analysis Programme, and preliminary results are available for the State of Idaho (F.W. Davis, pers. comm.).

At present, there is no evidence of a co-ordinated, functional, national programme to quantify South Africa's biodiversity, or develop a biodiversity conservation strategy (Lombard, August & Siegfried 1992). Many draft conservation policies have been outlined, for example, The National Plan for Nature Conservation (DEA 1979), the Republic of South Africa's (RSA) President's Council Report (1991), the documentation prepared for the UNCED conference (DEA 1992), and the White Paper on a National Environmental System for South Africa (DEA 1993). Many of the country's provincial conservancies are undertaking biodiversity assessments within their own regions, but the RSA President's Council Report (1991) suggests that the provincial legislation should be consolidated into a national Nature Conservation Act. The existing reserves (= publicly owned protected areas) in South Africa contain many of the same species, and it may be prudent to replace some of these reserves, or add to them, areas that support endemic, rare or threatened species, particularly the less charismatic ones for which the current reserves were not designed (e.g. subterranean endemic mammals, Gelderblom 1993). This can be achieved only if conservation strategies are developed nationally.

The need for collaboration and national databases

One of the major stumbling blocks to national co-ordination of conservation planning is the lack of communication between biologists and planners, but especially among biologists themselves (Chown & McGeoch 1995). The lack of collaboration among South African biologists has led to duplication of effort, unexplored opportunities and a tendency to feel pressurized to follow world trends which may not be relevant locally (Chown & McGeoch 1995). Mistrust has developed between the data curators (largely museums) and the data-hungry institutions, such as universities, government departments and private consultants. Although a government initiative is underway to produce a digital inventory of all available biological data (the National Nature Conservation Information System, Department of Environmental Affairs and Tourism), this effort pertains only to 'who has what', and three problems remain unsolved: (i) many biological databases are not in a digital form (e.g. many extensive museum collections remain uncomputerized), (ii) many data curators provide limited access to their databases, and (iii) there is no national repository for accurate, up to date biological data on which the country's biologists and decision-makers can draw for their research.

Countries such as the United States, Britain, Australia and Brazil are ahead of South Africa, with the advent of national data collection efforts and collation agencies (e.g. the National Biological Survey — USA, the National Endangered Species Assessment — USA, the Joint Nature Conservation Committee — UK, the Environmental Resource Information Network — Australia, and the Biodiversity Information Network — Brazil). In addition, international biological data collation efforts have long been underway, for example, The World Conservation Monitoring Centre (WCMC) and the United Nations Environment Programme Global Resource Information Database (UNEP GRID). Using these models as a starting point, South Africa should begin to design and implement a national environmental information network (van Jaarsveld & Lombard 1995).

South Africa's reserve estate

South Africa faces another problem. If one accepts that a large proportion of the country's biodiversity can be protected only within reserves (a point that is argued below), then an evaluation of existing reserves reveals several shortcomings. Three terrestrial biomes are greatly under-represented: the lowland fynbos, succulent Karoo, and highveld grasslands (Siegfried 1989; Huntley 1995). In addition, although Siegfried & Brown (1992) and Rainbird (1993) showed that the large, resident, terrestrial breeding mammals are well protected in existing reserves, many other species still remain unprotected, for example, the endemic birds of the Karoo and grassland biomes (Siegfried 1992).

South African reserves suffer from other inadequacies. Their combined area is less than 6% of the country's total area, more than 70% of them are small (< 5000 ha), and they are spatially isolated from one another, separated by a matrix of mostly transformed land (Siegfried 1989). MacDonald (1989) estimated that 22% of South Africa's surface area is currently transformed, and with the present rate of population increase (2,2% p.a., World Bank 1994), this figure will undoubtedly increase in the near future. This places some urgency not only on the need to quantify the current protection status of species and biomes, but also on the need to identify new areas requiring protection.

A collaborative effort to assess vertebrate protection status — Rationale

In recognition of the above-mentioned inadequacies (i.e. the lack of national strategies and the shortcomings of existing reserves), a group of biologists joined forces to assess the current protection status of South Africa's vertebrate fauna. These biologists represented various museums (Albany; Durban Natural Science; Port Elizabeth; South African; Transvaal) and institutions (Department of Zoology and Entomology, University of Pretoria; FitzPatrick Institute of African Ornithology; J.L.B. Smith Institute of Ichthyology). Their combined expertise allowed the review (all published in this number) of selected taxa within all five vertebrate classes: fresh-water fish (Skelton, Cambray, Lombard & Benn 1995); frogs (Drinkrow & Cherry 1995); tortoises and terrapins (Branch, Benn & Lombard 1995); birds (Lombard 1995); and various mammal orders (Mugo, Lombard, Bronner, Gelderblom & Benn 1995; Gelderblom, Bronner, Lombard & Taylor 1995). Two further studies, Gelderblom & Bronner (1995) and Freitag & van Jaarsveld (1995), were not part of the collaborative project, but they also address the protection status of vertebrates in South Africa and were thus included in this number for completeness. The identification of important areas for the protection of South Africa's snake fauna has already been completed (Lombard, Nicholls & August 1995).

Apart from the quantitative results produced by this collaborative project, many other advantages were gained: collaboration among research scientists at a national level; data sharing and the development of an element of trust between museums and other academic institutions; the amalgamation of disparate species distribution databases; the prototyping of a national biological database; the analogue-digital conversion of many museum collections; and the optimal use of expensive analytical hardware, software and skills.

Key questions

The key questions addressed by the collaborative research papers were:

(i) What is the current protection status of selected vertebrate taxa in existing reserves?

(ii) Which areas, outside of existing reserves, require protection for each taxon.

(iii) Which biomes require further protection?

Three important questions that were not addressed were: (i) which parts of the landscape are or will be subject to processes that reserves can offset (e.g. clearing, grazing, mining)?; (ii) which species are largely restricted to these habitats and thus require priority protection?; and (iii) which species cannot be adequately protected by reserves (e.g. animals with very large areal requirements)? At present, there is only an incomplete land-use database for the country, and in the absence of a complete database, these additional questions are difficult to answer. The distribution data compiled by the collaborative projects, however, can and should be reanalysed when land-use data become available.

The process

Key question one was answered as follows: hotspots of species richness, endemism and red-data species were identified by counting the numbers of total, endemic or red-data species per QDS (quarter-degree square = 15' × 15'). Endemic species are those that have at least 90% of their range in the greater South Africa (defined here as South Africa, Lesotho and Swaziland), and red-data species are those listed in the current South African Red Data Books (Foundation for Research Development, Pretoria), or are deemed rare, vulnerable or threatened by the authors. Once hotspots had been identified, their overlap with existing reserves could be determined. In a second step, some authors determined which species were not present in existing reserves, and based on the presently unprotected hotspots and species, recommendations were made regarding areas requiring future protection. Each author performed a few variations of the above analyses, but the philosophy of hotspots was a common thread, as was the use of species (as opposed to environmental units).

Once the relative locations of hotspots, unprotected species and existing reserves had been determined, key question two was easily answered. In addition to the hotspot analyses, a complementarity algorithm developed by Rebelo & Siegfried (1992) was used in many of the studies. The algorithm identified a system of reserves (QDS) that would capture all species in a given database, at least once, in the minimum (or close to minimum, Underhill 1994) number of QDS possible. The results of this algorithm give only one of many possible answers to the question of which set of QDS can represent all species efficiently (i.e. there is flexibility in the results). The results also do not reflect any measures of viability, owing to the lack of abundance data. Nevertheless, the results do give an indication of the total number of QDS that can represent all species, and the general pattern of distribution of these QDS gives an indication of a more representative reserve system for each particular taxon. The flexibility of selected QDS is driven by rare or restricted range species, and taxa with many of these species will have less flexibility in the algorithm's results. Comparisons of selected QDS, with existing reserves, can provide valuable information regarding the total number, and general distribution, of additional areas required for the protection of a particular taxon.

In the final question, the biomes defined by Rutherford &Westfall (1986) were used to determine which biomes were inadequately represented in existing reserves, and which species were biome specific.

The methods and databases used to answer the three key questions are discussed at the end of this introductory paper, as well as in the separate papers in this number. The basic philosophical tenets underlying the process described above deserve some discussion, however, owing to their controversial nature. Under the following five subheadings, several topics are discussed, *viz*.: methods of evaluating areas for conservation prioritization; hotspot analyses; the use of species or environments in reserve design; presence-only data; and, the role of reserves in conservation.

Evaluation of areas for conservation prioritization

The evaluation of areas for conservation prioritization has no standard recipe, but most methods can be categorized into one of four classes: (i) the analysis of species distributions; (ii) the analysis of the distribution of environmental units (defined here as habitats, ecosystems or landscapes); (iii) some amalgamation of species and habitats and other factors in a scoring or evaluation index; or, (iv) reserve selection algorithms.

Methods concerned with species distributions range from the conservation of minimum viable populations (Thomas, Forsman, Lint, Meslow, Noon & Verner 1990; Gilpin 1991), genetic variability (Vane-Wright, Humphries & Williams 1991; Williams, Humphries & Vane-Wright 1991; Faith 1992, 1994), areas of species richness or diversity (Scott, Csuti, Jacobs & Estes 1987; Lesica 1993; Sætersdal, Line & Birks 1993), areas of concentrated endemism or rare species (Terborgh & Winter 1983; Myers 1990; McIntyre 1992; Rebelo & Tansley 1993), areas of guild richness (McKenzie, Belbin, Margules & Keighery 1989), functional groups (Walker 1992), or communities (Austin & Margules 1986; Taggart 1994). On the other hand, conservation prioritization may be concerned with conserving some form of environmental unit: 'habitats' (Nilsson & Götmark 1992), 'environments' (Bedward, Pressey & Keith 1992), 'landscapes' (Noss 1983), 'national ecosystems' (Belbin 1993) or 'environmental gradients' (DeVelice, DeVelice & Park 1988). In addition, many scoring indexes have been used to prioritize areas for conservation (Margules & Usher 1981; Götmark, Ahlund & Eriksson 1986; Usher 1986; Järvinen 1985; Bedward, Pressey & Nicholls 1991). Finally, heuristic and mathematical complementarity algorithms have been applied to many databases, in order to identify a complementary system of reserves that would capture all species, or all habitats, in the minimum number of reserves, or area, possible (Kirkpatrick 1983; Margules & Nicholls 1987; Margules, Nicholls & Pressey 1988; Pressey & Nicholls 1989a; Vane-Wright *et al.* 1991; Bedward *et al.* 1992; Rebelo & Siegfried 1992; Nicholls & Margules 1993; Pressey, Ferrier, Hutchinson, Siversten & Manion, in press).

The present studies used three of these methods, namely the analysis of species and habitat distributions, and complementarity algorithms. Scoring indexes combining two or more factors were not used, because these indexes do not pay attention to complementarity, flexibility, or irreplaceability, three factors that are becoming increasingly important in reserve design (Götmark *et al.* 1986; Pressey & Nicholls 1989b; Bedward *et al.* 1991; Pressey, Humphries, Margules, Vane-Wright & Williams 1993).

Hotspot analyses

Lesica (1993) argued that plant communities predict overall species richness, but recent research is replete with examples showing that hotspots of richness, endemism and rarity rarely coincide either within, or among, taxa (Siegfried 1989, 1992; Crowe 1990; Currie 1991; Ryti 1992; Siegfried & Brown 1992; Prendergrast, Quinn, Lawton, Eversham & Gibbons 1993; Rebelo & Tansley 1993; Sætersdal *et al.* 1993; Lombard *et al.* 1995). As a result, the present studies did not combine richness, endemism and red-data species in hotspot analyses, but treated each separately. In addition, an attempt was made to analyse the distributions of as many taxa as possible. The three notable exceptions were plants, invertebrates and marine systems. Both hotspot and complementarity analyses for plants have already been completed (Cowling & Hilton-Taylor 1994; Rebelo 1994), invertebrate studies are currently underway (S.L. Chown & M.J. Samways, pers. comm.), and a national marine reserve system is the subject of ongoing research at the University of Cape Town's Marine Biology Research Institute (Emanuel, Bustamante, Branch, Eekhout & Odendaal 1992). The final challenge will be to combine all of these studies in the design of an ultimate reserve system for South Africa.

It was felt that a hotspot analysis (keeping richness, endemism and red-data species separate), coupled with a complementarity analysis, would strengthen our ability to prioritize areas for conservation. Although hotspots in any one taxon capture only a proportion of the total species, they do define areas of exceptional biological wealth (and often areas of high habitat variability), and are thus worthy of protection. Complementarity analyses provide many alternative solutions to total species representation (in a reserve system), and should thus be included in conservation prioritization exercises. In the absence of data on threats, we were unable to prioritize species of special conservation concern, but endemic species and Red Data Book species received additional weighting in that hotspots of endemism and hotspots of Red Data Book species were also identified. As discussed previously, richness, endemism and rarity seldom coincide, adding importance to the separation of these three factors in hotspot analyses.

Species or environments?

The use of species in defining areas for conservation prioritization is often criticized, and many authors advocate the use of metapopulations (Rojas 1992), functional groups (Walker 1992), landscapes (Noss 1983) or some form of environmental representativeness (Pressey & Nicholls 1991; Belbin 1993) instead. Criticisms of species conservation are usually based on the fact that species databases are seldom complete and often lack abundance information. In addition, species form part of functioning communities or ecosystems, and it is the integrity of these systems that should be conserved. Despite these criticisms, the species is still the unit of measurement most frequently used to assess biodiversity (Wilson 1988; Crowe, Siegfried, Lombard & du Plessis 1994), and many attempts are made to predict species distributions from environmental variables (Busby 1986; Nix 1986; Woodward 1987; Braithwaite, Turner & Kelly 1984; Huntley, Bartlein & Prentice 1989; Scott *et al.* 1993), or higher taxa (Williams & Gaston 1994), in order to prioritize areas for conservation.

One of the simpler definitions of biodiversity is the 'totality of genes, species and ecosystems in a region' (WRI, IUCN, UNEP 1992). If conservation biology is defined as the conservation of biodiversity, then genes and species must be conserved on the one end of the spectrum, and ecosystems or environments on the other. As Huntley (1995) noted, reserves in South Africa are performing adequately for plant species, but not for biomes. If *alpha, beta* and *gamma* diversity (i.e. diversity at all spatial scales) are to be conserved, one must accept that there is no one correct spatial scale to work at in conservation prioritization, because natural systems function at many different scales (Noss & Harris 1986) and this variation needs to be captured in the prioritization of areas for conservation.

At the species end of the biodiversity spectrum, one caveat is required: there is much evidence for the cryptic nature of many species in South Africa (Prinsloo & Robinson 1992; Crowe, Essop, Allan, Brooke & Komen 1994; Crowe, Ryan, Essop, Brooke, Hockey & Siegfried 1994; Siegfried & Brooke 1994), and although conservation biologists cannot afford to wait until the systematics of all groups has been finalized, the need to conserve genetic variability must be recognized (Vane-Wright *et al.* 1991; Crozier 1992; Rojas 1992; Krajewski 1994).

At the environment end of the spectrum, Pressey & Logan (1994) have warned that many ecoregions are highly heterogeneous and a reserve system designed to capture a certain percentage of an ecoregion may not capture this variation. Indeed, this criticism becomes more valid as one moves along the species-environment biodiversity spectrum.

In the absence of complete taxonomic data, and fine scale ecosystem data, it was decided that a species approach to conservation, coupled with an analysis of biome representativeness, were the most pragmatic methods of identifying areas of conservation concern in South Africa, at present. It should be noted that a comprehensive review of the conservation status of many southern African ecosystems (e.g. fynbos and Karoo biomes, forests, wetlands, estuaries, pelagic ecosystems) has already been completed (Huntley 1989).

Presence-only data

Further criticism is often aimed at the use of presence, and not presence-absence or abundance data. Austin (1991) and Nicholls (1991) emphasize the dangers of using presence-only data to predict species distributions from environmental variables. 'Confirmed absent' data are required by most spatial interpolation models (e.g. generalized linear models, Austin, Cunningham & Good 1983; Nicholls 1989). Depending on the assumed bias in the presence records, however, there may be instances in which spatial interpolation of presence-only data is possible, especially if data on habitat requirements are available, and if suitable habitat information exists for the entire study area. These data were not available for all vertebrate species in South Africa, and no suitable habitat map exists for the entire country. Consequently, no attempt was made to extrapolate known species distributions into unsampled areas.

The use of presence data only, in hotspot or complementarity analyses, may not provide optimal results, but it does provide the best result that is currently obtainable. The need for abundance information is important if viable populations of species are to be conserved, but in the absence of this information for most taxa, *a posteriori* field surveys within hotspots, and reserves selected by complementarity algorithms, can be conducted to examine the long-term survival prospects of species and populations within those areas. This is far more cost-effective than conducting extensive biological surveys, for all taxa, at a national scale. In all the results generated by the present studies, such a 'ground truthing' of selected areas is recommended. Ground truthing is also required because hotspots and complementary reserves are identified at a QDS scale, and a QDS will convert only roughly to a management boundary on the ground. The final management boundary may contain a different complement of species to the original QDS, and this will alter the potential contribution of all other selected reserves in the initial run of the reserve selection algorithm. If maximum efficiency is required in the final reserves system, the algorithm may need to be rerun after each reserve boundary is finalized. The same procedure will be necessary if any reserve is substituted by another reserve in order to maximize the viability of species.

The role of reserves

There are many criticisms of the role of reserves in conserving biodiversity. It may be argued that viable populations of species, or functional ecosystems, are frequently not captured in reserves (Lombard 1993), which are mere fragments of larger ecosystems. Indeed, the large spatial requirements of many species (e.g. martial eagles, migrating wildebeest) may not be met in even the largest reserves, and the nature of the matrix surrounding reserves becomes important in conserving these species (Hockey, Lombard & Siegfried 1994). Reserves are often seen as a cure-all, but only some of the processes that threaten biodiversity (e.g. commercial forestry) can be offset by reserves. The possibility of global climate change in the short term, and the inevitability of such change in the long term, may render current, static reserves of minimal value in the future. In addition, the location of many South African reserves is the result of politically or economically expedient decisions, and does not reflect a biologically optimal situation (Siegfried 1989).

In Africa especially, one cannot ignore the need to integrate reserves with the needs of local people, and South Africa could benefit from several expert systems that have already been developed to allow subjective, socio-economic decisions to enter into reserve design (Bedward *et al.* 1992; Götmark & Nilsson 1992; Newmark, Leonard, Sariko & Gamassa 1993; Pressey *et al.* in press). Despite these criticisms, reserves do have an important role to play in conserving the earth's dwindling natural resources, and it is their management, rather than their existence, that should be contested.

Novel research

The analyses performed in this collaborative exercise to evaluate vertebrate protection status have little novel value. However, the compilation of national species databases serves its purpose in the design of reserves, and may prove valuable in the land-allocation procedures of the Reconstruction and Development Programme (RDP) of the new Government of National Unity. National collaboration among South Africa's biologists could be of great value to government decision-makers in the future.

There is also scope for the testing of novel new hypotheses regarding species-energy theory (Wylie & Currie 1993), and the dynamics of ecosystems (Holling 1992). As suggested by Chown & McGeoch (in press), South African biologists should not ignore their growing data resources in the formulation and testing of new hypotheses. It is hoped that the data and ideas generated by the following manuscripts may encourage such research.

Detailed methods

Details of all data and analyses used in the collaborative research papers in this volume are provided below.

Species distributions

Point localities of museum specimens, as well as published records, were collated for each of the taxa (excluding snakes and birds) by the museum participants. The resolution of data points was either degrees, minutes, and seconds (exact localities); degrees and minutes (~1,7 × 1,7 km cells); or quarter-degree squares (QDS = 15' × 15'). No range maps were used. The final databases were not complete, and additional databases do exist in other South African, as well as international, museums. Owing to time constraints and administrative difficulties, these databases could not be incorporated into the analyses, but this problem can be addressed in future, and the existing databases can easily be updated for further analyses. The provision of funds to the museums for the purpose of computerizing their collections would greatly facilitate future research.

The snake and bird databases were compiled from sources outside of museums. Snake distribution data were digitized at the FitzPatrick Institute from QDS maps published by Broadley (1990). Bird data were obtained from the Southern African Bird Atlas Project (SABAP). These data were also at a QDS scale of resolution, and data were obtained only for the 595 species that breed within South Africa (Phil Hockey, pers. comm.).

After compilation, all data were converted to presence-only of species per QDS, to facilitate analyses at one scale. The size of the mapping unit used in species mapping can have severe consequences for conservation prioritization (Stoms 1994), but in the present study analyses had to be conducted at the size of the coarsest mapping unit encountered in the databases.

Biome data

A digital map of the biomes defined by Rutherford & Westfall (1986) was used. The forest biome was excluded because forests occur at a scale finer than a QDS, and all species and reserve data were at a QDS scale. An Alber's equal area projection was used for all spatial analyses.

Reserves

A digital map of the boundaries of the existing, publicly owned protected areas in South Africa was compiled from data obtained from the Department of Environmental Affairs and Tourism, GISlab (Department of Landscape Architecture, University of Pretoria), Eastern Cape Nature Conservation, Natal Parks Board, and Forestek (CSIR Division of Forest Science and Technology). The scale of the base maps ranged from 1:50000 to 1:250000. The final database was incomplete, and an additional database, compiled by the FitzPatrick Institute and updated by the Avian Demography Unit, was used. This database was at a QDS scale, with reserves coded as present or absent in QDS, but was more complete than the boundary map.

Data analyses

All digital data were loaded into a geographic information system (GIS - ARC/INFO version 6. 1. I., Environmental Systems Research Institute, Redlands, California) at the Fitz-Patrick Institute. Digital distribution maps were produced for each species, and final maps were verified by the museum participants. All overlay and hotspot analyses were performed by the GIS, and all reserve selection analyses were undertaken in dBASE using the algorithm developed by Rebelo & Siegfried (1992).

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