PATTERNS OF ANIMAL ENDEMISM IN THE MAPUTALAND-PONDOLAND-ALBANY BIODIVERSITY HOTSPOT

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As the candidate's Supervisor, I have approved this thesis for submission.

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ABSTRACT

The Maputaland-Pondoland-Albany (MPA) hotspot, as is the case of all such global biodiversity hotspots, has primarily been recognised based on its high floristic endemism and delimited intuitively. Boundaries of global biodiversity hotspots have seldom been empirically tested in terms of species distribution patterns and only a few have been examined for patterns of animal endemism. This thesis presents the results of a zoogeographical study of all five major vertebrate groups and selected invertebrate groups in south-eastern Africa, refining the delimitation of the MPA hotspot and identifying areas and centres of endemism within and around it. It also provides zoogeographical regionalisation schemata for the whole of south-eastern Africa. The study employed methods of, (a) preliminary qualitative identification of "Endemic Vertebrate Distributions", (b) phenetic clustering of operational geographical units based on species incidence matrices, using the Jaccard's coefficient of similarity and the Unweighted Pair-Group Method using Arithmetic means (UPGMA) clustering algorithm, (c) Parsimony Analysis of Endemicity, and (d) ArcGIS-based mapping of various measures of endemism (e.g. narrow endemism and weighted endemism).

The results reveal that the MPA hotspot, though defined so due to its exceptional floristic endemism, is a hotspot for the endemism of animals too, especially for the herpetofauna and invertebrate groups like the velvet worms, land snails and many others. But the current boundary of the hotspot is arbitrarily defined and not exactly matching the patterns of animal endemism (and, likely, neither those in plants). Hence, a greater Maputaland-Pondoland-Albany (GMPA) region of animal endemism is proposed as a broad priority region of conservation concern, while centres of endemism within the GMPA are identified and patterns of quantitative measures of endemism are mapped. The study also proposes a zoogeographical regionalisation placing the GMPA and Highveld regions at the province rank in the global zoogeographical hierarchy, within the south east African dominion, also describing zoogeographical districts and assemblages nested within each. Results from the vertebrate and invertebrate analyses reveals the possibility of a common zoogeographical regionalisation for south-eastern Africa. The study emphasises the importance of quantitative biogeographical methodologies in conservation biogeography, in addition to their uses in the theoretical/descriptive biogeography.

PREFACE

The work described in this PhD thesis was carried out in the School of Agricultural, Earth and Environmental Sciences, University of KwaZulu-Natal, Durban, from June 2009 to March 2013, under the supervision of Professor Şerban Procheş.

These studies represent original work by the author and have not otherwise been submitted in any form for any degree or diploma to any tertiary institution. Where use has been made of the work of others, it is duly acknowledged in the text.

DECLARATION 1 – PLAGIARISM

I, MERENNAGE SANDUN JAYALAL PERERA, declare that

1. The research reported in this thesis, except where otherwise indicated, is my original research.

2. This thesis has not been submitted for any degree or examination at any other university.

3. This thesis does not contain other persons' data, pictures, graphs or other information, unless specifically acknowledged as being sourced from other persons.

4. This thesis does not contain other persons' writing, unless specifically acknowledged as being sourced from other researchers. Where other written sources have been quoted, then:
    a. Their words have been re-written but the general information attributed to them has been referenced
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5. This thesis does not contain text, graphics or tables copied and pasted from the Internet, unless specifically acknowledged, and the source being detailed in the thesis and in the References sections.

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DECLARATION 2 – PUBLICATIONS

Publication 1 [Chapter 2]

Perera, S.J., Ratnayake-Perera, D. & Procheş, Ş. (2011) Vertebrate distributions indicate a greater Maputaland-Pondoland-Albany region of endemism. *South African Journal of Science* **107**: 49-63. doi:10.4102/sajs.v107i7/8.462

Author contributions: Ş.P. and S.J.P. conceived the ideas and led the writing; S.J.P. and D.R-P. collected and analysed the data.

Publication 2 [Chapter 3]

Perera, S.J., Procheş, Ş. & Ratnayake-Perera, D. (in review) A biodiversity hotspot numerically revisited based on vertebrate Endemism.

Submitted to *Journal of Biogeography*

Author contributions: S.J.P. and Ş.P. conceived the ideas and led the writing; S.J.P. and D.R-P. collected and analysed the data.

Publication 3 [Chapter 4]

Perera, S.J., Procheş, Ş. & Herbert, D.G. (in preparation) A hotspot for invertebrates too: numerical analyses on the distribution of selected lineages in south-eastern Africa

Formatted for *Journal of Biogeography*

Author contributions: S.J.P. and Ş.P. conceived the ideas and led the writing; S.J.P. collated and analysed the data, while D.G.H. provided the data and technical expertise on land snails. All authors discussed the results and contributed to writing.

Publication 4 [Chapter 5]

Perera, S.J., Ramdhani, S., Procheş, Ş. & Navarro, R.A. (in preparation) Herpetofaunal zoogeography and endemism in eastern South Africa, Lesotho & Swaziland

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Author contributions: S.J.P. and Ş.P. conceived the ideas; RAN provided the data. S.J.P. collated the data which were then analysed by S.J.P. and S.R., S.J.P., Ş.P. and S.R. led the writing while all authors discussed the results and contributed to writing.

Conference presentations (Published abstracts)

Appendix 1: Perera, S. J. (2010) A preliminary assessment of areas of vertebrate endemism in south-east Africa. *Faculty of science and agriculture postgraduate research day, University of KwaZulu-Natal*. 23 September 2010, Pietermaritzburg, South Africa. p. J9.

Appendix 2: Perera, S.J., Ratnayake-Perera, D. & Procheş, Ş. (2011) A greater Maputaland-Pondoland-Albany region of vertebrate endemism, In Conference Abstracts: South African Association of Botanists – Annual Meeting 2011. *South African Journal of Botany* **77**, 550-551. doi:10.1016/j.sajb.2011.03.003

Appendix 3: Perera, S. J. (2013) "Hottest spots" in a hotspot: patterns of animal endemism in and around the Maputaland-Pondoland-Albany biodiversity hotspot. *Student Conference on Conservation Sciences, University of Cambridge*. 19-21 March 2013, Cambridge, United Kingdom.

An additional publication

Appendix 4: Clark, V.R., **Perera, S.J.**, Stiller, M., Stirton, C.H., Weston, P., Stoev, P., Coombs, G., Morris, D.B., Ratnayake-Perera, D., Barker, N.P. & MacGregor, G.K. (2012) A rapid multi-disciplinary biodiversity assessment of the Kamdebooberge (Sneeuberg, Eastern Cape, South Africa): implications for conservation. *SpringerPlus* 1:56 doi:10.1186/2193-1801-1-56

Description and my contribution: This paper is not directly contributing to the arguments discussed in the thesis. But it describes a field-based rapid asessment of a section of the Sneeuberg, which this thesis identifies as a distinct zoogeographic unit with an uncertain zoogeographical affinity, partly because the biodiversity of the area is largely unexplored. I contributed to this study by coordinating the faunal rapid assessment in the field, and writing up the section on the vertebrate fauna.

N.B. Chapter 2 and the Appendix 4 are given in the thesis in their published form. All the chapters except for 1, 2 and 6 are submitted to or formatted for *Journal of Biogeography* or *Diversity and Distributions*. Hence, all the references given in the thesis follow the common format for references for the above journals, except in Chapter 2 and Appendix 4, published elsewhere.

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Prof. Urmilla Bob and Vadi Moodley of the School of Agricultural, Earth and Environmental Sciences and their families are thanked for all their support throughout, while all the staff of the School is acknowledged for all sorts of assistance during this work, and the administrative support.

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Among many other mentors to me, Prof. Sarath Kotagama and Channa Bambaradeniya stand out, who inspired me to join and stay in the field of biodiversity conservation and the academia. In the latter respect I thank Prof. Mahinda Rupasinghe for the initiation of the Natural Resources Department in SUSL then at its infancy, only with four lucky students, including me. My gratitude to you, including many more teachers who taught me about science and life.

This achievement is a heartfelt gift of thanks to my parents; Rupa and Sarath Perera, for letting me take an uncertain path in life, exclusively on my interest, after all their efforts in bringing me up and providing education.

This thesis is dedicated to;

Nilu (Dayani), my wife, who was behind (but, indeed ahead of) me all the way through, for her unconditional love and patience, especially during the last few long years

&

Sārinda our son, who was born while this work is in progress and enlightened our lives

You two added to this work, much more meaning than the words can ever say…

Sandun J. Perera

March 2013, Westville, Durban

Whatever living beings there are,

fearful or fearless,

long, large, medium, or small - minute or massive,

seen or unseen

remote or living nearby,

born or seeking birth:

May all beings be blissful and happy in themselves!

excerpt from Karanīya Metta Sutta

(translated from Pāli)

TABLE OF CONTENTS

CHAPTER 1

General Introduction

Biogeography, the study of spatial distribution patterns of biological diversity, both past and present, fundamentally seeks to understand which species live where, why and why not elsewhere? (see Quammen, 1996; Humphries & Parenti, 1999; Huggett, 2004; Cox & Moore, 2005; Lomolino *et al.*, 2006). The discipline crosses paths with evolutionary biology, ecology, geography and systematics (Fosberg, 1976; Huggett, 2004). It is growing from the seminal work of regionalising the Earth based on bird and mammal distributions by Sclater (1858) and Wallace (1876), and that of evolutionary thinkers in 18th and 19th centuries (Fosberg, 1976; Huggett, 2004; Lomolino *et al.*, 2006). Fosberg (1976) distinguished three major fields within the discipline: (a) faunistic and floristic biogeography (chorology) - describing the spatial patterns of plant and animal distributions, (b) ecological biogeography, and (c) historical biogeography. The last two, first distinguished from each other by de Candolle (1820) explain the reasons for patterns observed in (a). In a modern perspective, the difference between ecological and historical biogeography can mainly be attributed to the spatial and temporal scales of analysis, where historical biogeography deals with much larger areas over much longer periods of time (Myers & Giller, 1988; Huggett, 2004).

In dealing with the first, descriptive, aspect, biogeographers have been using increasingly advanced methods to identify (a) biogeographical regions (i.e. regions characterised by distinct assemblages of species, as adapted from Wallace, 1894; also see Cox, 2001; Kreft & Jetz, 2010) and (b) areas of endemism (AOEs, i.e. areas characterised by the congruent distribution of at least two endemic species; Nelson & Platnick, 1981; Rosen, 1988; Platnick, 1991; also see Linder, 2001; Crother & Murray, 2011). Subsequently, they attempted to explain their results using key biogeographical processes such as dispersal, vicariance, speciation/radiation, relictual/refugial survival, and extinction (Huggett, 2004; McDowall, 2004; Lomolino *et al.*, 2006). Among them, perhaps the most disputed aspect was assessing the relative importance of vicariance and dispersal in explaining present-day disjunct distributions (see Stace, 1989; Zink *et al.*, 2000). Nevertheless, concepts such as biogeographic regions and AOEs are fundamental, pertaining to the descriptive biogeography of any particular area (Kreft & Jetz, 2010).

Regionalisation: from intuitive to numerical

Biogeographic regionalisation is the process of classifying geographic units according to their species assemblages, and, by derivation, the outcome of this process, presented in the form of maps (Cox, 2001; Lomolino *et al.*, 2006; Mackey *et al*., 2008; Procheş, 2008; Kreft & Jetz, 2010). It is methodologically similar to systematic biology, akin to taxonomists classifying organisms based on their morphological and/or molecular characters (Kreft & Jetz, 2010). Regionalisations are key to the theoretical understanding of ecological and historical biogeography − besides applications in evolutionary biology, systematics and conservation (Procheş, 2008; Morrone, 2009; Kreft & Jetz, 2010). The initial global studies on the distribution of biota marked the very beginnings of biogeography. Based on their expertise in taxonomy and faunas/floras, the early biogeographers delimited initial global regions purely on intuitive grounds (Sclater, 1858; Wallace, 1876 for animals, and Engler, 1879–1882; Good, 1974; and Takhtajan, 1978, 1986 for plants). The ability of the human eye and mind to identify patterns from large amounts of factual and visual data ("perception or intuitive discernment"; White, 1993) has been the commonly used tool in the geographical regionalisations of early times. From their initial intuitive attempts biogeographers also realised that only a hierarchical system of biogeographic units can make sense of the distribution of life on Earth (see McLaughlin, 1992). With an increasing number of intuitive regionalisations and differences between them, a need arose for objective and repeatable methods in their identification. This in turn influenced the development of quantitative biogeography (Crovello, 1981; Birks, 1987), using numerical methods of analyses (ordination and hierarchical clustering; Kent, 2006) to classify areas according to their biotic assemblages. Hence, subsequent global/continental regionalisations involved numerical analyses on the incidence of biota in operational geographic units (OGUs; Crovello, 1981) within their study areas (e.g. Williams *et al.*, 1999; de Klerk *et al.*, 2002; Linder *et al.*, 2005, 2012; Procheş, 2005, 2006; Heikinheimo *et al.*, 2007; Kreft & Jets, 2010; Procheş & Ramdhani, 2012; and Holt *et al.*, 2013). These regionalisations vastly increased the understanding of global patterns of biological diversity, also showing the possibility of a single global "bio"-geographical regionalisation involving both the plants and animals (Procheş & Ramdhani, 2012). Furthermore, Holt *et al*. (2013) recently linked the phylogenetic relationships among species to the data on their distributions in a global regionalisation analysis thus providing insights into historical relationships among the resulting regions, and also identifying evolutionarily unique regions of the world.

While the global picture is now coming together, much work is needed in biogeographic regionalisations at the regional/local scales. This raises problems with the availability and quality of data, fine-scale species distribution databases being incomplete and/or biased due to lack of uniform sampling throughout the study areas (e.g. Reddy & Dávalos, 2003; Botts *et al*., 2011 for Africa).

Nevertheless, the use of atlas data and museum-based informatics are currently contributing immensely to better-quality distribution data (Graham *et al*., 2004; Meier & Dikow, 2004; Robertson *et al*., 2010), and many such are now made available electronically [e.g. The Virtual Museum, for southern Africa (ADU, 2013); Atlas of breeding birds in Britain and Ireland (BTO, 2013); The EBCC atlas of European breeding birds (Hagemeijer and Blair, 1997); Breeding bird atlases in the U.S. & Canada (USGS & NBII, 2013)]. The field of biogeographical regionalisation is thus placing much emphasis on regional/local scales and reaching deeper levels of biogeographic hierarchy (i.e. "biogeographic assemblages"; also see Ebach *et al.*, 2008), and the process is facilitated by new developments in the field of Geographic Information Systems and enhanced computer power for the analysis of large datasets.

Endemism in theoretical and conservation biogeography

Endemism, the restriction of the natural range of a taxon to a well-defined geographical area for historical, ecological or physiological reasons (Major, 1988; Anderson, 1994; Gaston, 1994; Cowling & Samways, 1995; Crisp *et al.*, 2001; Laffan & Crisp, 2003) is central to both historical biogeography (Morrone & Crisci, 1995) and conservation biogeography (Whittaker *et al*., 2005; Ladle & Whittaker, 2011). According to the classical biogeographical perspective, an endemic taxon is restricted to a particular geographical area, irrespective of whether the area is large or small (Major, 1988; Anderson, 1994; Huggett, 2004). More often nowadays, endemism is interpreted as a form of rarity – namely range-restricted rarity (Gaston, 1994; Cowling, 2001). However, the geographic context of endemism still needs to be defined wherever referred to, providing clear taxonomic and geographical references (Anderson, 1994).

While species are widely accepted as operational taxonomic units, OGUs vary across analyses in quantitative biogeography (Crovello, 1981). The current trend is to establish equal-area OGUs by placing a grid overlay on a map of the study area (e.g. Williams *et al.*, 1999; de Klerk *et al.*, 2002; and Linder *et al.*, 2005, 2012 for Africa; and Procheş, 2005, 2006; Kreft & Jetz, 2010; and Holt *et al.*, 2013 at global scale). Such units are free of predetermined biogeographical meaning and require a minimum of assumptions (Ramdhani *et al.*, 2008; Procheş & Ramdhani, 2012). However, for historical biogeography, ideal OGUs should be natural geographic units that harbour exclusive assemblages of species, analogous to a combination of unique characters defining a species in taxonomy. In this context, AOEs are useful OGUs in historical biogeography, especially in cladistic-based approaches (Humphries & Parenti, 1999; Huggett, 2004; Lomolino *et al*., 2006).

Centres of endemism (not to be confused with AOEs describe before); areas where (narrow) endemic species concentrate, usually having more endemics in comparison to the surrounding areas and often termed as ‘hotspots’ (Myers, 1988, 1990; Williams *et al.*, 1996; Linder, 1998; Myers *et al*., 2000; Linder, 2001; Crisp *et al*., 2001; Laffan & Crisp, 2003; Jetz *et al.*, 2004), are of particular interest for conservation biogeographers. Geographic mapping to identify peaks for different measures of endemism calculated for each OGU also provide insights into where conservation attempts should be focused (Cowling & Samways, 1995; e.g. Crisp *et al*., 2001; Laffan & Crisp, 2003; Huang *et al.*, 2008). These include direct measures, such as the absolute number of endemics, the number of endemic species as a percentage of the species richness (Cowling & Samways, 1995), the number of narrow endemics (Linder, 2001), various calculations evaluating endemism as a continuous variable: range-restricted rarity (i.e. the proportion of taxa with a range size lower than the average among all taxa in the area concerned; Cowling, 2001), weighted endemism (i.e. the sum of the inverse range sizes of all taxa within area concerned (Williams *et al*., 1994; Crisp *et al.*, 2001), and others.

Conservation biogeography, endemism and global conservation priorities

Biodiversity on Earth is now facing a crisis unprecedented in 65 million years, as the natural but irreversible process of extinction has markedly been accelerated by anthropogenic impacts (Pimm *et al.*, 1995; Vitousek *et al.*, 1997; Mittermeier *et al.*, 1998). Mass extinctions of this magnitude have only previously occurred five times in Earth’s history, all due to natural causes (Raup & Sepkoski, 1982). A number of 737 animal and 121 plant species have been documented as extinct, and a lot more have presumably gone extinct before even being described, while 31% of the extant animal and plant species assessed are found to be threatened with extinction (IUCN, 2012). Given the fact that the global distribution of biodiversity is uneven (Gaston, 2000), it has been suggested to set global conservation priorities to conserve what is possible within minimum time, without trying to save everything (Reid & Miller, 1989; McNeely *et al.*, 1990; Margules & Pressey, 2000). In order to curtail the extinction crisis, it is essential to target the areas with the highest need for, and maximum payoff from, conservation efforts globally (Myers *et al*., 2000; Mittermeier *et al.*, 2004). Such a priority-setting approach developed on a scientific basis (e.g. systematic conservation planning; Margules & Pressey, 2000) can also create more public acceptance for conservation decision making (Johnson, 1995). Biogeographical principles have increasingly been used by conservationists, making biogeography one of the key disciplines relevant to conservation biology, and hence giving birth to a new field of study, that of conservation biogeography (Vane-Wright *et al*., 1991; Eldredge, 1992; Forey *et al.*, 1994; Humphries & Parenti, 1999; Margules & Pressey, 2000; Seymour *et al*., 2001;

Araújo *et al*., 2005; Whittaker *et al*., 2005; Lomolino *et al*., 2006; Brooks *et al*., 2006; Ladle & Whittaker, 2011).

Conservation implications of endemism

Systematic conservation planning involves assessing (a) the representativeness of the protected area network (extent to which the network includes all the natural features of the region; Austin & Margules, 1986; Rojas, 1992; Margules *et al*., 2002), that can be achieved through the complementarity of biotic assemblages across protected areas in the network (e.g. Global 200 Ecoregions approach; Olson & Dinerstein, 1998), and (b) irreplaceability of protected areas (the extent to which the representativeness of the network is lost if the particular site is lost; Pressey *et al*., 1994), that can be achieved through the inclusion of protected areas with narrowly endemic and vulnerable biota that cannot be found elsewhere (e.g. Biodiversity Hotspots; Myers *et al*., 2000; Mittermeier *et al.*, 2004; and the Endemic Bird Areas; Stattersfield *et al*., 1998). Endemics are more vulnerable to extinction (Pimm *et al*., 1995). Therefore, endemism hotspots (areas with high congruence of endemic taxa, with a particular emphasis on narrow endemism) are identified as priorities in conservation planning, where a small investment can yield the maximum profit in terms of species conservation (Myers, 1988, 1990; Myers *et al*., 2000; Mittermeier *et al.*, 2004; Stattersfield *et al*., 1998). Biogeographers' involvement is thus critical, as they can provide accurate delimitation and historical explanations relevant for preserving the functioning of such centres of endemism (Lomolino *et al*., 2006).

Global conservation prioritisation and the Biodiversity Hotspots

Several attempts have been made to set geographic conservation priorities globally, towards the allocation of the limited available conservation funding (Johnson, 1995; Wilson *et al*., 2006). Some notable approaches included the Biodiversity Hotspots (Myers, 1988, 1990; Mittermeier *et al.*, 1998; Myers *et al*., 2000; Mittermeier *et al*., 2004), where species- and especially endemic-rich ecosystems under imminent threat are selected; Endemic Bird Areas (Birdlife International − Bibby *et al*., 1992; Stattersfield *et al*., 1998); Global 200 Ecoregions (Olson & Dinerstein, 1998) identified on the basis of representativeness; Tropical Wilderness Areas (McCloskey & Spalding, 1989; Mittermeier *et al*., 1998), aimed at maintaining evolutionary process; and Megadiversity Nations (Mittermeier *et al*., 1997) − countries that are unusually rich in biodiversity.

Despite the numerous limitations of the biodiversity hotspots approach (see Ginsberg, 1999; Brummitt & Lughadha, 2003; Ovadia, 2003; Orme *et al*., 2005; Ceballos and Ehrlich, 2006; Grenyer *et al*., 2006), it can hardly be denied that it has made a significant impact on global conservation. Conservation International and the MacArthur foundation adopted Myers' hotspots as the guiding approach for their conservation investment, making them receive the largest financial investment for any single conservation strategy (Myers, 2003; Myers and Mittermeier, 2003). Biodiversity hotspots have been designated using a biological criterion of floristic endemism, i.e. the area must contain at least 0.5% of the world's vascular plant species (1 500 species) as endemics, in addition to a threat criterion where 70% or more of the primary vegetation of the area must have been lost due to human impact (Myers, *et al*., 2000; Mittermeier *et al*., 2004). This means that animal endemism *per se* has not been critical for hotspot selection. Nevertheless, vertebrates are being assumed to follow a similar pattern of endemism to higher plants (Myers *et al*., 2000).

South-east African context

Regionalisation

Zoogeographical interest on south-eastern Africa dates back to Poynton (1960, 1961), who initially identified a broad transition zone of amphibian zoogeography in this area, between the Afrotropical fauna of East Africa and the southern temperate fauna of the Cape. Poynton (1961) further elaborated on the transitional nature of the area's biota by adding preliminary observations on plants, other vertebrates, as well as some invertebrate taxa into his discussion, and also emphasising the biogeographical importance of the area for further studies. Nevertheless, the subtropical coastal belt of south-eastern Africa, the adjacent escarpment and the Highveld region further inland have not received particular attention in subsequent biogeographical studies (all of which were of continental or southern African regional focus). The region harbours a heterogeneous mosaic of habitats including matrices and patches of subtropical (Albany) thicket, savanna, grassland, (Afromontane) forest, and the Indian ocean coastal belt biomes (the last one, itself a patchwork, Mucina and Rutherford, 2006). Similar to the scenario in global biogeography, African biotic regions were initially identified by visual sorting and matching of geographical ranges of taxa, based on perception or intuitive discernment (Poynton, 1964, 1999; White, 1983, 1993; van Wyk & Smith, 2001), and later involved multivariate cluster analyses: Linder (1998) and Linder *et al*. (2005) for plants, and Crowe & Crowe (1982), Guillet & Crowe (1985, 1986), Crowe (1990), Turpie & Crowe (1994), Seymour *et al*. (2001), de Klerk *et al*. (2002) and Alexander *et al*. (2004) for vertebrates. A simultaneous analysis of combined taxa was not attempted until recently (Linder *et al*., 2012), and when done it used 1° squares, too coarse to pick sub-regional patterns and areas of narrow endemism. No attempt has yet been made to produce a numerical regionalisation of the area for invertebrates, except for the intuitive approaches by Endrödy-Younga (1978) and Herbert & Kilburn (2004).

Endemism

The floristic diversity and endemism is not evenly spread over southern Africa, but concentrated mainly along and below the Great Escarpment, as demonstrated by the intuitively-defined centres of floristic endemism (Cowling & Hilton-Taylor, 1994; van Wyk & Smith, 2001). Although similar diversity and endemism patterns are indicated in animals in some of the biogeographical studies mentioned above, the faunistic endemism in the area has not received enough attention, and areas/centres of endemism are not well-established.

Biodiversity Hotspots

Three of the 34 global biodiversity hotspots: the Cape Floristic Region, the Succulent Karoo and the Maputaland-Pondoland-Albany (MPA) are either within South Africa or extending marginally into neighbouring countries. The MPA hotspot is a region stretching along the east coast of southern Africa, below the south-eastern section of the Great Escarpment. It is an important centre of plant endemism, being home to 1,900 endemic species (Steenkamp *et al*., 2004). The boundaries of MPA hotspot follow van Wyk & Smith's (2001) Maputaland-Pondoland region and the Albany centre of plant endemism, while the Maputaland-Pondoland region corresponds broadly to the delimitation of the White's (1993) Tongaland-Pondoland Regional Mosaic. None of these is based on rigorous analyses of species distribution ranges.

Outline of the thesis

Boundaries of many biodiversity hotspots including the MPA have not been empirically tested in terms of species distribution patterns and only a few hotspots have been examined for their patterns of animal endemism. While refining the delimitation of the MPA hotspot through a zoogeographical analysis, this thesis attempts to contribute to the understanding of the regional zoogeography and identify local conservation priorities within and around the hotspot, adopting an objective and analytical approach based on animal endemism.

Even though the main focus of this thesis is on the MPA hotspot, faunal regionalisation and patterns of endemism are addressed for south-eastern Africa as a whole. South-eastern Africa is delimited here by artificial latitude-longitude boundaries, but the choice of these boundaries is influenced by natural biogeographical barriers. The eastern section of the Cape Floristic Region is also included into the study area in order to account for the Knysna transition zone, as many south-east African taxa extend their ranges in this direction. An analysis on an area larger than the MPA hotspot is of particular importance to understand its biogeographical links and natural boundaries.

Considering all these points, the aim of the thesis is to produce a detailed comparative picture of animal endemism and regional species assemblage patterns in south-eastern Africa, with emphasis on the Maputaland-Pondoland-Albany biodiversity hotspot. Specific objectives are to (1) analytically evaluate the boundaries of the hotspot, (2) illustrate patterns of endemism within the area, (3) describe the area in terms of hierarchical biogeographical regionalisation, (4) assess to what extent qualitative methods, applicable in other hotspots with poorer species distribution data, can be confirmed quantitatively, (5) compare vertebrate and invertebrate patterns, and (6) compare regionalisation results when employing different methods and different types of OGUs.

Chapter 2 of the thesis starts by documenting vertebrate diversity and endemism within the MPA hotspot as currently defined, reviewing the latest available literature. It subsequently uses several qualitative rules to set the geographic template for numerical analyses, discussed in the next three chapters. Here Endemic Vertebrate Distributions (EVDs) are delimited through a qualitative method involving overlapping species range maps. EVDs are then used to discuss the adequacy of the current boundary of the MPA hotspot for animal distributions, proposing a greater MPA (GMPA) region of endemism. EVDs are also used in proposing a set of zoogeographical units, which become OGUs in Chapter 3 for a numerical analyses (phenetic approach: hierarchical cluster analysis) on species incidence data of endemic terrestrial and freshwater vertebrates. The earlier qualitative delimitation of the GMPA region is here quantitatively evaluated. This chapter also proposes a preliminary zoogeographical regionalisation for south-eastern Africa. Repeating the same procedures, Chapter 4 analyses a distribution database of selected invertebrate groups, seeking confirmation that the GMPA is a region of animal endemism (for both the vertebrates and invertebrates). Similar to the above, this chapter produces a first ever numerical regionalisation for invertebrates in south-eastern Africa, involving lineages that show a high degree of endemism within the area. This chapter, for the first time in the thesis uses a parsimony approach (Parsimony Analysis of Endemicity) to numerically establish invertebrate AOEs. Since predefined OGUs are used in the first three chapters of the thesis, there is a need to confirm results of above analyses with one using equal-area OGUs, while keeping in mind the data incompleteness problems these incur. Therefore, in Chapter 5, the distribution of herpetofaunal species is analysed, this being a group with both high endemism in south-east Africa and comparatively good data in the form of online atlases, using quasi-equal-size units (half-degree-squares) as OGUs. The chapter presents robust analyses using both the phenetic and parsimony approaches, to illustrate the herpetogeographic regionalisation and the areas of endemism respectively.

Thus, in the relevant respective chapters, the thesis provides relevant faunal regionalisations at finer geographic resolution, and reaching deeper levels of the biogeographic hierarchy than any previous studies. Animal endemism remains the key feature in all the chapters of this thesis, and hence the patterns observed for several quantitative measures of endemism are used throughout in establishing centres of endemism that are of conservation importance for the taxa relevant in each chapter. Chapter 6 concludes the thesis with a synopsis of findings especially emphasising (a) patterns of animal endemism in and around the MPA hotspot, leading to the delimitation of the GMPA region of animal endemism and (b) zoogeographical regionalisation of south-eastern Africa. This chapter also comparatively discusses the biogeographical methods used, as well as future prospects for biogeographical and conservation research in the area.

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Vertebrate distributions indicate a greater Maputaland-Pondoland-Albany region of endemism

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The Maputaland-Pondoland-Albany (MPA) biodiversity hotspot (~274 316 km^2) was primarily recognised based on its high plant endemism. Here we present the results of a qualitative biogeographical study of the endemic vertebrate fauna of south-eastern Africa, in an exercise that (1) refines the delimitation of the MPA hotspot, (2) defines zoogeographical units and (3) identifies areas of vertebrate endemism. Initially we listed 62 vertebrate species endemic and 60 near endemic to the MPA hotspot, updating previous checklists. Then the distributions of 495 vertebrate taxa endemic to south-eastern Africa were reviewed and 23 endemic vertebrate distributions (EVDs: distribution ranges congruent across several endemic vertebrate taxa) were recognised, amongst which the most frequently encountered were located in the Eastern Escarpment, central KwaZulu-Natal, Drakensberg and Maputaland. The geographical patterns illustrated by the EVDs suggest that an expansion of the hotspot to incorporate sections of the Great Escarpment from the Amatola-Winterberg-Sneeuberg Mountains through the Drakensberg to the Soutpansberg would be justified. This redefinition gives rise to a Greater Maputaland-Pondoland-Albany (GMPA) region of vertebrate endemism adding 135% more endemics with an increase of only 73% in surface area to the MPA hotspot. The GMPA region has a more natural boundary in terms of EVDs as well as vegetation units. An accurate delimitation of this hotspot, as well as a better understanding of biogeography in the region, would greatly benefit conservation planning and implementation. Towards these aims, we used EVDs to delimit non-overlapping zoogeographical units (including 14 areas of vertebrate endemism), facilitating numerical biogeographical analyses. More importantly, this study opens up possibilities of refining hotspot delimitation and identifying local conservation priorities in regions of the world where data do not allow numerical analyses.

Introduction

Despite criticism over their selection and delimitation, biodiversity hotspots[1,2] have undeniably become a popular approach for prioritising conservation efforts globally,[3] as well as in South Africa.[4] Of the 34 global biodiversity hotspots, 3 are either within South Africa or extend marginally into neighbouring countries: the Cape Floristic Region, the Succulent Karoo and the Maputaland-Pondoland-Albany (MPA). In a broader context, southern Africa, defined as the area south of the Cunene, Okavango and Zambezi Rivers,[5] fully encompasses these three hotspots together with the southern parts of the Coastal Forests of Eastern Africa hotspot.[1] The major biological criterion for the designation of biodiversity hotspots is floristic endemism, that is, the area must contain at least 0.5% of the world's vascular plant species (1500 species) as endemics.[1,2] This means that animal endemism *per se* is not critical for hotspot selection, although vertebrates are most likely to become hotspot flagship species.[6]

The MPA biodiversity hotspot stretches along the eastern coast of southern Africa from Maputo in the north-east to Port Elizabeth in the south-west, extending inland towards the Great Escarpment.[7] In compliance with the criteria for defining biodiversity hotspots, it is an important centre of plant endemism, being home to 1900 endemic species.[5,7] The delimitation of floristic regions by White[8] and van Wyk and Smith[5] provided the basis for the original recognition of this hotspot. White's Tongaland-Pondoland regional mosaic has been extended further inland by van Wyk and Smith[5] as the Maputaland-Pondoland region of floristic endemism, to include the Afromontane elements below 1800 m a.s.l. along the Great Escarpment. In delimiting the MPA hotspot, Mittermeier et al.[2] followed the suggestion of van Wyk and Smith[5] and extended the Maputaland-Pondoland region in a south-westerly direction to the Albany centre, giving rise to a hotspot encompassing all three centres (Maputaland, Pondoland and Albany). Nevertheless, the hotspot has not yet been well documented in terms of its animal endemism, except for the species accounts given by Mittermeier et al.[2], those in the terrestrial vertebrate species database of Conservation International[9] and in the draft ecosystem profile of the hotspot.[10]

Even though the vertebrate fauna of southern Africa is relatively well studied, greater emphasis on vascular plants (with 60% species endemism)[5] and perhaps on large widespread mammals has overshadowed the broader picture of southern African vertebrate endemism (especially with regard to smaller vertebrates) in the scientific literature. A relatively strong correlation in global endemism patterns has been observed between plants and vertebrates,[11] although the congruence is not always high at regional scales (e.g. eastern Madagascar[12] and the Cape Floristic Region[13]). In the tropical forest hotspots of Africa (i.e. the Eastern Arc and the Coastal Forests of Eastern Africa), the patterns of plant endemism are matched by those of vertebrates, but this congruence is lower in the Cape Floristic Region, which has a Mediterranean-type climate.[1] It is yet to be tested whether the floristic endemism in south-eastern Africa, ranging from subtropical to temperate latitudes, will show congruence with patterns of vertebrate endemism.

Early phytogeographical studies of Africa have used intuitive chorological approaches to delimit floristic regions (phytochoria) and centres of floristic endemism,[5,8] and recent studies have tested their validity using multivariate cluster analyses.[14,15,16] In turn, vertebrate biogeography has addressed patterns in different vertebrate classes across Africa, initially by grouping species ranges qualitatively through visual sorting and matching,[17,18] and later by numerical cluster analyses on distribution data.[19,20,21,22,23,24,25] However, the databases used for most of the numerical analyses were incomplete and/or biased because various subjective factors were involved as a result of the lack of uniform sampling throughout the study areas. All these analyses were based on distribution patterns of taxa in single vertebrate classes (frogs,[17,18,23,25] large mammals[22] and birds[19,20,21,24]). Crowe[26] summarised faunal zones for several terrestrial vertebrate groups through numerical analyses, but used larger and different grid quadrats (~110 km × 110 km for water birds, ~220 km × 220 km for frogs, snakes and lizards, and ~400 km × 400 km for larger mammals and terrestrial birds), which may have been too coarse to pick up patterns of narrow endemism. No attempt has yet been made to delimit zoogeographical units or areas of endemism for the entire vertebrate fauna of southern Africa.

Therefore, this paper documents vertebrate diversity and endemism in the MPA hotspot as currently defined, using the latest available literature. Subsequently, distribution ranges that are congruent across several endemic vertebrate taxa in south-eastern Africa are identified and used (1) to discuss the adequacy of the current boundary of the MPA hotspot, and (2) to propose a set of non-overlapping geographical units for a rigorous numerical analysis of south-east African zoo-(bio-) geography. The results we present here are not based on any numerical analysis, and as such our methods can be replicated in regions of the world where data are scarce.

Methods

Study area

This paper focuses on south-eastern Africa, delimited in the west by the Nelspoort interval in the southern Great Escarpment[27,28] (about 24° E), and in the north by the northernmost loop of the Limpopo valley (about 22° S). The study area fully encompassed the MPA hotspot[7] and the Maputaland, Pondoland, Albany, Drakensberg, Barberton, Wolkberg, Sekhukhuneland and Soutpansberg centres of floristic endemism,[5] together with the Highveld and Bushveld bioregions,[29] to the west and north-west of the MPA, respectively, and the Lowveld and Mopane bioregions[29] in the north-east.

Assessment of vertebrate endemism

Vertebrate species richness and endemism within the MPA hotspot, and endemism only for south-eastern Africa, were assessed based on distribution data available in the literature. We used the latest available atlases as the primary sources of data for amphibians, reptiles and birds (with data at quarter degree square[30] scale, hereafter QDS), supplemented with other data where QDS data were not available. The use of data other than atlases is of particular importance (1) as sources of distribution data beyond the atlas regions of 'South Africa, Lesotho and Swaziland' for the herpetofauna, (2) to assess their endemicity in south-eastern Africa (see below for our definition of south-east African endemism) and (3) to assess whether the atlas records are of breeding populations or migrants in the case of birds. Freshwater fish distributions were sourced from Skelton[31,32] and further validated using *FishBase* (Froese and Pauly[33]). The amphibian atlas of Minter et al.[34], mirrored by the online Virtual Museum of the Animal Demography Unit, University of Cape Town, was supplemented with data from du Preez and Carruthers[35] and similarly the reptile atlas of the Southern African Reptile Conservation Assessment, available online (Animal Demography Unit[36]) was supplemented with data from Branch[37]. The original bird atlas of Harrison et al.[38], and updated atlas-based maps in Hockey et al.[39] were used as sources of bird data, whilst the comprehensive treatment by Skinner and Chimimba[40] was used for mammals, as the mammal data in the online Virtual Museum of the Animal Demography Unit is as yet far from complete. Museum databases were not considered in the cases of freshwater fish and mammals, as they are particularly incomplete and collection biases are prominent, especially in freshwater fish. Species taxonomy follows the latest treatment mentioned above for each taxon, that is Froese and Pauly[33] for freshwater fish, du Preez and Carruthers[35] for amphibians, Animal Demography Unit[36] (as at 31 January 2010) for reptiles, updated following Kelly et al[41] for the family Lamprophiidae, Hockey et al.[39] for birds, and Skinner and Chimimba[40] for mammals, whilst other sources[42,43,44] were used in updating familial-level taxonomy.

Vertebrate species richness and endemism in the MPA hotspot

We compiled checklists of vertebrate species for the MPA hotspot as currently defined, updated those available in the terrestrial vertebrate species database of Conservation International,[9] and produced a first checklist of freshwater fish species for the region. The list also includes the secondary freshwater species (coastal/estuarine species that also occur in fresh water, excluding the stragglers or sporadic marine fishes that are sometimes found living, but not breeding, in inland waters[31]). Besides endemic species, near-endemic species were also listed for the hotspot, as they are important in recognising biogeographical links between the hotspot and surrounding regions. MPA near endemics were defined as those species with more than 50% of their range within the hotspot, and extending outside the hotspot only marginally (e.g. bush blackcap, *Lioptilus nigricapillus* and Natal red rock rabbit, *Pronolagus crassicaudatus*) and/or with small distant satellite populations outside it (e.g. Natal mountain catfish, *Amphilius natalensis*; Phongolo suckermouth, *Chiloglanis emarginatus*; and laminate vlei rat, *Otomys laminatus*). In order to minimise subjectivity in including or excluding marginal species, those that occurred along the boundary of the hotspot were included only if they showed a prominent association with habitat types that occur within the hotspot.

Vertebrate taxa endemic to south-eastern Africa

In order to correct for possible errors induced by having a latitude-longitude boundary for the study area when dealing with natural distribution ranges, we defined south-east African endemics as taxa with more than 50% of their extent of occurrence (at the QDS scale when data were available and approximately elsewhere) south of 22°S and east of 24°E. Therefore, even the taxa that cross 22°S and 24°E latitude-longitude boundaries were included in the analysis, as long as they were endemic to south-eastern Africa in a broader sense, and met the above criterion. Taxa endemic to the Cape Floristic Region and the Coastal Forests of Eastern Africa hotspots were excluded.

A database was compiled comprising all taxa endemic to south-eastern Africa. Taxa referred to here are species, whilst infraspecific taxa (subspecies, subspecies complexes and populations) were also taken into account wherever there was a considerable geographical disjunction. More specifically, a disjunct subspecies or subspecies complex isolated by a gap of more than one degree (~100 km) or a disjunct population (not recognised as a subspecies) isolated by a gap of more than 2 degrees (~200 km) or (in the case of freshwater fish) when found occurring in different major river systems that were not in contact under current drainage patterns, were included as a separate taxa. An exception was made for subspecies of range-restricted species endemic to south-eastern Africa, where subspecies were accepted as disjunct with a gap of more than 50 km.

The extent of occurrence of a given taxon was determined using records of naturally occurring breeding populations, excluding migrant and vagrant records as well as introduced (deliberately or unintentionally) and relocated populations extralimital to their natural range. Marine taxa were excluded from the analysis. The separation of terrestrial and freshwater taxa from marine taxa was self-explanatory in the case of marine mammals, pelagic sea birds and marine reptiles. In the case of fish, all taxa listed by Skelton[31] as freshwater or secondary freshwater taxa were considered. Any ambiguity in taxonomy or distribution, and difficulties in delimiting range boundaries (e.g. because of recent taxonomic revisions or single historical records not verified by recent extensive surveys) resulted in disqualifying the taxon or a particular record. The undescribed species listed by the Animal Demography Unit[36] and du Preez and Carruthers[35] were included when distribution data were provided and matched our criteria.

Precautions were taken when plotting bird distributions to minimise the bias caused by their higher dispersal ability compared to other vertebrates. Therefore, single outlying occupied QDSs were considered to be part of a taxon's extent of occurrence only if the reporting rate was more than 2% (see methods in Harrison et al.[38]). Single outlying occupied QDSs more than 200 km away from core populations were omitted from the extent of occurrence, and not considered as isolated populations. Isolated records/subpopulations of bird species that were widely but sparsely distributed, especially in the case of aquatic birds (e.g. spotted crake, *Porzana pusilla* and lesser jacana, *Microparra capensis*) were not regarded as disjunct. Bats (Order Chiroptera) were treated only at the species level, considering isolated records as parts of a single scattered population because they are long-distance flyers that are not easily detected and hence may have been overlooked. Disjunct populations of small mammals were also disregarded when disjunctions were likely to be the result of insufficient observations.

Identification of endemic vertebrate distributions

Distribution ranges that are congruent across several endemic vertebrate taxa are defined as endemic vertebrate distributions (EVDs). They often overlap each other, and hence cannot be used as exclusive biogeographical units, or considered for a hierarchical geographical analysis, but serve here as a first step in the qualitative grouping of distribution ranges. The EVDs were used in (1) identifying spatial relationships amongst endemic vertebrate assemblages, in an effort to refine the delimitation of the MPA hotspot and (2) delimiting non-overlapping geographical units for a hierarchical biogeographical analysis.

EVDs were detected through an extensive review of the distribution data followed by plotting, visual sorting and matching of distribution ranges. This qualitative method was developed based on the classical biogeographical methods of White[8] and van Wyk and Smith[5] for the flora, and Poynton[17,18] for amphibians. The subjectivity of the results obtained through this method can be reduced with wider experience, a critical outlook and possession of a good eye and memory.[45] Whilst White[45] emphasises the importance of subsequent rigorous analysis for intuitively defined biogeographical regions, subsequent analytical confirmations of such regions (e.g. Linder[14] and Linder et al.[15] for White's[8] phytochoria of Africa; Procheş[46] and Kreft and Jetz[47] for Wallace's[48] zoographical regions of the world) have added credibility to such methods. Where our study area is concerned, even though Poynton's[18] intuitively defined regions of amphibian biogeography are not exactly matched by those identified in the subsequent numerical analysis of Alexander et al.[25], the general biogeographical patterns were largely congruent. Further to that, it has been noted[49] that the frog atlas[34] representing the database for Alexander et al.[25] has some serious sampling biases and is of limited use for fine-scale analysis. Alexander et al.[25] themselves accepted this as a fact, using half-degree squares for their analysis, whilst the atlas provides data at the QDS scale. Thus, the discrepancies between Poynton's[18] and Alexander et al.'s[25] results may be attributed to data-related limitations, rather than to different methods.

Once the EVDs were delimited, every taxon selected for the study was then assigned to the narrowest of the EVDs encompassing all of its accepted breeding records, to assess the frequency of occupation of each EVD. The EVDs were then used in refining the delimitation of the MPA hotspot.

Delimitation of zoogeographical units

A set of non-overlapping zoogeographical units was designed based on (1) the core regions of EVDs (delimited adopting Linder and Mann's[50] method of 'mapping individual species distributions and seeking areas of overlap for range restricted taxa'), (2) the overlapping margins of EVDs and (3) the patterns of narrower endemism within broader EVDs. When borders of adjacent units thus delimited did not align with each other, the coverage of relevant EVDs was taken into consideration, and the borders were further adjusted using the boundaries of biomes and bioregions.[29] Amongst the zoogeographical units delimited, those harbouring two or more narrow-range endemic vertebrate species characteristic of them were treated here as areas of vertebrate endemism (AOVEs), following Nelson and Platnick's[51] definition for 'areas of endemism'.

Results

Vertebrate species richness and endemism in the Maputaland-Pondoland-Albany biodiversity hotspot as currently defined

A list of 1217 regularly occurring indigenous species of vertebrates (representing 586 genera in 184 families), including 62 (5.1%) endemic and 60 (4.9%) near-endemic species is provided for the MPA hotspot (Table 1). In addition, at least 51 bird species were recorded from the hotspot as vagrants, and at least 25 alien species were introduced to the hotspot and have well-established populations. Birds show the highest species richness within the MPA hotspot (668 naturally occurring species including vagrants), whilst the herpetofauna show the highest endemism (21.3% in amphibians and 14.3% in reptiles). Endemic and near-endemic vertebrates of the MPA hotspot are listed in Appendix 1, whilst a complete checklist of all vertebrates occurring in the hotspot is available as online supplementary material to this paper (vagrants and alien species excluded).

The ichthyofauna of the MPA hotspot includes narrow-range endemics such as the Amatola barb, *Barbus amatolicus* and the Border barb, *B. trevelyani* of the Amatola Mountains, the Eastern Cape rocky, *Sandelia bainsii* of Albany, the redtail barb, *Barbus gurneyi* and Tugela labeo, *Labeo rubromaculatus* of KwaZulu-Natal and the pennant-tailed suckermouth, *Chiloglanis anoterus* of Maputaland, together with the secondary freshwater endemics Sibayi goby, *Silhouettea sibayi* in Maputaland and the golden sleeper, *Hypseleotris dayi* along the coast of Maputaland and KwaZulu-Natal. The barbs in genus *Barbus* show the highest diversity and endemicity amongst fishes in the MPA hotspot with 18 indigenous species, 3 of which (mentioned above) are endemic and 2 are near endemic to the hotspot. The amphibian fauna of the MPA hotspot includes two endemic genera: the monotypic genus *Natalobatrachus* represented by the kloof frog, *N. bonebergi* (restricted to the KwaZulu-Natal coastal belt and Pondoland), and the genus *Anhydrophryne*, represented by the Natal chirping frog, *A. hewitti* and the mistbelt chirping frog, *A. ngongoniensis*, narrow-range endemics in KwaZulu-Natal and the KwaZulu-Natal Midlands, respectively, together with the Hogsback chirping frog, *A. rattrayi*, largely restricted to the Amatola Mountains. Amongst the reptiles, the monotypic endemic genus *Macrelaps* is represented by the Natal black snake, *M. microlepidotus*, restricted to Maputaland, KwaZulu-Natal and Podoland. Prominent reptile genera showing a great deal of diversification and narrow endemism within the hotspot are flat geckos in the genus *Afroedura* (15 species: 6 endemic and 7 near endemic), dwarf burrowing skinks in the genus *Scelotes* (11 species: 7 endemic and 3 near endemic) and dwarf chameleons in the genus *Bradypodion* (9 species: 8 endemic and 1 near endemic). Even though the avifauna shows the highest species richness in the MPA hotpsot, there are no endemic birds in the hotspot. However, 14 bird species are listed in Appendix 1 as near endemic to the MPA hotspot, with ranges extending towards the south-eastern escarpment and/or Knysna. The hotspot also forms a part of BirdLife International's 'South-east African Coast' endemic bird area[52] with species extending north from the MPA hotspot along the coastal belt. The only three species of mammals endemic to the MPA hotspot are two golden moles (the giant golden mole, *Chrysospalax trevelyani* and Marley's golden mole, *Amblysomus marleyi*, narrowly endemic to the Transkei coastal belt and Maputaland, respectively), and one shrew (Sclater's forest shrew, *Myosorex sclateri* in KwaZulu-Natal). However, the numerous non-endemic species make the hotspot an important area for small mammals, especially for golden moles (with seven species representing five genera, two of which are endemic and one is near endemic in the MPA hotspot).

TABLE 1: Vertebrate species richness and endemism in the Maputaland-Pondoland-Albany (MPA) biodiversity hotspot, as currently defined, and according to data from two additional sources, Mittermeier et al.[2] and Conservation International[9].

Class	Current assessment					Mittermeier et al.[2] (2004)		Conservation International[9] (2005)	
	Number of families	Number of genera	Number of species	Endemic species	Near endemic species	Number of species	Endemic species	Number of species	Endemic species
Mammalia	37	129	198 (1[mg])	3 (1.5%)	3 (1.5%)	193	5 (2.6%)	194	4 (2.1%)
Aves	86	300	617 (72[mg])	0 (0%)	14 (2.3%)	541	0 (0.0%)	541	0 (0.0%)
Reptilia	24	83	230	33 (14.3%)	25 (10.9%)	205	36 (17.6%)	209	30 (14.4%)
Amphibia	12	26	75	16 (21.3%)	8 (10.7%)	80	12 (15.0%)	72	11 (15.3%)
Pisces	25	48	97 (24[sf])	10 (10.3%)	10 (10.3%)	73	20 (27.4%)	no data	no data
Total	**184**	**586**	**1217**	**62 (5.1%)**	**60 (4.9%)**	**1092**	**73 (6.7)**	**1016**	**45 (4.4%)**

Note: Please see the full reference list of the article, Perera SJ, Ratnayake-Perera D, Procheş Ş. Vertebrate distributions indicate a greater Maputaland-Pondoland-Albany region of endemism. S Afr J Sci. 2011;107(7/8), Art. #462, 15 pages. doi:10.4102/sajs.v107i7/8.462, for more information.
[mg], non-breeding migrants; [sf], secondary freshwater fish species – coastal/estuarine species that also occur in fresh water.
Percentage endemism is given in parentheses, and calculated out of all regularly occurring indigenous vertebrate species within the MPA hotspot (breeding residents, migrants and secondary freshwater fish), excluding vagrant birds and introduced or alien species.

Vertebrate taxa endemic to south-eastern Africa

A total of 495 vertebrate taxa (259 species and 236 infraspecific taxa) were found to have restricted ranges endemic to south-eastern Africa (see last panel in Figure 1), making the area an important region of vertebrate endemism, especially for reptiles (211 endemic taxa). Birds, as expected, showed higher endemism in infraspecific taxa (88) than in species (44), as their mobility retards isolation-driven speciation, whilst greater numbers of endemic species compared to infraspecific taxa were recorded for the herpetofauna (with endemic species: endemic infraspecific taxa ratios of 131:80 in reptiles and 33:09 in amphibians), although it can be argued that many more taxa await description.

Endemic vertebrate distributions

A total of 23 EVDs were identified within the study area based on the distribution ranges of 495 endemic taxa. Figure 1 presents maps for all EVDs, together with the numbers of endemic species and infraspecific taxa they harbour for each vertebrate class. Different EVDs were found to possess exceptionally high endemism for different vertebrate classes. For example, from north to south, the Eastern Escarpment EVD had the highest number of endemic reptile taxa (28 taxa: 19 species and 9 infraspecific taxa) and endemic mammal taxa (8 taxa: 2 species and 6 infraspecific taxa); the Maputaland EVD had the highest number of endemic freshwater fish taxa (12 endemic taxa: 2 species and 10 infraspecific taxa); the KwaZulu-Natal EVD had the highest number of endemic amphibian taxa (9 endemic species); and the Escarpment Extension of the South-eastern Coast EVD had the highest number of endemic bird taxa (18 taxa: 5 species and 13 infraspecific taxa). In general, the Eastern Escarpment, KwaZulu-Natal, Drakensberg, and Maputaland are the most outstanding amongst the narrow-range EVDs in south-eastern Africa (with 26, 20, 15 and 12 endemic species, respectively), and hence can be regarded as priority areas for vertebrate conservation.

The greater Maputaland-Pondoland-Albany region of vertebrate endemism

There are seven narrow-range EVDs in south-eastern Africa: Maputaland, KwaZulu-Natal, Transkei Coastal Belt and Albany Coastal Belt along the south-eastern coast, and the Eastern Escarpment, Drakensberg and Amatola-Winterberg-Sneeuberg along the south-eastern Great Escarpment (Figure 2a). These narrow-range EVDs together with two EVDs showing endemic range extensions from the coastal belt towards the escarpment (the Escarpment Extension EVD and the Escarpment and Knysna Extension EVD of the south-eastern coast; Figure 2b), and two transitional extensions (the Inhambane and Mopane Extension in the north-east and the Knysna Extension in the south-west; Figure 2b), were used to demarcate a Greater Maputaland-Pondoland-Albany (GMPA) region of vertebrate endemism (Figure 2b and 2c). Some species, such as the bronze caco, *Cacosternum nanum*; chorister robin-chat, *Cossypha dichroa*; Knysna turaco, *Tauraco corythaix* and Hottentot golden mole, *Amblysomus hottentotus* have distributions almost identical to the extent of the GMPA region. The Maputaland, KwaZulu-Natal, Transkei Coastal Belt and Albany Coastal Belt EVDs form the coastal section of the GMPA region, largely matching the borders of the MPA hotspot, whilst the Eastern Escarpment, Drakensberg and Amatola-Winterberg-Sneeuberg EVDs are situated inland, forming the Great Escarpment section of the GMPA region.

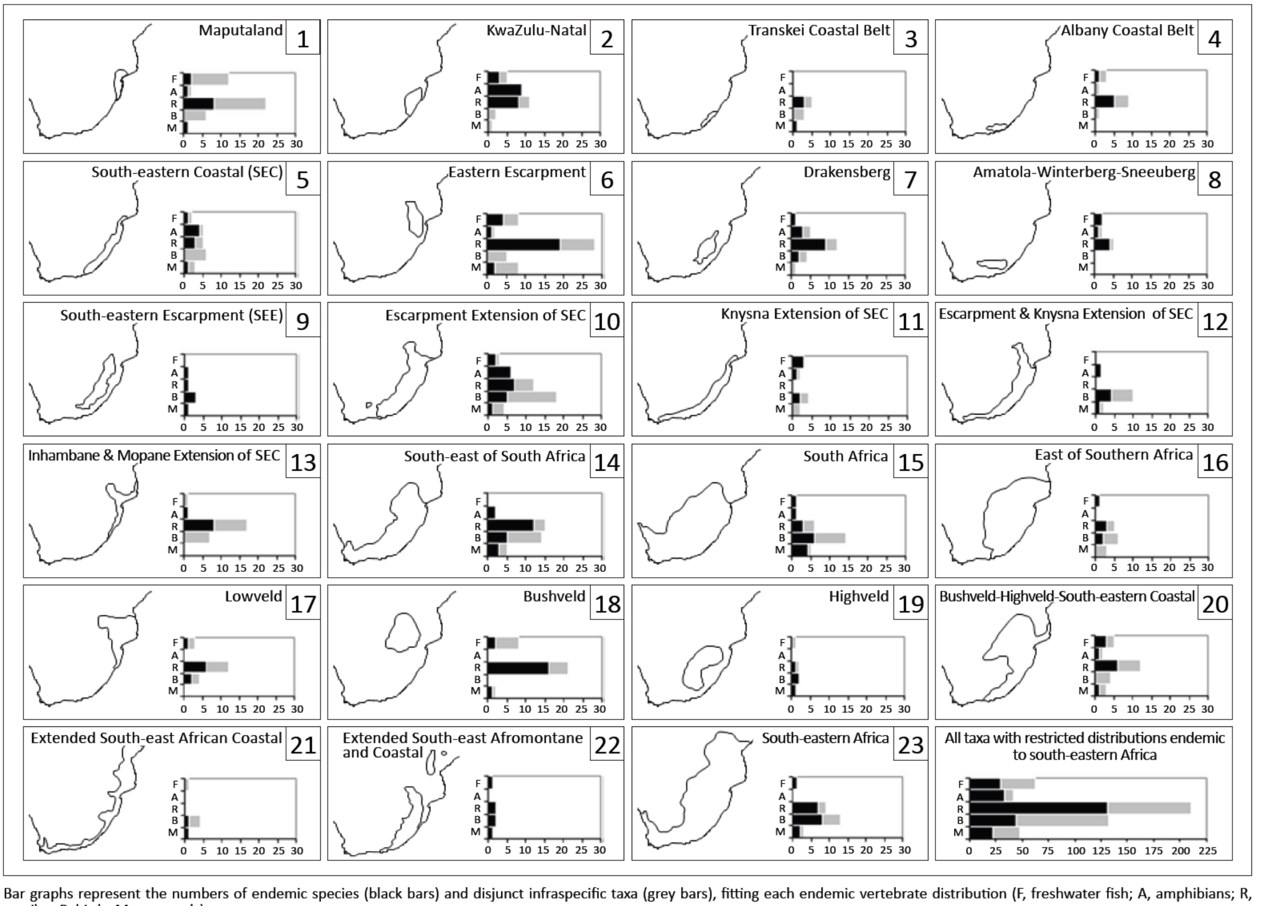
The total vertebrate endemism of the GMPA region is thus as high as 146 species (19 freshwater fishes, 29 amphibians, 75 reptiles, 15 birds and 8 mammals – see Appendix 1), 135% higher than for the MPA hotspot (62 species), within an area only 73% larger than the hotspot (~274 316 km^2).[7] The area added by the Inhambane and Mopane and the Knysna transitional extensions overlaps with the Lowveld and Bushveld bioregions, and the Cape Floristic Region, respectively. If the overlaps were reduced to include only forest patches in these areas (where most of the elements characteristic of the GMPA region are found), then the actual increase in area would be even smaller. Even if the GMPA region excluded these transitional extensions, it would still include 125 endemic species (a 103% increase in endemism from the MPA hotspot), with an increase in area of only 50%.

It is particularly remarkable that the GMPA region harbours 15 endemic bird species in contrast to the MPA hotspot, which has no endemic bird species. Three reptile genera extralimital to the MPA hotspot (genera of the Woodbush legless skink, *Acontophiops*; the Swazi rock snake, *Inyoka* and the cream-spotted mountain snake, *Montaspis*), together with the amphibian genus of the Natal cascade frog *Hadromophryne* and the bird genus of the bush blackcap *Lioptilus*, all monotypic and extending towards the escarpment from the MPA hotspot, are endemic within the GMPA region. This results in a total of eight genera (three amphibian genera – *Anhydrophryne*, *Hadromophryne* and *Natalobatrachus*, four reptile genera – *Acontophiops*, *Inyoka*, *Macrelaps* and *Montaspis* and the bird genus *Lioptilus*) endemic to the GMPA region, in contrast to the only three vertebrate genera (*Anhydrophryne*, *Natalobatrachus* and *Macrelaps*) endemic to the MPA hotspot. Furthermore, two golden mole genera, namely *Chrysospalax* and *Neamblysomus*, are near endemic to the GMPA region (each genus having two species, one of each endemic to the GMPA region and the others extending to the Northern Mesic Highveld and Central Bushveld bioregions, respectively[29]). Appendix 1 lists all the vertebrate species endemic to the GMPA region, their status within the MPA hotspot and the EVDs they are characteristic to.

Zoogeographical units and areas of vertebrate endemism

Using the core regions of EVDs, their overlapping margins and the patterns of narrower endemism within them, we demarcated 24 non-overlapping zoogeographical units within the GMPA region (Figure 2c), including 13 AOVEs (Table 2).

Overall, 37 zoogeographical units (Figure 3) can be recognised for south-eastern Africa (south of 22°S and east



Bar graphs represent the numbers of endemic species (black bars) and disjunct infraspecific taxa (grey bars), fitting each endemic vertebrate distribution (F, freshwater fish; A, amphibians; R, reptiles; B, birds; M, mammals).

FIGURE 1: Endemic vertebrate distributions (EVDs) in south-eastern Africa: Narrow-range EVDs along the south-eastern coast (1–4), South-eastern Coastal composite EVD (5), narrow-range EVDs along the south-eastern escarpment (6–8), South-eastern Escarpment composite EVD (9), EVDs extending from the south-eastern coast (10–13) and other broader EVDs (14–23).

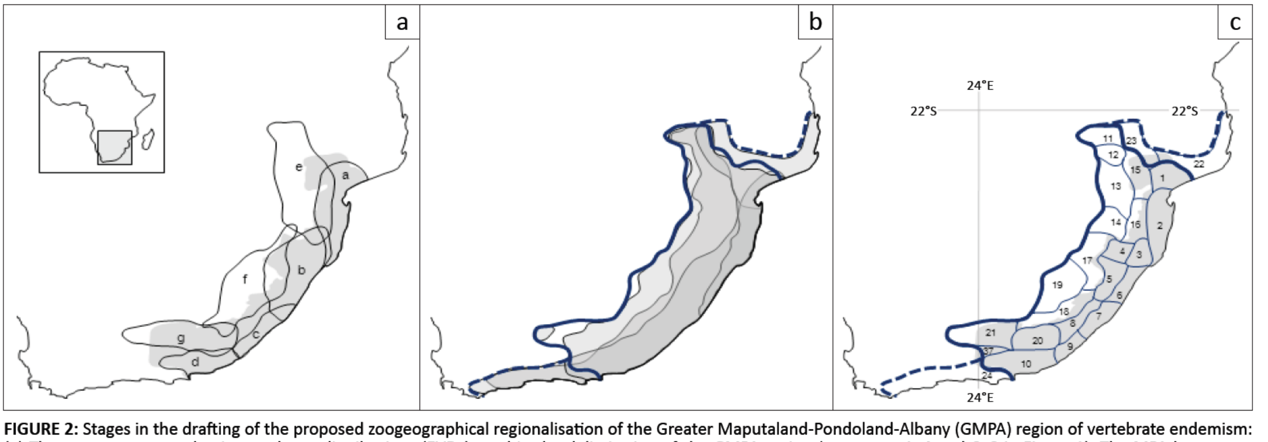


FIGURE 2: Stages in the drafting of the proposed zoogeographical regionalisation of the Greater Maputaland-Pondoland-Albany (GMPA) region of vertebrate endemism: (a) The narrow-range endemic vertebrate distributions (EVDs) used in the delimitation of the GMPA region (see panes 1–4 and 6–8 in Figure 1). The MPA hotspot as currently defined is shaded. (b) The broad-range EVDs used in the delimitation of the GMPA region (see panes 10–13 in Figure 1). The thick line depicts the GMPA region, whilst the broken lines show its transitional extensions. (c) The GMPA region of vertebrate endemism showing its 24 zoogeographical units, delimited from the core regions of EVDs, their overlapping margins and patterns of narrower endemism within them. Numbers 1–24 and 37 depict the same zoogeographical units as given in Figure 3. Thick lines as in pane (b); shading as in pane (a).

of 24°E) based on the EVDs illustrated in Figure 1. Of these, 14 represent AOVEs (13 are within the GMPA region and listed in Table 2 and 1 AOVE represents the Waterberg), whilst 7 are transitional units because taxa occupying them show considerable links with units on either side of them: the Northern Mopane, Southern Mopane, Inhambane, Northern Middleveld, Southern Middleveld, KwaZulu-Natal Midlands and Knysna (the Northern Middleveld, Southern

Middleveld and KwaZulu-Natal Midlands transitional units are also AOVEs). The characteristic narrow endemics of each AOVE are listed in Table 3.

Within the GMPA region, six units are relatively endemic poor: the Southern Mpumalanga Escarpment, Northern Maputaland, Northern KwaZulu-Natal, Drakensberg Plateau, Transkei Midlands and Southern Transkei Coastal Belt; amongst which the last two, taken together, provide evidence for the existence of a 'Transkei gap'.[53]

Discussion

Methods revisited

We used the distribution ranges of endemic vertebrate taxa to qualitatively identify a region of conservation priority as well as zoogeographical units for south-eastern Africa, given that the distribution databases for some taxa are far from complete and not particularly accurate. The available distribution data for different vertebrate classes in south-eastern Africa vary considerably in their completeness and resolution, as a result of varied intensities of collection and different scales of mapping. Some of the available atlas data sets do not completely cover our study region (most being limited to South Africa, Lesotho and Swaziland), and other references from which these data can be supplemented give distribution maps at different resolutions. Therefore, we used a qualitative approach to delimit EVDs congruent amongst vertebrate classes. From these, a set of zoogeographical units were developed in order to incorporate the available data into a subsequent rigorous numerical analysis, reducing both data incompleteness (as compared to QDSs), and the arbitrary nature of boundaries (compared to half- or full-degree squares if QDS data were to be pooled). However, data are far scarcer in most of the world's biodiversity hotspots (e.g. the Guinean Forests of West Africa,[54] the Himalayas,[55] Indo-Burma,[56] Western Ghats and Sri Lanka[57]). Hence we propose EVDs as a tool for understanding biogeographical patterns, refining the boundaries of biodiversity hotspots and identifying local conservation priorities within them, where distribution data are inappropriate for comprehensive numerical analyses.

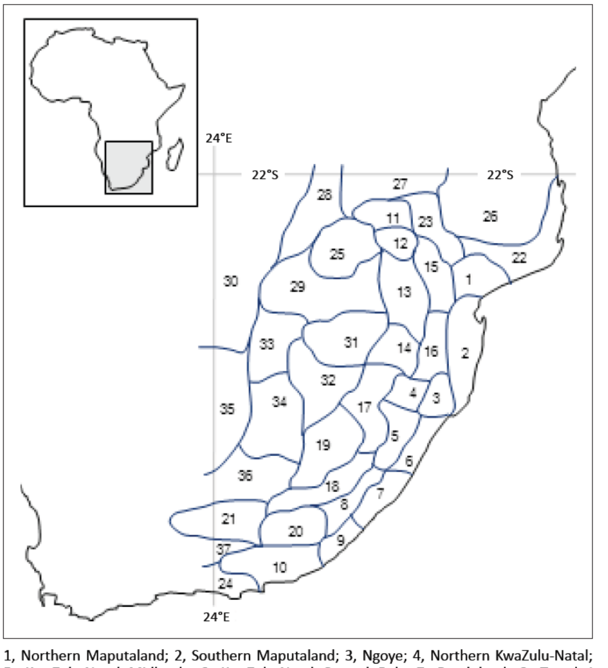
Vertebrate endemism in the Maputaland-Pondoland-Albany biodiversity hotspot as currently defined

Although the MPA hotspot is identified as a biodiversity hotspot primarily based on its floristic endemism, it is evident that vertebrates also show an increased endemism in and towards the hotspot, albeit with comparatively lower degrees of endemism (5.1%) and near-endemism (4.9%) than is the case for plants, which have a degree of endemism of 23.5%.[2] Vertebrate endemism in the MPA hotspot is comparable with that of the Succulent Karoo (4.2%) but lower than that of the Cape Floristic Region (10.3%), the other southern African biodiversity hotspots. It is certainly low by global standards, with the MPA hotspot ranking 31st out of the 34 biodiversity hotspots currently recognised.[2] The figure for vertebrate endemism in the MPA hotspot is largely stable in comparison with prior assessments (Table 1), although many details have changed since, because of the discovery of new species (e.g. cacos, *Cacosternum* spp., flat geckos, *Afroedura* spp. and dwarf chameleons, *Bradypodion* spp.) and taxonomic revisions. The number of MPA-endemic fish species in Mittermeier et al.[2] seems to be erroneously higher than the actual values. This, together with the increase in species richness as a result of the availability of better distribution data, especially in birds,

TABLE 2: The greater Maputaland-Pondoland-Albany (GMPA) region of vertebrate endemism (146 endemic species), its two major geographical sections and areas of vertebrate endemism (AOVEs) within it.

Section of the GMPA region	Areas of vertebrate endemism
South-eastern Coastal section (51 endemic species)	Southern Maputaland (9+21)
	Ngoye (3+2)
	KwaZulu-Natal Midlands (6+0)
	KwaZulu-Natal Coastal Belt (3+4)
	Pondoland (2+3)
	Albany Coastal Belt (6+8)
South-eastern Escarpment section (54 endemic species)	Soutpansberg (2+5)
	Wolkberg (4+3)
	Northern Mpumalanga Escarpment (2+2)
	Northern Middleveld (7+3)
	Southern Middleveld (4+2)
	Drakensberg-KZN Escarpment (6+2)
	Amatola-Winterberg (5+2)

Number of endemic species + endemic disjunct infraspecific taxa for each area of vertebrate endemism is given in parentheses.



1, Northern Maputaland; 2, Southern Maputaland; 3, Ngoye; 4, Northern KwaZulu-Natal; 5, *KwaZulu-Natal Midlands*; 6, KwaZulu-Natal Coastal Belt; 7, Pondoland; 8, Transkei Midlands; 9, Southern Transkei Coastal Belt; 10, Albany Coastal Belt; 11, Soutpansberg; 12, Wolkberg; 13, Northern Mpumalanga Escarpment; 14, Southern Mpumalanga Escarpment; 15, *Northern Middleveld*; 16, *Southern Middleveld*; 17, Drakensberg-KwaZulu-Natal Escarpment; 18, Drakensberg-Eastern-Cape Escarpment; 19, Drakensberg Plateau; 20, Amatola-Winterberg; 21, Sneeuberg; 22, *Inhambane*; 23, *Southern Mopane*; 24, *Knysna*; 25, Waterberg; 26, Mozambique Lowveld; 27, *Northern Mopane*; 28, *Northern Bushveld*; 29, Central Bushveld; 30, Kalahari Bushveld; 31, Northern Mesic Highveld; 32, Southern Mesic Highveld; 33, Northern Dry Highveld; 34, Southern Dry Highveld; 35, Upper Karoo; 36, *Highveld-Upper Karoo*; 37, Succulent Karoo.
Note that italicised names depict transitional units.

FIGURE 3: Proposed zoogeographical units for south-eastern Africa delimited based on endemic vertebrate distributions.

TABLE 3: Characteristic narrow-range endemics in south-east African areas of vertebrate endemism.

Area of vertebrate endemism	Characteristic narrow endemic species
Albany Coastal Belt	*Sandelia bainsii, Bitis albanica, Cordylus tasmani, Goggia essexi, Nucras taeniolata, Scelotes anguineus*
Amatola-Winterberg	*Afroedura amatolica, Afroedura tembulica, Barbus amatolicus, Barbus trevelyani, Vandijkophrynus amatolicus*
Drakensberg-KZN Escarpment	*Afroedura nivaria, Bradypodion dracomontanum, Bradypodion* sp. nov. 'emerald', *Montaspis gilvomaculata, Pseudocordylus langi, Pseudocordylus spinosus*
KwaZulu-Natal Coastal Belt	*Hyperolius pickersgilli, Scelotes guentheri, Scelotes inornatus*
KwaZulu-Natal Midlands	*Anhydrophryne ngongoniensis, Bradypodion thamnobates, Cacosternum poyntoni, Cacosternum* sp. nov. 'A', *Leptopelis xenodactylus, Scelotes bourquini*
Ngoye	*Bradypodion caeruleogula, Bradypodion nemorale, Bradypodion ngomeense*
Northern Middleveld	*Afroedura* sp. nov. 'mariepi', *Afroedura* sp. nov. 'rupestris', *Afroedura* sp. nov. 'rondavelica', *Afroedura* sp. nov. 'granitica', *Barbus brevipinnis, Barbus treurensis, Chiloglanis bifurcus*
Northern Mpumalanga Escarpment	*Afroedura* sp. nov. 'leoleonsis', *Amblysomus robustus*
Pondoland	*Acontias poecilus, Bradypodion caffer*
Southern Maputaland	*Amblysomus marleyi, Bradypodion setaroi, Leptotyphlops telloi, Lycophidion pygmaeum, Platysaurus lebomboensis, Scelotes arenicolus, Scelotes fitzsimonsi, Scelotes vestigifer, Silhouettea sibayi*
Southern Middleveld	*Afroedura major, Afroedura* sp. nov. 'lebomboensis', *Afroedura* sp. nov. 'pongolae', *Varicorhinus nelspruitensis*
Soutpansberg	*Australolacerta rupicola, Platysaurus relictus*
Waterberg	*Afroedura* sp. nov. 'waterbergensis', *Cordylus breyeri, Lygodactylus waterbergensis, Platysaurus guttatus, Platysaurus minor*
Wolkberg	*Acontophiops lineatus, Lygodactylus methueni, Neamblysomus gunningi, Tetradactylus eastwoodae*

has contributed to the percentage endemism in the present assessment being lower than in Mittermeier et al.[2], despite the discovery of new endemic species. One other factor that accounts for differences between the numbers of species listed in previous assessments and the present one is the inclusion and exclusion of marginal species (see numbers for endemic species in the Critical Ecosystem Partnership Fund[10]). Here we took a conservative approach when dealing with marginal occurrences of species, taking their habitat preferences into consideration.

South-east African vertebrate endemism and its congruence with vegetation types

As one would expect, the EVDs described here showed a considerable degree of congruence with vegetation patterns (biomes and bioregions).[29] Most of the south-east African endemic vertebrates are associated with either forests or grasslands, and a few of them with thicket (in Albany and azonal fire-free habitat patches elsewhere) and with savanna (especially in northern South Africa). But, in general, most narrow endemic species occupy azonal microhabitats (e.g. rock outcrops and marshy areas) within those biomes and hence are not quite characteristic of the biomes as such. Some bioregions, such as the Dry Highveld Grasslands and Eastern Kalahari Bushveld, are poor in south-east African endemics.

Several narrow endemics of forest affinities fall within the south-eastern coastal belt, represented in patches of sand, scarp and coastal forest.[29] In addition, mistbelt forests[29] found along the sub-escarpment belt together with Afrotemperate[29] (Afromontane) forest patches along the Drakensberg-KwaZulu-Natal Escarpment, are also rich in endemic vertebrates. Forest patches that stand out in terms of vertebrate endemism (from north to south, with their respective endemics) are: the remnant Afromontane forests of the Wolkberg (Methuen's dwarf gecko, *Lygodactylus methueni* and Gunning's golden mole, *Neamblysomus gunningi*), the coastal (dune) forests of Southern Maputaland (e.g. Setaro's dwarf chameleon, *Bradypodion setaroi*; Zululand dwarf burrowing skink, *Scelotes arenicolus* and FitzSimons' dwarf burrowing skink, *S. fitzsimonsi*), the scarp and mistbelt forests of southern Zululand (our Ngoye 'area of endemism'; uMlalazi dwarf chameleon, *Bradypodion caeruleogula*; Qudeni dwarf chameleon, *B. nemorale* and Ngome dwarf chameleon, *B. ngomeense*), the mistbelt forest patches of the KwaZulu-Natal Midlands (Natal Midlands dwarf chameleon, *Bradypodion thamnobates*), the Afromontane forests along the Drakensberg-KwaZulu-Natal Escarpment (Drakensberg dwarf chameleon, *Bradypodion dracomontanum* and an undescribed dwarf chameleon species, *B.* sp. nov. 'emerald'), and the scarp forests of KwaZulu-Natal Coastal Belt and Pondoland (kloof frog, *Natalobatrachus bonebergi*), coastal forests of Pondoland (variable legless skink, *Acontias poecilus* and Pondo dwarf chameleon, *Bradypodion caffer*) and Southern Transkei Coastal Belt (giant golden mole, *Chrysospalax trevelyani*). In addition to the narrow endemics, a few avian forest endemics are found in most of the GMPA region (e.g. forest buzzard, *Buteo trizonatus*; chorister robin-chat, *Cossypha dichroa* and Knysna turaco, *Tauraco corythaix*).

Similarly, a few grassland endemics are fairly widespread in the GMPA region (e.g. Sloggett's vlei rat, *Otomys sloggetti* and the Natal red rock rabbit, *Pronolagus crassicaudatus*), whilst some sections of the grassland biome support narrow endemic vertebrates, namely, from north to south, the montane grasslands of the Wolkberg (Woodbush legless skink, *Acontophiops lineatus*) and Mpumalanga Escarpment (robust golden mole, *Amblysomus robustus*), the coastal grasslands of Southern Maputaland (pygmy wolf snake, *Lycophidion pygmaeum*), the mistbelt grasslands of the KwaZulu-Natal Midlands (mistbelt chirping frog, *Anhydrophryne ngongoniensis*; long-toed tree frog, *Leptopelis xenodactylus* and Bourquin's dwarf burrowing skink *Scelotes bourquini*), KwaZulu-Natal Midlands and Coastal Belt grasslands (striped caco, *Cacosternum striatum*), marshy areas within KwaZulu-Natal Coastal Belt grasslands (Pickersgill's reed frog, *Hyperolius pickersgilli*), montane grasslands along the Drakensberg-KwaZulu-Natal and Drakensberg-Eastern-Cape Escarpments (Drakensberg flat gecko, *Afroedura nivaria*; Lang's crag lizard, *Pseudocordylus langi*; Cottrell's mountain lizard, *Tropidosaura cottrelli* and Essex's mountain lizard, *T. essexi*), alpine grasslands on the Drakensberg Plateau and Escarpments (Drakensberg river frog, *Amietia dracomontana*; Maluti river frog, *A. umbraculata*; Hall's flat gecko, *Afroedura halli*; mountain pipit, *Anthus hoeschi* and Drakensberg Siskin, *Crithagra symonsi*) and the montane grasslands of the Amatolas (Amatola flat gecko, *Afroedura amatolica*; Tembo flat gecko, *A. tembulica* and Amatola toad, *Vandijkophrynus amatolicus*), as well as the Sneeuberg (plain mountain adder, *Bitis inornata*).

Few narrow endemics inhabit thicket in the Albany Coastal Belt (Albany adder, *Bitis albanica*; Tasman's girdled lizard, *Cordylus tasmani* and the striped scrub lizard, *Nucras taeniolata*), and fire-free habitat patches elsewhere (e.g. Kentani dwarf chameleon, *Bradypodion kentanicum*, in the Transkei Coastal Belt). Similarly, few narrow-endemic vertebrates exist within the savanna biome: in the Waterberg – the Waterberg girdled lizard, *Cordylus breyeri*; dwarf flat lizard, *Platysaurus guttatus* and Waterberg flat lizard, *P. minor*; the Soutpansberg – the Soutpansberg rock lizard, *Australolacerta rupicola* and Soutpansberg flat lizard, *Platysaurus relictus*; and the Northern Mpumalanga Escarpment – the Sekhukhune flat lizard, *Platysaurus orientalis*), whilst relatively widespread savanna endemics are found in the Bushveld EVD (e.g. Van Dam's girdled lizard, *Cordylus vandami*; black-spotted dwarf gecko, *Lygodactylus nigropunctatus* and Juliana's golden mole, *Neamblysomus julianae*).

The Northern Middleveld, Southern Maputaland, KwaZulu-Natal Midlands, Drakensberg-KwaZulu-Natal Escarpment, Albany Coastal Belt and the Amatola-Winterberg stand out as the AOVEs with the highest numbers of characteristic narrow endemics within the GMPA region (that is, more than five; see Table 2). Interestingly, the narrow endemics within these richest AOVEs show major habitat affinities to forests, grasslands and thicket vegetation, emphasising the importance of these habitats for vertebrate endemism in the region.

The structural features of the flora determine the faunal assemblages in a region,[5] resulting in the narrow AOVEs coinciding well with vegetation units such as Ngoye, Pondoland and Albany Coastal Belt, even though broader EVDs tend to cut across different vegetation types. It is also evident that the patterns derived from vertebrates are largely congruent with van Wyk and Smith's[5] centres of floristic endemism, the most notable difference being in the delimitation of the Albany region, which is a single centre of plant endemism but encompasses two distinct EVDs. Whilst the prominent EVD of KwaZulu-Natal has not hitherto been formally recognised as a centre of plant endemism,[5] there are numerous narrow endemic plant species in the area[58] (e.g. dune aloe, *Aloe thraskii*; woolly calpurnia, *Calpurnia woodii*; sticky star-apple, *Diospyros glandulifera*; parrot tree erica, *Erica psittacina*; Tugela spikethorn, *Gymnosporia macrocarpa*; Wood's spikethorn, *G. woodii*; Rudatis' dwarf currant, *Searsia rudatisii* and Tugela bush-milkwood, *Vitellariopsis dispar*), albeit some have only recently been described.

Congruence of endemic vertebrate distributions and the greater Maputaland-Pondoland-Albany region with published zoogeographical regions

The GMPA region, as well as the narrow-range EVDs presented here, shows congruent patterns with published zoogeographical regionalisation schemes developed with numerical analyses for single vertebrate classes (Table 4). The faunal zones identified by Crowe[26] for southern African vertebrates also captured similar patterns, with frogs, lizards, snakes and birds having increased species richness towards the GMPA region, whilst the herpetofauna also showed an increased endemism towards the GMPA region.

TABLE 4: Congruence of the Greater Maputaland-Pondoland-Albany (GMPA) region and some endemic vertebrate distributions (EVDs) illustrated here with published zoographical regionalisations for amphibians and birds.

Region/ EVD (present study)	Published zoogeographical regionalisations			
	Amphibians		Birds	
	Poynton[18]	Alexander et al.[25]	Crowe and Crowe[19]	De Klerk et al.[24]
GMPA region (excluding transitional extensions)	Congruent with SEL + ST (excl. Cape ext.)	Congruent with EECD (*sensu lato*)	Congruent with SED (*sensu lato*)	Congruent with TPP (*sensu lato*)
South-eastern Coastal EVD	Congruent with SEL	Within EECD	Within SED	Within TPP
South-eastern Escarpment EVD	Congruent with ST (excl. Cape ext.)	Marginally within EECD	Marginally within SED	Marginally within TPP
Maputaland EVD	At the southern tip of EAL, marginally in SEL	Within MA	Within SED	Within TPP
Natal EVD	Within SEL	Southern tip of MA and mid-SoGA	Within SED	Within TPP
Pondoland EVD	Within SEL	Southern tip of SoGA	Within SED	Within TPP
Albany Coastal Belt EVD	Within SEL	Within SCECUA	Within SED	Within TPP
Eastern Escarpment EVD	Within ST	Northern SoGA	Within SED	Within TPP
Drakensberg EVD	Within ST	Marginally between SoGA, SCECUA and south-east SwGA	Within SED	Marginally between TPP and HD
Amatola-Winterberg-Sneeuberg EVD	Within ST	Marginally between SCECUA and south-east SRKD	Marginally between SED and FD	Marginally between TPP and FD

Note: Please see the full reference list of the article, Perera SJ, Ratnayake-Perera D, Procheş Ş. Vertebrate distributions indicate a greater Maputaland-Pondoland-Albany region of endemism. S Afr J Sci. 2011;107(7/8), Art. #462, 15 pages. doi:10.4102/sajs.v107i7/8.462, for more information.
SEL, South-east Lowland Region; ST, South Temperate Region; EAL, East African Lowland Region; EECD, Eastern Escarpment/Coastal District of the Eastern Subregion; MA, Maputaland Assemblage of EECD; SoGA, Sour Grasslands Assemblage of EECD; SCECUA, South Coast/Eastern Cape Uplands Assemblage of EECD; SwGA, Sweet Grasslands Assemblage of Central District in Eastern Subregion; SRKD, Summer Rainfall Karoo District of Western Subregion; SED, South-east District; FD, Fynbos District (both SED and FD are within the Southern Province of Southern Savanna Subregion); TPP, Tongaland-Pondoland Province of Southern Savanna Subregion; HD, Highveld District of South-western Subregion; FD, Fynbos District of South-western Subregion.

The greater Maputaland-Pondoland-Albany region of vertebrate endemism and its conservation significance

The importance of the zoogeographically delimited GMPA region as a more comprehensive area for conservation prioritisation needs to be understood by comparing it with the MPA hotspot as currently defined. The coastal section of the GMPA region is largely congruent – if narrower – with the MPA hotspot. Inland, even though the hotspot encompasses most of the Amatola-Winterberg-Sneeuberg EVD and the southern parts of the Eastern Escarpment EVD, these extend well beyond the current boundary of the hotspot. Furthermore, some taxa occupying these EVDs continue their ranges along the Drakensberg Escarpment, which lies almost completely outside the hotspot. This incongruence explains the inconsistency between the current boundary of the MPA hotspot and the patterns of vertebrate endemism (Figure 2a). Only 82.3% of the MPA hotspot's endemism is captured within the coastal section of the GMPA region (Table 5), the remainder of the endemic species have ranges that extend towards the south-eastern Great Escarpment (mostly towards the Eastern Escarpment and a few towards the Amatola-Winterberg-Sneeuberg and Drakensberg EVDs: see Appendix 1). Hence, we propose that a GMPA region that merges coastal and escarpment EVDs represents a more natural region of vertebrate endemism.

The GMPA region can be further validated by vertebrate species near endemic to the MPA hotspot. Amongst the near endemics of the MPA hotspot, 53.3% were found extending from the coastal section towards the south-eastern Great Escarpment and hence are endemic to the GMPA region. Moreover, when the GMPA region is considered to include the Inhambane and Mopane and the Knysna transitional extensions, it encompasses 86.7% of the MPA hotspot's near endemics (Table 5 and Appendix 1). The eight MPA near endemics that are not endemic to the GMPA region nevertheless have their core populations restricted to the GMPA region, with disjunct satellite populations (namely. Barratt's warbler, *Bradypterus barratti* and Gurney's sugarbird, *Promerops gurneyi* with satellite populations in the Chimanimani-Nyanga Mountains of eastern Zimbabwe; the Natal mountain catfish, *Amphilius natalensis* in the Chimanimani-Nyanga Mountains and southern Malawi; Fornasini's worm snake, *Afrotyphlops fornasinii*, the golden blind legless skink, *Typhlosaurus aurantiacus* and the speckled quill-snouted snake, *Xenocalamus transvaalensis* in the Lowveld region; Phongolo suckermouth, *Chiloglanis emarginatus* in the Bushveld region; and the laminate vlei rat, *Otomys laminatus* in the Western Cape).

The mismatches between EVDs and boundaries of the MPA hotspot, in the south-west and especially in the north-west (Figure 2a), also validate the recognition of the GMPA region as a more natural region of conservation significance. The north-western boundary of the hotspot is currently delimited along the 1800 m a.s.l. contour, making several species with restricted ranges along this boundary near endemic to the MPA hotspot (six species of reptiles: the montane dwarf burrowing skink, *Scelotes mirus*; giant Swazi flat gecko, *Afroedura major* and four undescribed flat gecko species, *A.* sp. nov. 'mariepi', *A.* sp. nov. 'rupestris', *A.* sp. nov. 'rondavelica' and *A.* sp. nov. 'granitica', together with four freshwater fish species: the shortfin barb, *Barbus brevipinnis*; Treur River barb, *B. treurensis*; Incomati suckermouth, *Chiloglanis bifurcus* and Incomati chiselmouth, *Varicorhinus nelspruitensis*). These species are indeed restricted to a Middleveld strip along the slopes of the Eastern Escarpment, which we identify as a transition zone between the Bushveld and Lowveld bioregions. This transition zone descends to an elevation of about 1000 m a.s.l. and extends south through western Swaziland to north-western KwaZulu-Natal (west of the Lebombo Mountains). Whilst the aforesaid species occurring in the northern parts of the transition zone are near endemic to the MPA hotspot, species occupying its southern parts, like the undescribed flat geckos, *Afroedura* sp. nov. 'lebomboensis' and *Afroedura* sp. nov. 'pongolae', are endemic to the hotspot, providing further evidence for the inconsistency of the hotspot boundary. In contrast, the GMPA region, with a more natural boundary, encompasses all of them as endemics. Along the south-western corner, the boundary of the MPA hotspot follows the Albany centre of plant endemism. In the demarcation of the Albany centre, van Wyk and Smith[5] incorporated a number of different floristic elements, creating a mosaic of bioregions within it. In contrast, the Albany Coastal Belt EVD is much narrower than the Albany centre of plant endemism. Here, the GMPA region encompasses two well-delimited EVDs, the Albany Coastal Belt and the Amatola-Winterberg-Sneeuberg, with coastal and escarpment affinities, respectively.

TABLE 5: Representation of the Maputaland-Pondoland-Albany (MPA) hotspot endemic and near endemic vertebrates within the Greater Maputaland-Pondoland-Albany (GMPA) region of vertebrate endemism.

Class	Species endemic to MPA	Species near endemic to MPA	Species endemic to coastal section of GMPA	MPA near endemics	
				Endemic to GMPA (without transitional extensions)	Endemic to GMPA (with transitional extensions)
Mammalia	3	3	3	1	2
Aves	0	14	0	6	12
Reptilia	33	25	27	15	22
Amphibia	16	8	14	5	8
Pisces	10	10	7	5	8
Total	**62**	**60**	**51 (82.3%[a])**	**32 (53.3%[b])**	**52 (86.7%[b])**

[a], Percentage of the Maputaland-Pondoland-Albany hotspot endemics, endemic within the coastal section of the Greater Maputaland-Pondoland-Albany region.
[b], Percentage of the Maputaland-Pondoland-Albany hotspot near endemics, endemic within the Greater Maputaland-Pondoland-Albany region.

The existence of the GMPA region is also supported by plants, as shown by the distribution patterns of some species in the thicket genera: *Encephalartos* (Zamiaceae), *Rhoicissus* (Vitaceae) and *Cussonia* (Araliaceae),[59] whilst van Wyk's[60] notation on outliers of some Maputaland endemic plants supports the Inhambane and Mopane extension. Redefining Africa's biodiversity hotspots, Küper at al.[61] also proposed a region similar to the GMPA region (except for the Inhambane and Mopane extension) as a hotspot of higher plant endemism. The conservation importance of the area covered under the GMPA region is also supported by Olson and Dinerstein[62], who prioritised Maputaland-Pondoland Dry Forests as an example for the Tropical, Subtropical, Dry and Monsoon Broadleaf Forest Ecoregion, and the South African Montane Grasslands and Shrublands as an example for the Tropical Montane Grassland and Savanna Ecoregion. Whilst both the above ecoregions are represented within the GMPA region, the MPA hotspot alone only encompasses the Maputaland-Pondoland Dry Forests.

Conclusions

This study emphasises south-eastern Africa as an important region for endemic vertebrates, especially with respect to herpetofauna. It also provides evidence for congruent endemic distributions amongst different vertebrate taxa, deriving patterns largely congruent with recognised centres of floristic endemism. The importance of the MPA hotspot is assessed for vertebrate endemism, providing less convincing evidence when compared to its flora. But the fact that vertebrate endemism in south-eastern Africa is concentrated towards the coastal belt and adjacent sections of the Great Escarpment provides an option to expand the boundaries of the MPA hotspot to include relevant Afromontane AOVEs. Supported by the zoogeographical links between the coastal and escarpment EVDs, the GMPA region of vertebrate endemism is proposed to serve as a better and more natural region of conservation significance. Simultaneously, the use of EVDs is proposed as a qualitative approach to identify conservation priorities, especially in situations where distributional data do not facilitate a numerical biogeographical analysis.

As suggested by White[45] and van Wyk and Smith[5], biogeographical patterns detected by means of intuitive perception should be followed by rigorous analysis to establish the extent of biogeographical regions and centres of endemism. Hence, the zoogeographical units presented in this paper are meant to be used in rigorous numerical analyses (e.g. Born et al.[63] – for the Greater Cape Floristic Region). Even though it is far from complete, the understanding of invertebrate diversity and distribution in southern Africa is better than in many parts of the world. Hence, the distributional data on invertebrates also need to be incorporated into such a rigorous analysis to visualise the broader picture of faunal endemism – invertebrates forming an incomparably higher share of the fauna than vertebrates. Finally, linking the AOVEs to the phylogenetic relatedness of the congruent, range-restricted taxa occupying them will provide clues to the origin and evolution of the faunal endemism in south-eastern Africa, revealing its historical biogeography. Simultaneously, the incorporation of these patterns of endemism in systematic conservation planning is envisaged, prioritising the AOVEs with high congruence across taxa.

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Appendix 1 starts on the next page →

Appendix 1

APPENDIX 1: Endemic vertebrates of the Greater Maputaland-Pondoland-Albany (GMPA) region

Class	Family	Species	Status within MPA hotspot[a]	Representation in EVDs[b]
Pisces	Anabantidae	*Sandelia bainsii* (Eastern Cape Rocky)	End	ACB
Pisces	Cichlidae	*Chetia brevis* (Orange-fringed Largemouth)	N-End	Esc-Ext
Pisces	Cichlidae	*Serranochromis meridianus* (Lowveld Largemouth)	End	Esc-Ext
Pisces	Cyprinidae	*Barbus amatolicus* (Amatola Barb)	End	AWS
Pisces	Cyprinidae	*Barbus brevipinnis* (Shortfin Barb)	N-End	EE
Pisces	Cyprinidae	*Barbus gurneyi* (Redtail Barb)	End	KZN
Pisces	Cyprinidae	*Barbus treurensis* (Treur River Barb)	N-End	EE
Pisces	Cyprinidae	*Barbus trevelyani* (Border Barb)	End	AWS
Pisces	Cyprinidae	*Labeo rubromaculatus* (Tugela Labeo)	End	KZN
Pisces	Cyprinidae	*Labeobarbus natalensis* (Scaly)	End	KZN
Pisces	Cyprinidae	*Pseudobarbus afer* (Eastern Cape Redfin)	N-End	Kny-Ext
Pisces	Cyprinidae	*Pseudobarbus quathlambae* (Drakensberg Minnow)	M-Out	D
Pisces	Cyprinidae	*Varicorhinus nelspruitensis* (Incomati Chiselmouth)	N-End	EE
Pisces	Eleotridae	*Hypseleotris dayi* (Golden Sleeper)	End	SEC (M-KZN-CT)
Pisces	Gobiidae	*Redigobius dewaali* (Checked Goby)	N-End	Kny-Ext
Pisces	Gobiidae	*Silhouettea sibayi* (Sibayi Goby)	End	M
Pisces	Mochokidae	*Chiloglanis anoterus* (Pennant-tailed Suckermouth)	End	M
Pisces	Mochokidae	*Chiloglanis bifurcus* (Incomati Suckermouth)	N-End	EE
Pisces	Mugilidae	*Myxus capensis* (Freshwater Mullet)	N-End	Kny-Ext
Amphibia	Arthroleptidae	*Arthroleptis wahlbergi* (Bush Squeaker)	End	SEC (M-KZN)
Amphibia	Arthroleptidae	*Leptopelis natalensis* (Natal Tree Frog)	End	SEC (KZN-CT)
Amphibia	Arthroleptidae	*Leptopelis xenodactylus* (Long-toed Tree Frog)	End	KZN
Amphibia	Breviceptidae	*Breviceps bagginsi* (Bilbo's Rain Frog)	End	KZN
Amphibia	Breviceptidae	*Breviceps sopranos* (Whistling Rain Frog)	End	M
Amphibia	Breviceptidae	*Breviceps sylvestris* (Northern Forest Rain Frog)	M-Out	EE
Amphibia	Breviceptidae	*Breviceps verrucosus* (Plaintive Rain Frog)	N-End	Esc-Ext
Amphibia	Bufonidae	*Amietophrynus pardalis* (Eastern Leopard Toad)	N-End	Kny-Ext
Amphibia	Bufonidae	*Vandijkophrynus amatolicus* (Amatola Toad)	End	AWS
Amphibia	Heleophrynidae	*Hadromophryne natalensis* (Natal Cascade Frog)	N-End	Esc-Ext
Amphibia	Hemisotidae	*Hemisus guttatus* (Spotted Shovel-nosed Frog)	N-End	Esc-Ext
Amphibia	Hyperoliidae	*Afrixalus aureus* (Golden Leaf-folding Frog)	N-End	Inh&Mop-Ext
Amphibia	Hyperoliidae	*Afrixalus spinifrons* (Natal Leaf-folding Frog)	End	SEC (KZN-CT)
Amphibia	Hyperoliidae	*Hyperolius pickersgilli* (Pickersgill's Reed Frog)	End	KZN
Amphibia	Hyperoliidae	*Hyperolius semidiscus* (Yellow-striped Reed Frog)	N-End	Esc-Ext
Amphibia	Pyxicephalidae	*Amietia dracomontana* (Drakensberg River Frog)	M-Out	D
Amphibia	Pyxicephalidae	*Amietia umbraculata* (Maluti River Frog)	M-Out	D
Amphibia	Pyxicephalidae	*Amietia vertebralis* (Phofung River Frog)	M-Out	D
Amphibia	Pyxicephalidae	*Anhydrophryne hewitti* (Natal Chirping Frog)	End	KZN
Amphibia	Pyxicephalidae	*Anhydrophryne ngongoniensis* (Mistbelt Chirping Frog)	End	KZN
Amphibia	Pyxicephalidae	*Anhydrophryne rattrayi* (Hogsback Chirping Frog)	End	Esc-Ext
Amphibia	Pyxicephalidae	*Cacosternum nanum* (Bronze Caco)	N-End	Esc&Kny-Ext
Amphibia	Pyxicephalidae	*Cacosternum parvum* (Mountain Caco)	Ext-Out	SEE (EE-D)
Amphibia	Pyxicephalidae	*Cacosternum poyntoni* (Poynton's Caco)	End	KZN
Amphibia	Pyxicephalidae	*Cacosternum* sp. nov. 'A' (Rhythmic Caco)	End	KZN
Amphibia	Pyxicephalidae	*Cacosternum* sp. nov. 'B' (KwaZulu Caco)	End	KZN
Amphibia	Pyxicephalidae	*Cacosternum striatum* (Striped Caco)	End	KZN
Amphibia	Pyxicephalidae	*Natalobatrachus bonebergi* (Kloof Frog)	End	SEC (KZN-CT)
Amphibia	Pyxicephalidae	*Strongylopus wageri* (Plain Stream Frog)	N-End	Esc-Ext
Reptilia	Amphisbaenidae	*Zygaspis violacea* (Violet Dwarf Worm Lizard)	N-End	Inh&Mop-Ext
Reptilia	Atractaspididae	*Amblyodipsas concolor* (Natal Purple-glossed Snake)	N-End	Esc-Ext
Reptilia	Atractaspididae	*Amblyodipsas microphthalma* (Eyeless Purple-glossed Snake)	N-End	Inh&Mop-Ext
Reptilia	Atractaspididae	*Aparallactus nigriceps* (Mozambique Centipede-eater)	Ext-Out	Inh&Mop-Ext
Reptilia	Atractaspididae	*Macrelaps microlepidotus* (Natal Black Snake)	End	SEC (M-KZN-CT)

[a], Status within the Maputaland-Pondoland-Albany (MPA) hotspot: End, endemic to MPA; N-End, near endemic to MPA (≥ 50% of the range inside MPA, see text for the definition); Ext-out, extending out from MPA (> 50% of the range outside MPA); M-Out, marginally outside MPA; Out, outside MPA. Eight additional MPA hotspot near endemics that are not endemic to the GMPA region are not listed above: *Bradypterus barratti* (Barratt's warbler), *Promerops gurneyi* (Gurney's sugarbird), *Amphilius natalensis* (Natal mountain catfish), *Afrotyphlops fornasinii* (Fornasini's worm snake), *Typhlosaurus aurantiacus* (golden blind legless skink), *Xenocalamus transvaalensis* (speckled quill-snouted snake), *Chiloglanis emarginatus* (Phongolo suckermouth) and *Otomys laminatus* (laminate vlei rat).

[b], Endemic vertebrate distributions (EVDs): SEC, South-eastern Coastal; M, Maputaland; KZN, KwaZulu-Natal; TCB, Transkei Coastal Belt; ACB, Albany Coastal Belt; Esc-Ext, South-eastern Escarpment Extension of SEC; Kny-Ext, Knysna Extension of SEC; Esc&Kny-Ext, South-eastern Escarpment and Knysna Extension of SEC; Inh&Mop-Ext, Inhambane and Mopane Extension of SEC; SEE, South-eastern Escarpment; EE, Eastern Escarpment; D, Drakensberg; AWS, Amatola-Winterberg-Sneeuberg; Ext-A&C, Extended South-eastern Afromontane and Coastal; SE-Africa, South-eastern Africa; SE-SAfrica, South-east of South Africa (Figure 1).

Appendix 1 continues on the next page →

APPENDIX 1: Endemic vertebrates of the Greater Maputaland-Pondoland-Albany (GMPA) region

Class	Family	Species	Status within MPA hotspot[a]	Representation in EVDs[b]
Reptilia	Chamaeleonidae	*Bradypodion caeruleogula* (uMlalazi Dwarf Chameleon)	End	KZN
Reptilia	Chamaeleonidae	*Bradypodion caffer* (Pondo Dwarf Chameleon)	End	TCB
Reptilia	Chamaeleonidae	*Bradypodion dracomontanum* (Drakensberg Dwarf Chameleon)	M-Out	D
Reptilia	Chamaeleonidae	*Bradypodion kentanicum* (Kentani Dwarf Chameleon)	End	TCB
Reptilia	Chamaeleonidae	*Bradypodion melanocephalum* (KwaZulu Dwarf Chameleon)	End	KZN
Reptilia	Chamaeleonidae	*Bradypodion nemorale* (Qudeni Dwarf Chameleon)	End	KZN
Reptilia	Chamaeleonidae	*Bradypodion ngomeense* (Ngome Dwarf Chameleon)	End	KZN
Reptilia	Chamaeleonidae	*Bradypodion setaroi* (Setaro's Dwarf Chameleon)	End	M
Reptilia	Chamaeleonidae	*Bradypodion* sp. nov. 'emerald' (Emerald Dwarf Chameleon)	M-Out	D
Reptilia	Chamaeleonidae	*Bradypodion thamnobates* (Natal Midlands Dwarf Chameleon)	End	KZN
Reptilia	Chamaeleonidae	*Bradypodion transvaalense* (Wolkberg Dwarf Chameleon)	M-Out	EE
Reptilia	Chamaeleonidae	*Bradypodion ventrale* (Eastern Cape Dwarf Chameleon)	N-End	Esc-Ext
Reptilia	Colubridae	*Dasypeltis inornata* (Southern Brown Egg Eater)	N-End	Esc-Ext
Reptilia	Cordylidae	*Cordylus tasmani* (Tasman's Girdled Lizard)	End	ACB
Reptilia	Cordylidae	*Cordylus warreni* (Warren's Girdled Lizard)	Ext-Out	EE
Reptilia	Cordylidae	*Platysaurus lebomboensis* (Lebombo Flat Lizard)	End	M
Reptilia	Cordylidae	*Platysaurus orientalis* (Sekhukhune Flat Lizard)	M-Out	EE
Reptilia	Cordylidae	*Platysaurus relictus* (Soutpansberg Flat Lizard)	Out	EE
Reptilia	Cordylidae	*Pseudocordylus langi* (Lang's Crag Lizard)	M-Out	D
Reptilia	Cordylidae	*Pseudocordylus spinosus* (Spiny Crag Lizard)	N-End	D
Reptilia	Gekkonidae	*Afroedura amatolica* (Amatola Flat Gecko)	End	AWS
Reptilia	Gekkonidae	*Afroedura halli* (Hall's Flat Gecko)	M-Out	D
Reptilia	Gekkonidae	*Afroedura karroica* (Karoo Flat Gecko)	N-End	AWS
Reptilia	Gekkonidae	*Afroedura langi* (Lowveld Flat Gecko)	N-End	Inh&Mop-Ext
Reptilia	Gekkonidae	*Afroedura major* (Giant Swazi Flat Gecko)	N-End	EE
Reptilia	Gekkonidae	*Afroedura marleyi* (Marley's Flat Gecko)	End	M
Reptilia	Gekkonidae	*Afroedura multiporis* (Woodbush Flat Gecko)	M-Out	EE
Reptilia	Gekkonidae	*Afroedura nivaria* (Drakensberg Flat Gecko)	M-Out	D
Reptilia	Gekkonidae	*Afroedura pondolia* (Pondo Flat Gecko)	End	SEC (KZN-CT)
Reptilia	Gekkonidae	*Afroedura* sp. nov. 'granitica'	N-End	EE
Reptilia	Gekkonidae	*Afroedura* sp. nov. 'lebomboensis'	End	EE
Reptilia	Gekkonidae	*Afroedura* sp. nov. 'leoleonsis'	Out	EE
Reptilia	Gekkonidae	*Afroedura* sp. nov. 'mariepi'	N-End	EE
Reptilia	Gekkonidae	*Afroedura* sp. nov. 'pongolae'	End	EE
Reptilia	Gekkonidae	*Afroedura* sp. nov. 'rondavelica'	N-End	EE
Reptilia	Gekkonidae	*Afroedura* sp. nov. 'rupestris'	N-End	EE
Reptilia	Gekkonidae	*Afroedura tembulica* (Tembo Flat Gecko)	End	AWS
Reptilia	Gekkonidae	*Goggia essexi* (Essex's Pygmy Gecko)	End	ACB
Reptilia	Gekkonidae	*Lygodactylus methueni* (Methuen's Dwarf Gecko)	Out	EE
Reptilia	Gerrhosauridae	*Tetradactylus africanus* (Eastern Long-tailed Seps)	N-End	Esc-Ext
Reptilia	Gerrhosauridae	*Tetradactylus eastwoodae* (Eastwood's Long-tailed Seps)	Out	EE
Reptilia	Lacertidae	*Australolacerta rupicola* (Soutpansberg Rock Lizard)	Out	EE
Reptilia	Lacertidae	*Nucras taeniolata* (Striped Scrub Lizard)	End	ACB
Reptilia	Lacertidae	*Tropidosaura cottrelli* (Cottrell's Mountain Lizard)	M-Out	D
Reptilia	Lacertidae	*Tropidosaura essexi* (Essex's Mountain Lizard)	M-Out	D
Reptilia	Lamprophiidae	*Inyoka swazicus* (Swazi Rock Snake)	M-Out	EE
Reptilia	Lamprophiidae	*Lycodonomorphus laevissimus* (Dusky-bellied Water Snake)	N-End	Esc-Ext
Reptilia	Lamprophiidae	*Lycophidion pygmaeum* (Pygmy Wolf Snake)	End	M
Reptilia	Lamprophiidae	*Lycophidion semiannule* (Bazaruto Wolf Snake)	N-End	Inh&Mop-Ext
Reptilia	Leptotyphlopidae	*Leptotyphlops sylvicolus* (Forest Thread Snake)	End	SEC (M-KZN-CT)
Reptilia	Leptotyphlopidae	*Leptotyphlops telloi* (Tello's Thread Snake)	End	M
Reptilia	Prosymnidae	*Prosymna janii* (Mozambique Shovel-snout)	N-End	Inh&Mop-Ext
Reptilia	Pseudoxyrhophiidae	*Duberria variegate* (Variegated Slug-eater)	N-End	Inh&Mop-Ext
Reptilia	Pseudoxyrhophiidae	*Montaspis gilvomaculata* (Cream-spotted Mountain Snake)	M-Out	D
Reptilia	Scincidae	*Acontias breviceps* (Short-headed Legless Skink)	N-End	SEE (EE-D-AWS)
Reptilia	Scincidae	*Acontias poecilus* (Variable Legless Skink)	End	TCB

[a], Status within the Maputaland-Pondoland-Albany (MPA) hotspot: End, endemic to MPA; N-End, near endemic to MPA (≥ 50% of the range inside MPA, see text for the definition); Ext-out, extending out from MPA (> 50% of the range outside MPA); M-Out, marginally outside MPA; Out, outside MPA. Eight additional MPA hotspot near endemics that are not endemic to the GMPA region are not listed above: *Bradypterus barratti* (Barratt's warbler), *Promerops gurneyi* (Gurney's sugarbird), *Amphilius natalensis* (Natal mountain catfish), *Afrotyphlops fornasinii* (Fornasini's worm snake), *Typhlosaurus aurantiacus* (golden blind legless skink), *Xenocalamus transvaalensis* (speckled quill-snouted snake), *Chiloglanis emarginatus* (Phongolo suckermouth) and *Otomys laminatus* (laminate vlei rat).

[b], Endemic vertebrate distributions (EVDs): SEC, South-eastern Coastal; M, Maputaland; KZN, KwaZulu-Natal; TCB, Transkei Coastal Belt; ACB, Albany Coastal Belt; Esc-Ext, South-eastern Escarpment Extension of SEC; Kny-Ext, Knysna Extension of SEC; Esc&Kny-Ext, South-eastern Escarpment and Knysna Extension of SEC; Inh&Mop-Ext, Inhambane and Mopane Extension of SEC; SEE, South-eastern Escarpment; EE, Eastern Escarpment; D, Drakensberg; AWS, Amatola-Winterberg-Sneeuberg; Ext-A&C, Extended South-eastern Afromontane and Coastal; SE-Africa, South-eastern Africa; SE-SAfrica, South-east of South Africa (Figure 1).

Appendix 1 continues on the next page →

APPENDIX 1: Endemic vertebrates of the Greater Maputaland-Pondoland-Albany (GMPA) region

Class	Family	Species	Status within MPA hotspot[a]	Representation in EVDs[b]
Reptilia	Scincidae	*Acontophiops lineatus* (Woodbush Legless Skink)	Out	EE
Reptilia	Scincidae	*Scelotes anguineus* (Algoa Dwarf Burrowing Skink)	End	ACB
Reptilia	Scincidae	*Scelotes arenicolus* (Zululand Dwarf Burrowing Skink)	End	M
Reptilia	Scincidae	*Scelotes bidigittatus* (Lowveld Dwarf Burrowing Skink)	N-End	Inh&Mop-Ext
Reptilia	Scincidae	*Scelotes bourquini* (Bourquin's Dwarf Burrowing Skink)	End	KZN
Reptilia	Scincidae	*Scelotes fitzsimonsi* (FitzSimons' Dwarf Burrowing Skink)	End	M
Reptilia	Scincidae	*Scelotes guentheri* (Guenthers' Dwarf Burrowing Skink)	End	KZN
Reptilia	Scincidae	*Scelotes inornatus* (Durban Dwarf Burrowing Skink)	End	KZN
Reptilia	Scincidae	*Scelotes mirus* (Montane Dwarf Burrowing Skink)	N-End	EE
Reptilia	Scincidae	*Scelotes mossambicus* (Mozambique Dwarf Burrowing Skink)	N-End	Esc-Ext
Reptilia	Scincidae	*Scelotes vestigifer* (Coastal Dwarf Burrowing Skink)	End	M
Reptilia	Testudinidae	*Kinixys natalensis* (Natal Hinged Tortoise)	End	Esc-Ext
Reptilia	Viperidae	*Bitis albanica* (Albany Adder)	End	ACB
Reptilia	Viperidae	*Bitis inornata* (Plain Mountain Adder)	End	AWS
Aves	Accipitridae	*Buteo trizonatus* (Forest Buzzard)	N-End	Esc&Kny-Ext
Aves	Alaudidae	*Heteromirafra ruddi* (Rudd's Lark)	Ext-Out	SEE (EE-D)
Aves	Chaetopidae	*Chaetops aurantius* (Drakensberg Rock-jumper)	N-End	SEE (D-AWS)
Aves	Cisticolidae	*Prinia hypoxantha* (Drakensberg Prinia)	N-End	Esc-Ext
Aves	Fringillidae	*Crithagra scotops* (Forest Canary)	N-End	Esc&Kny-Ext
Aves	Fringillidae	*Crithagra symonsi* (Drakensberg Siskin)	M-Out	D
Aves	Megaluridae	*Bradypterus sylvaticus* (Knysna Warbler)	N-End	Kny-Ext
Aves	Motacillidae	*Anthus chloris* (Yellow-breasted Pipit)	N-End	SEE (EE-D)
Aves	Motacillidae	*Anthus hoeschi* (Mountain Pipit)	M-Out	D
Aves	Muscicapidae	*Cossypha dichroa* (Chorister Robin-Chat)	N-End	Esc&Kny-Ext
Aves	Muscicapidae	*Oenanthe bifasciata* (Buff-streaked Chat)	N-End	Esc-Ext
Aves	Musophagidae	*Tauraco corythaix* (Knysna Turaco)	N-End	Esc&Kny-Ext
Aves	Picidae	*Campethera notata* (Knysna Woodpecker)	N-End	Kny-Ext
Aves	Psittacidae	*Poicephalus robustus* (Cape Parrot)	N-End	Esc-Ext
Aves	Timaliidae	*Lioptilus nigricapillus* (Bush Blackcap)	N-End	Esc-Ext
Mammalia	Chrysochloridae	*Amblysomus hottentotus* (Hottentot Golden Mole)	N-End	Esc&Kny-Ext
Mammalia	Chrysochloridae	*Amblysomus marleyi* (Marley's Golden Mole)	End	M
Mammalia	Chrysochloridae	*Amblysomus robustus* (Robust Golden Mole)	Out	EE
Mammalia	Chrysochloridae	*Chrysospalax trevelyani* (Giant Golden Mole)	End	TCB
Mammalia	Chrysochloridae	*Neamblysomus gunningi* (Gunning's Golden Mole)	Out	EE
Mammalia	Leporidae	*Pronolagus crassicaudatus* (Natal Red Rock Rabbit)	N-End	Esc-Ext
Mammalia	Muridae	*Otomys sloggetti* (Sloggett's Vlei Rat)	Ext-Out	SEE (EE-D)
Mammalia	Soricidae	*Myosorex sclateri* (Sclater's Forest Shrew)	End	SEC (M-KZN)

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[b], Endemic vertebrate distributions (EVDs): SEC, South-eastern Coastal; M, Maputaland; KZN, KwaZulu-Natal; TCB, Transkei Coastal Belt; ACB, Albany Coastal Belt; Esc-Ext, South-eastern Escarpment Extension of SEC; Kny-Ext, Knysna Extension of SEC; Esc&Kny-Ext, South-eastern Escarpment and Knysna Extension of SEC; Inh&Mop-Ext, Inhambane and Mopane Extension of SEC; SEE, South-eastern Escarpment; EE, Eastern Escarpment; D, Drakensberg; AWS, Amatola-Winterberg-Sneeuberg; Ext-A&C, Extended South-eastern Afromontane and Coastal; SE-Africa, South-eastern Africa; SE-SAfrica, South-east of South Africa (Figure 1).

Online supplementary material to Perera *et al*. (2011)

A checklist of the vertebrates in the Maputaland-Pondoland-Albany (MPA) biodiversity hotspot, as currently defined

Species taxonomy follows Froese and Pauly[33] for freshwater fish, du Preez and Carruthers[35] for amphibians, Animal Demography Unit[36] (as at 31 January 2010) for reptiles updated following Kelly et al.[41] for the family Lamprophiidae, Hockey et al.[39] for birds and Skinner and Chimimba[40] for mammals, whilst Alström et al.[42], Johansson et al.[43] and Kelly et al.[44] were used in updating familial-level taxonomy.

Class	Family	Species	Common name(s)	Status within MPA biodiversity hotspot
Pisces	Alestidae	*Brycinus imberi*	Imberi	Breeding resident
Pisces	Alestidae	*Brycinus lateralis*	Striped Robber	Breeding resident
Pisces	Alestidae	*Hydrocynus vittatus*	Tigerfish	Breeding resident
Pisces	Alestidae	*Micralestes acutidens*	Silver Robber	Breeding resident
Pisces	Ambassidae	*Ambassis gymnocephalus*	Bald Glassy	Breeding resident (secondary freshwater)
Pisces	Ambassidae	*Ambassis natalensis*	Slender Glassy	Breeding resident (secondary freshwater)
Pisces	Ambassidae	*Ambassis productus*	Longspine Glassy	Breeding resident (secondary freshwater)
Pisces	Amphiliidae	*Amphilius natalensis*	Natal Mountain Catfish	Near endemic
Pisces	Amphiliidae	*Amphilius uranoscopus*	Common (Stargazer) Mountain Catfish	Breeding resident
Pisces	Anabantidae	*Ctenopoma multispine*	Manyspined Climbing Perch	Breeding resident
Pisces	Anabantidae	*Microctenopoma intermedium*	Blackspot Climbing Perch	Breeding resident
Pisces	Anabantidae	*Sandelia bainsii*	Eastern Cape Rocky	Endemic
Pisces	Angullidae	*Anguilla bengalensis*	African Mottled Eel	Breeding resident
Pisces	Angullidae	*Anguilla bicolor*	Shortfin Eel	Breeding resident
Pisces	Angullidae	*Anguilla marmorata*	Madagascar Mottled Eel	Breeding resident
Pisces	Angullidae	*Anguilla mossambica*	Longfin Eel	Breeding resident
Pisces	Atherinidae	*Atherina breviceps*	Cape Silverside	Breeding resident (secondary freshwater)
Pisces	Carcharhinidae	*Carcharhinus leucas*	Bull Shark	Breeding resident (secondary freshwater)
Pisces	Cichlidae	*Chetia brevis*	Orange-fringed Largemouth	Near endemic
Pisces	Cichlidae	*Oreochromis mossambicus*	Mozambique Tilapia	Breeding resident
Pisces	Cichlidae	*Oreochromis placidus*	Black Tilapia	Breeding resident
Pisces	Cichlidae	*Pseudocrenilabrus philander*	Southern Mouthbrooder	Breeding resident
Pisces	Cichlidae	*Serranochromis meridianus*	Lowveld Largemouth	Endemic
Pisces	Cichlidae	*Tilapia rendalli*	Redbreast Tilapia	Breeding resident
Pisces	Cichlidae	*Tilapia sparrmanii*	Banded Tilapia	Breeding resident
Pisces	Clariidae	*Clarias gariepinus*	Sharptooth Catfish	Breeding resident
Pisces	Clariidae	*Clarias ngamensis*	Blunttooth Catfish	Breeding resident
Pisces	Clariidae	*Clarias theodorae*	Snake Catfish	Breeding resident
Pisces	Clupeidae	*Gilchristella aestuaria*	Estuarine Round-Herring	Breeding resident (secondary freshwater)
Pisces	Cyprinidae	*Barbus afrohamiltoni*	Hamilton's Barb	Breeding resident
Pisces	Cyprinidae	*Barbus amatolicus*	Amatola Barb	Endemic
Pisces	Cyprinidae	*Barbus annectens*	Broadstriped Barb	Breeding resident
Pisces	Cyprinidae	*Barbus anoplus*	Chubbyhead Barb	Breeding resident
Pisces	Cyprinidae	*Barbus argenteus*	Rosefin Barb	Breeding resident
Pisces	Cyprinidae	*Barbus bifrenatus*	Hyphen Barb	Breeding resident
Pisces	Cyprinidae	*Barbus brevipinnis*	Shortfin Barb	Near endemic
Pisces	Cyprinidae	*Barbus eutaenia*	Orangefin Barb	Breeding resident
Pisces	Cyprinidae	*Barbus gurneyi*	Redtail Barb	Endemic
Pisces	Cyprinidae	*Barbus pallidus*	Goldie Barb	Breeding resident
Pisces	Cyprinidae	*Barbus paludinosus*	Straightfin Barb	Breeding resident
Pisces	Cyprinidae	*Barbus radiatus*	Beira Barb	Breeding resident
Pisces	Cyprinidae	*Barbus toppini*	East Coast Barb	Breeding resident
Pisces	Cyprinidae	*Barbus treurensis*	Treur River Barb	Near endemic
Pisces	Cyprinidae	*Barbus trevelyani*	Border Barb	Endemic
Pisces	Cyprinidae	*Barbus trimaculatus*	Threespot Barb	Breeding resident
Pisces	Cyprinidae	*Barbus unitaeniatus*	Longbeard Barb	Breeding resident
Pisces	Cyprinidae	*Barbus viviparus*	Bowstripe Barb	Breeding resident
Pisces	Cyprinidae	*Labeo congoro*	Purple Labeo	Breeding resident
Pisces	Cyprinidae	*Labeo cylindricus*	Redeye Labeo	Breeding resident
Pisces	Cyprinidae	*Labeo molybdinus*	Leaden Labeo	Breeding resident
Pisces	Cyprinidae	*Labeo rosae*	Rednose Labeo	Breeding resident
Pisces	Cyprinidae	*Labeo rubromaculatus*	Tugela Labeo	Endemic
Pisces	Cyprinidae	*Labeo ruddi*	Silver Labeo	Breeding resident
Pisces	Cyprinidae	*Labeo umbratus*	Moggel	Breeding resident
Pisces	Cyprinidae	*Labeobarbus marequensis*	Largescale Yellowfish	Breeding resident

Pisces	Cyprinidae	*Labeobarbus natalensis*	Scaly	Endemic
Pisces	Cyprinidae	*Labeobarbus polylepis*	Smallscale Yellowfish	Breeding resident
Pisces	Cyprinidae	*Mesobola brevianalis*	River Sardine	Breeding resident
Pisces	Cyprinidae	*Opsaridium zambezense*	Barred Minnow	Breeding resident
Pisces	Cyprinidae	*Pseudobarbus afer*	Eastern Cape Redfin	Near endemic
Pisces	Cyprinidae	*Pseudobarbus quathlambae*	Drakensberg Minnow	Breeding resident
Pisces	Cyprinidae	*Varicorhinus nelspruitensis*	Incomati Chiselmouth	Near endemic
Pisces	Eleotridae	*Eleotris fusca*	Dusky Sleeper	Breeding resident (secondary freshwater)
Pisces	Eleotridae	*Eleotris melanosoma*	Broadhead Sleeper	Breeding resident (secondary freshwater)
Pisces	Eleotridae	*Hypseleotris dayi*	Golden Sleeper	Endemic (secondary freshwater)
Pisces	Gobiidae	*Awaous aeneofuscus*	Freshwater Goby	Breeding resident (secondary freshwater)
Pisces	Gobiidae	*Croilia Mossambica*	Burrowing Goby	Breeding resident (secondary freshwater)
Pisces	Gobiidae	*Glossogobius callidus*	River Goby	Breeding resident (secondary freshwater)
Pisces	Gobiidae	*Glossogobius giuris*	Tank Goby	Breeding resident (secondary freshwater)
Pisces	Gobiidae	*Redigobius dewaali*	Checked Goby	Near endemic (secondary freshwater)
Pisces	Gobiidae	*Silhouettea sibayi*	Sibayi Goby	Endemic (secondary freshwater)
Pisces	Kneriidae	*Kneria auriculata*	Southern Kneria	Breeding resident
Pisces	Megalopidae	*Megalops cyprinoides*	Oxeye Tarpon	Breeding resident
Pisces	Mochokidae	*Chiloglanis anoterus*	Pennant-tailed Suckermouth	Endemic
Pisces	Mochokidae	*Chiloglanis bifurcus*	Incomati Suckermouth	Near endemic
Pisces	Mochokidae	*Chiloglanis emarginatus*	Phongolo Suckermouth	Near endemic
Pisces	Mochokidae	*Chiloglanis paratus*	Sawfin Suckermouth	Breeding resident
Pisces	Mochokidae	*Chiloglanis pretoriae*	Shortspine Suckermouth	Breeding resident
Pisces	Mochokidae	*Chiloglanis swierstrai*	Lowveld Suckermouth	Breeding resident
Pisces	Mochokidae	*Synodontis zambezensis*	Brown Squeaker	Breeding resident
Pisces	Monodactylidae	*Monodactylus argenteus*	Natal Moony	Breeding resident (secondary freshwater)
Pisces	Monodactylidae	*Monodactylus falciformis*	Cape Moony	Breeding resident (secondary freshwater)
Pisces	Mormyridae	*Marcusenius macrolepidotus*	Bulldog	Breeding resident
Pisces	Mormyridae	*Petrocephalus catostoma*	Churchill	Breeding resident
Pisces	Mugilidae	*Liza macrolepis*	Largescale Mullet	Breeding resident (secondary freshwater)
Pisces	Mugilidae	*Mugil cephalus*	Flathead Mullet	Breeding resident (secondary freshwater)
Pisces	Mugilidae	*Myxus capensis*	Freshwater Mullet	Near endemic (secondary freshwater)
Pisces	Nothobranchiidae	*Nothobranchius orthonotus*	Spotted Killifish	Breeding resident
Pisces	Nothobranchiidae	*Nothobranchius rachovii*	Rainbow Killifish	Breeding resident
Pisces	Poeciliidae	*Aplocheilichthys johnstoni*	Johnston's Topminnow	Breeding resident
Pisces	Poeciliidae	*Aplocheilichthys katangae*	Striped Topminnow	Breeding resident
Pisces	Poeciliidae	*Aplocheilichthys myaposae*	Natal Topminnow	Breeding resident
Pisces	Pristidae	*Pristis microdon*	Smalltooth Sawfish	Breeding resident (secondary freshwater)
Pisces	Schilbeidae	*Schilbe intermedius*	Silver Catfish	Breeding resident
Pisces	Sparidae	*Acanthopagrus berda*	Riverbream	Breeding resident (secondary freshwater)
Pisces	Syngnathidae	*Microphis brachyurus*	Shorttail Pipefish	Breeding resident (secondary freshwater)
Pisces	Syngnathidae	*Microphis fluviatilis*	Freshwater Pipefish	Breeding resident (secondary freshwater)
Amphibia	Arthroleptidae	*Arthroleptis stenodactylus*	Shovel-footed (Common) Squeaker	Breeding resident
Amphibia	Arthroleptidae	*Arthroleptis wahlbergi*	Bush Squeaker	Endemic
Amphibia	Arthroleptidae	*Leptopelis mossambicus*	Brown-backed Tree Frog	Breeding resident
Amphibia	Arthroleptidae	*Leptopelis natalensis*	Natal Tree Frog	Endemic
Amphibia	Arthroleptidae	*Leptopelis xenodactylus*	Long-toed Tree Frog	Endemic
Amphibia	Breviceptidae	*Breviceps adspersus*	Bushveld (Common) Rain Frog	Breeding resident
Amphibia	Breviceptidae	*Breviceps bagginsi*	Bilbo's Rain Frog	Endemic
Amphibia	Breviceptidae	*Breviceps mossambicus*	Mozambique Rain Frog	Breeding resident
Amphibia	Breviceptidae	*Breviceps sopranus*	Whistling Rain Frog	Endemic
Amphibia	Breviceptidae	*Breviceps verrucosus*	Plaintive Rain Frog	Near endemic

Amphibia	Bufonidae	*Amietophrynus garmani*	Eastern Olive Toad	Breeding resident
Amphibia	Bufonidae	*Amietophrynus gutturalis*	Guttural Toad	Breeding resident
Amphibia	Bufonidae	*Amietophrynus maculatus*	Flat-backed Toad	Breeding resident
Amphibia	Bufonidae	*Amietophrynus pardalis*	Eastern Leopard Toad	Near endemic
Amphibia	Bufonidae	*Amietophrynus rangeri*	Raucous (Ranger's) Toad	Breeding resident
Amphibia	Bufonidae	*Poyntonophrynusn fenoulheti*	Northern Pygmy Toad	Breeding resident
Amphibia	Bufonidae	*Poyntonophrynusn vertebralis*	Southern PygmyToad	Breeding resident
Amphibia	Bufonidae	*Schismaderma carens*	Red Toad	Breeding resident
Amphibia	Bufonidae	*Vandijkophrynus amatolicus*	Amatola Toad	Endemic
Amphibia	Bufonidae	*Vandijkophrynus gariepensis*	Karoo Toad	Breeding resident
Amphibia	Heleophrynidae	*Hadromophryne natalensis*	Natal Cascade (Ghost) Frog	Near endemic
Amphibia	Hemisotidae	*Hemisus guttatus*	Spotted Shovel-nosed Frog (Snout-burrower)	Near endemic
Amphibia	Hemisotidae	*Hemisus marmoratus*	Mottled Shovel-nosed Frog (Marbled Snout-burrower)	Breeding resident
Amphibia	Hyperoliidae	*Afrixalus aureus*	Golden Leaf-folding (Dwarf Reed) Frog	Near endemic
Amphibia	Hyperoliidae	*Afrixalus delicatus*	Delicate Leaf-folding (Pickersgill's Banana) Frog	Breeding resident
Amphibia	Hyperoliidae	*Afrixalus fornasinii*	Greater Leaf-folding Frog	Breeding resident
Amphibia	Hyperoliidae	*Afrixalus spinifrons*	Natal Leaf-folding (Banana) Frog	Endemic
Amphibia	Hyperoliidae	*Hyperolius acuticeps*	Sharp-nosed Reed Frog	Breeding resident
Amphibia	Hyperoliidae	*Hyperolius argus*	Argus Reed Frog	Breeding resident
Amphibia	Hyperoliidae	*Hyperolius marmoratus*	Painted (Marbled) Reed Frog	Breeding resident
Amphibia	Hyperoliidae	*Hyperolius pickersgilli*	Pickersgill's Reed Frog	Endemic
Amphibia	Hyperoliidae	*Hyperolius pusillus*	Water Lily Frog	Breeding resident
Amphibia	Hyperoliidae	*Hyperolius semidiscus*	Yellow-striped Reed Frog	Near endemic
Amphibia	Hyperoliidae	*Hyperolius tuberilinguis*	Tinker Reed Frog	Breeding resident
Amphibia	Hyperoliidae	*Kassina maculata*	Red-legged Kassina	Breeding resident
Amphibia	Hyperoliidae	*Kassina senegalensis*	Bubbling Kassina	Breeding resident
Amphibia	Hyperoliidae	*Semnodactylus wealii*	Rattling (Weale's Running) Frog	Breeding resident
Amphibia	Microhylidae	*Phrynomantis bifasciatus*	Banded Rubber Frog	Breeding resident
Amphibia	Phrynobatrachidae	*Phrynobatrachus acridoides*	East African Puddle Frog	Breeding resident
Amphibia	Phrynobatrachidae	*Phrynobatrachus mababiensis*	Dwarf Puddle Frog	Breeding resident
Amphibia	Phrynobatrachidae	*Phrynobatrachus natalensis*	Snoring (Natal Dwarf) Puddle Frog	Breeding resident
Amphibia	Pipidae	*Xenopus laevis*	Common Platanna	Breeding resident
Amphibia	Pipidae	*Xenopus muelleri*	Muller's Platanna	Breeding resident
Amphibia	Ptychadenidae	*Hildebrandtia ornata*	Ornate Frog	Breeding resident
Amphibia	Ptychadenidae	*Ptychadena anchietae*	Plain Grass Frog	Breeding resident
Amphibia	Ptychadenidae	*Ptychadena mascareniensis*	Mascarene Grass (Ridged) Frog	Breeding resident
Amphibia	Ptychadenidae	*Ptychadena mossambica*	Broad-banded Grass (Mozambique Ridged) Frog	Breeding resident
Amphibia	Ptychadenidae	*Ptychadena oxyrhynchus*	Sharp-nosed Grass Frog	Breeding resident
Amphibia	Ptychadenidae	*Ptychadena porosissima*	Striped Grass Frog	Breeding resident
Amphibia	Ptychadenidae	*Ptychadena taenioscelis*	Dwarf Grass Frog	Breeding resident
Amphibia	Pyxicephalidae	*Amietia angolensis*	Common River Frog	Breeding resident
Amphibia	Pyxicephalidae	*Amietia fuscigula*	Cape River Frog	Breeding resident
Amphibia	Pyxicephalidae	*Anhydrophryne hewitti*	Natal Chirping (Hewitt's Moss) Frog	Endemic
Amphibia	Pyxicephalidae	*Anhydrophryne ngongoniensis*	Mistbelt Chirping (Ngoni Moss) Frog	Endemic
Amphibia	Pyxicephalidae	*Anhydrophryne rattrayi*	Hogsback Chirping Frog	Endemic
Amphibia	Pyxicephalidae	*Cacosternum boettgeri*	Boettger's Caco (Dainty Frog)	Breeding resident
Amphibia	Pyxicephalidae	*Cacosternum nanum*	Bronze Caco	Near endemic
Amphibia	Pyxicephalidae	*Cacosternum parvum*	Mountain Caco (Small Dainty Frog)	Breeding resident
Amphibia	Pyxicephalidae	*Cacosternum poyntoni*	Poynton's Caco	Endemic
Amphibia	Pyxicephalidae	*Cacosternum* sp. nov. 'A'	Rhythmic Caco	Endemic
Amphibia	Pyxicephalidae	*Cacosternum* sp. nov. 'B'	KwaZulu Caco	Endemic
Amphibia	Pyxicephalidae	*Cacosternum striatum*	Striped Caco	Endemic
Amphibia	Pyxicephalidae	*Natalobatrachus bonebergi*	Kloof Frog	Endemic
Amphibia	Pyxicephalidae	*Pyxicephalus adspersus*	Giant (African) Bullfrog	Breeding resident
Amphibia	Pyxicephalidae	*Pyxicephalus edulis*	African (Edible) Bullfrog	Breeding resident
Amphibia	Pyxicephalidae	*Strongylopus fasciatus*	Striped Stream Frog	Breeding resident
Amphibia	Pyxicephalidae	*Strongylopus grayii*	Clicking (Gray's) Stream Frog	Breeding resident
Amphibia	Pyxicephalidae	*Strongylopus wageri*	Plain (Wager's) Stream Frog	Near endemic
Amphibia	Pyxicephalidae	*Tomopterna cryptotis*	Tremolo (Common) Sand Frog	Breeding resident
Amphibia	Pyxicephalidae	*Tomopterna delalandii*	Cape (Delalande's) Sand Frog	Breeding resident
Amphibia	Pyxicephalidae	*Tomopterna krugerensis*	Knocking Sand Frog	Breeding resident
Amphibia	Pyxicephalidae	*Tomopterna marmorata*	Russet-backed (Marbled) Sand Frog	Breeding resident
Amphibia	Pyxicephalidae	*Tomopterna natalensis*	Natal Sand Frog	Breeding resident
Amphibia	Pyxicephalidae	*Tomopterna tandyi*	Tandy's Sand Frog	Breeding resident
Amphibia	Rhacophoridae	*Chiromantis xerampelina*	Southern Foam Nest Frog (Grey Foam-nest Treefrog)	Breeding resident

Reptilia	Agamidae	*Acanthocercus atricollis*	Blue-throated Agama	Breeding resident
Reptilia	Agamidae	*Agama aculeata*	Ground Agama	Breeding resident
Reptilia	Agamidae	*Agama armata*	Peter's Ground Agama	Breeding resident
Reptilia	Agamidae	*Agama atra*	Southern Rock Agama	Breeding resident
Reptilia	Amphisbaenidae	*Monopeltis decosteri*	De Coster's (Spade-snouted) Worm Lizard	Breeding resident
Reptilia	Amphisbaenidae	*Monopeltis infuscata*	Dusky (Spade-snouted) Worm Lizard	Breeding resident
Reptilia	Amphisbaenidae	*Monopeltis sphenorhynchus*	Slender (Spade-snouted) Worm Lizard	Breeding resident
Reptilia	Amphisbaenidae	*Zygaspis vandami*	Van Dam's Dwarf (Round-headed) Worm Lizard	Breeding resident
Reptilia	Amphisbaenidae	*Zygaspis violacea*	Violet Dwarf (Round-headed) Worm Lizard	Near endemic
Reptilia	Atractaspididae	*Amblyodipsas concolor*	Natal Purple-glossed Snake	Near endemic
Reptilia	Atractaspididae	*Amblyodipsas microphthalma*	Eyeless Purple-glossed Snake	Near endemic
Reptilia	Atractaspididae	*Amblyodipsas polylepis*	Common Purple-glossed Snake	Breeding resident
Reptilia	Atractaspididae	*Aparallactus capensis*	Cape Centipede-eater	Breeding resident
Reptilia	Atractaspididae	*Aparallactus guentheri*	Black Centipede-eater	Breeding resident
Reptilia	Atractaspididae	*Aparallactus lunulatus*	Reticulate Centipede-eater	Breeding resident
Reptilia	Atractaspididae	*Aparallactus nigriceps*	Mozambique Centipede-eater	Breeding resident
Reptilia	Atractaspididae	*Atractaspis bibronii*	Bibron's Stiletto Snake	Breeding resident
Reptilia	Atractaspididae	*Homoroselaps dorsalis*	Striped Harlequin Snake	Breeding resident
Reptilia	Atractaspididae	*Homoroselaps lacteus*	Spotted Harlequin Snake	Breeding resident
Reptilia	Atractaspididae	*Macrelaps microlepidotus*	Natal Black Snake	Endemic
Reptilia	Atractaspididae	*Xenocalamus lineatus*	Striped Quill-snouted Snake	Breeding resident
Reptilia	Atractaspididae	*Xenocalamus transvaalensis*	Speckled (Transvaal) Quill-snouted Snake	Near endemic
Reptilia	Boidae	*Python natalensis*	Southern African (Rock) Python	Breeding resident
Reptilia	Chamaeleonidae	*Bradypodion caeruleogula*	uMlalazi Dwarf Chameleon	Endemic
Reptilia	Chamaeleonidae	*Bradypodion caffer*	Pondo (Transkei) Dwarf Chameleon	Endemic
Reptilia	Chamaeleonidae	*Bradypodion kentanicum*	Kentani Dwarf Chameleon	Endemic
Reptilia	Chamaeleonidae	*Bradypodion melanocephalum*	KwaZulu (Black-headed) Dwarf Chameleon	Endemic
Reptilia	Chamaeleonidae	*Bradypodion nemorale*	Qudeni (Zululand) Dwarf Chameleon	Endemic
Reptilia	Chamaeleonidae	*Bradypodion ngomeense*	Ngome Dwarf Chameleon	Endemic
Reptilia	Chamaeleonidae	*Bradypodion setaroi*	Setaro's Dwarf Chameleon	Endemic
Reptilia	Chamaeleonidae	*Bradypodion thamnobates*	Natal Midlands Dwarf Chameleon	Endemic
Reptilia	Chamaeleonidae	*Bradypodion ventrale*	Eastern Cape (Southern) Dwarf Chameleon	Near endemic
Reptilia	Chamaeleonidae	*Chamaeleo dilepis*	Flapneck Chameleon	Breeding resident
Reptilia	Colubridae	*Crotaphopeltis hotamboeia*	Herald Snake	Breeding resident
Reptilia	Colubridae	*Dasypeltis inornata*	Southern Brown Egg-eater	Near endemic
Reptilia	Colubridae	*Dasypeltis medici*	East African Egg-eater	Breeding resident
Reptilia	Colubridae	*Dasypeltis scabra*	Rhombic (Common) Egg-eater	Breeding resident
Reptilia	Colubridae	*Dipsadoboa aulica*	Marbled Tree Snake	Breeding resident
Reptilia	Colubridae	*Dipsadoboa flavida*	Cross-barred Tree Snake	Breeding resident
Reptilia	Colubridae	*Dispholidus typus*	Boomslang	Breeding resident
Reptilia	Colubridae	*Meizodon semiornatus*	Semiornate Snake	Breeding resident
Reptilia	Colubridae	*Natriciteres olivacea*	Olive Marsh Snake	Breeding resident
Reptilia	Colubridae	*Natriciteres sylvatica*	Forest Marsh Snake	Breeding resident
Reptilia	Colubridae	*Philothamnus angolensis*	Angola Green Snake	Breeding resident
Reptilia	Colubridae	*Philothamnus hoplogaster*	South Eastern Green Snake	Breeding resident
Reptilia	Colubridae	*Philothamnus natalensis*	East Natal Green Snake	Breeding resident
Reptilia	Colubridae	*Philothamnus semivariegatus*	Variegated Green Snake	Breeding resident
Reptilia	Colubridae	*Telescopus semiannulatus*	Eastern Tiger Snake	Breeding resident
Reptilia	Colubridae	*Thelotornis capensis*	Twig Snake	Breeding resident
Reptilia	Cordylidae	*Chamaesaura aenea*	Coppery (Transvaal) Grass Lizard	Breeding resident
Reptilia	Cordylidae	*Chamaesaura anguina*	Cape Grass Lizard	Breeding resident
Reptilia	Cordylidae	*Chamaesaura macrolepis*	Large-scaled Grass Lizard	Breeding resident
Reptilia	Cordylidae	*Cordylus cordylus*	Cape Girdled Lizard	Breeding resident
Reptilia	Cordylidae	*Cordylus jonesii*	Jones' Girdled Lizard	Breeding resident
Reptilia	Cordylidae	*Cordylus polyzonus*	Karoo Girdled Lizard	Breeding resident
Reptilia	Cordylidae	*Cordylus tasmani*	Tasman's Girdled Lizard	Endemic
Reptilia	Cordylidae	*Cordylus vittifer*	Transvaal Girdled Lizard	Breeding resident
Reptilia	Cordylidae	*Cordylus warreni*	Warren's Girdled Lizard	Breeding resident
Reptilia	Cordylidae	*Platysaurus intermedius*	Common Flat Lizard	Breeding resident
Reptilia	Cordylidae	*Platysaurus lebomboensis*	Lebombo Flat Lizard	Endemic
Reptilia	Cordylidae	*Pseudocordylus melanotus*	Common Crag Lizard	Breeding resident
Reptilia	Cordylidae	*Pseudocordylus microlepidotus*	Cape Crag Lizard	Breeding resident
Reptilia	Cordylidae	*Pseudocordylus spinosus*	Spiny Crag Lizard	Near endemic
Reptilia	Crocodylidae	*Crocodylus niloticus*	Nile Crocodile	Breeding resident

Reptilia	Elapidae	*Aspidelaps lubricus*	South African Coral Snake	Breeding resident
Reptilia	Elapidae	*Aspidelaps scutatus*	Shieldnose Cobra	Breeding resident
Reptilia	Elapidae	*Dendroaspis angusticeps*	Green (Common) Mamba	Breeding resident
Reptilia	Elapidae	*Dendroaspis polylepis*	Black Mamba	Breeding resident
Reptilia	Elapidae	*Elapsoidea boulengeri*	Boulenger's Garter Snake	Breeding resident
Reptilia	Elapidae	*Elapsoidea sundevallii*	Sundevall's Garter Snake	Breeding resident
Reptilia	Elapidae	*Hemachatus haemachatus*	Rinkhals	Breeding resident
Reptilia	Elapidae	*Naja annulifera*	Snouted Cobra	Breeding resident
Reptilia	Elapidae	*Naja melanoleuca*	Forest Cobra	Breeding resident
Reptilia	Elapidae	*Naja mossambica*	Mozambique Spitting Cobra	Breeding resident
Reptilia	Elapidae	*Naja nivea*	Cape Cobra	Breeding resident
Reptilia	Gekkonidae	*Afroedura amatolica*	Amatola Flat Gecko	Endemic
Reptilia	Gekkonidae	*Afroedura halli*	Hall's Flat Gecko	Breeding resident
Reptilia	Gekkonidae	*Afroedura karroica*	Karoo Flat Gecko	Near endemic
Reptilia	Gekkonidae	*Afroedura langi*	Lowveld Flat Gecko	Near endemic
Reptilia	Gekkonidae	*Afroedura major*	Giant Swazi Flat Gecko	Near endemic
Reptilia	Gekkonidae	*Afroedura marleyi*	Marley's Flat Gecko	Endemic
Reptilia	Gekkonidae	*Afroedura multiporis*	Woodbush Flat Gecko	Breeding resident
Reptilia	Gekkonidae	*Afroedura pondolia*	Pondo Flat Gecko	Endemic
Reptilia	Gekkonidae	*Afroedura* sp. nov. 'granitica'	-	Near endemic
Reptilia	Gekkonidae	*Afroedura* sp. nov. 'lebomboensis'	-	Endemic
Reptilia	Gekkonidae	*Afroedura* sp. nov. 'mariepi'	-	Near endemic
Reptilia	Gekkonidae	*Afroedura* sp. nov. 'pongolae'	-	Endemic
Reptilia	Gekkonidae	*Afroedura* sp. nov. 'rondavelica'	-	Near endemic
Reptilia	Gekkonidae	*Afroedura* sp. nov. 'rupestris'	-	Near endemic
Reptilia	Gekkonidae	*Afroedura tembulica*	Tembo Flat Gecko	Endemic
Reptilia	Gekkonidae	*Afrogecko porphyreus*	Marbled Leaf-toed Gecko	Breeding resident
Reptilia	Gekkonidae	*Chondrodactylus bibronii*	Bibron's (Thick-toed) Gecko	Breeding resident
Reptilia	Gekkonidae	*Chondrodactylus turneri*	Turner's (Thick-toed) Gecko	Breeding resident
Reptilia	Gekkonidae	*Goggia essexi*	Essex's Pygmy (Dwarf Leaf-toed) Gecko	Endemic
Reptilia	Gekkonidae	*Hemidactylus mabouia*	Common Tropical (Cosmopolitan) House Gecko	Breeding resident
Reptilia	Gekkonidae	*Homopholis wahlbergii*	Wahlberg's Velvet Gecko	Breeding resident
Reptilia	Gekkonidae	*Lygodactylus capensis*	Common (Cape) Dwarf Gecko	Breeding resident
Reptilia	Gekkonidae	*Pachydactylus capensis*	Cape (Thick-toed) Gecko	Breeding resident
Reptilia	Gekkonidae	*Pachydactylus geitje*	Ocellated (Thick-toed) Gecko	Breeding resident
Reptilia	Gekkonidae	*Pachydactylus maculatus*	Spotted (Thick-toed) Gecko	Breeding resident
Reptilia	Gekkonidae	*Pachydactylus mariquensis*	Marico (Ceres) (Thick-toed) Gecko	Breeding resident
Reptilia	Gekkonidae	*Pachydactylus oculatus*	Golden-spotted (Inland) (Thick-toed) Gecko	Breeding resident
Reptilia	Gekkonidae	*Pachydactylus punctatus*	Speckled (Thick-toed) Gecko	Breeding resident
Reptilia	Gekkonidae	*Pachydactylus vansoni*	Van Son's (Thick-toed) Gecko	Breeding resident
Reptilia	Gekkonidae	*Ptenopus garrulus*	Common Barking Gecko	Breeding resident
Reptilia	Gerrhosauridae	*Gerrhosaurus flavigularis*	Yellow-throated Plated Lizard	Breeding resident
Reptilia	Gerrhosauridae	*Gerrhosaurus major*	Rough-scaled Plated Lizard	Breeding resident
Reptilia	Gerrhosauridae	*Gerrhosaurus nigrolineatus*	Black-lined Plated Lizard	Breeding resident
Reptilia	Gerrhosauridae	*Gerrhosaurus typicus*	Karoo (Namaqua) Plated Lizard	Breeding resident
Reptilia	Gerrhosauridae	*Gerrhosaurus validus*	Common Giant Plated Lizard	Breeding resident
Reptilia	Gerrhosauridae	*Tetradactylus africanus*	Eastern Long-tailed Seps (African Whip Lizard)	Near endemic
Reptilia	Gerrhosauridae	*Tetradactylus breyeri*	Breyer's Long-tailed Seps	Breeding resident
Reptilia	Gerrhosauridae	*Tetradactylus seps*	Short-legged Seps (Five-toed Whip Lizard)	Breeding resident
Reptilia	Gerrhosauridae	*Tetradactylus tetradactylis*	Cape (Common) Long-tailed Seps	Breeding resident
Reptilia	Lacertidae	*Heliobolus lugubris*	Bushveld Lizard	Breeding resident
Reptilia	Lacertidae	*Ichnotropis capensis*	Ornate (Cape) Rough-scaled Lizard	Breeding resident
Reptilia	Lacertidae	*Ichnotropis squamulosa*	Common Rough-scaled Lizard	Breeding resident
Reptilia	Lacertidae	*Nucras caesicaudatus*	Blue-tailed Sandveld Lizard	Breeding resident
Reptilia	Lacertidae	*Nucras holubi*	Holub's Sandveld Lizard	Breeding resident
Reptilia	Lacertidae	*Nucras intertexta*	Spotted Sandveld Lizard	Breeding resident
Reptilia	Lacertidae	*Nucras lalandii*	Delalande's Sandveld Lizard	Breeding resident
Reptilia	Lacertidae	*Nucras livida*	Karoo Sandveld Lizard	Breeding resident
Reptilia	Lacertidae	*Nucras ornata*	Ornate Sandveld Lizard	Breeding resident
Reptilia	Lacertidae	*Nucras taeniolata*	Striped Scrub Lizard (Albany Sandveld Lizard)	Endemic
Reptilia	Lacertidae	*Pedioplanis burchelli*	Burchell's Sand Lizard	Breeding resident

Reptilia	Lacertidae	*Pedioplanis laticeps*	Karoo Sand Lizard	Breeding resident
Reptilia	Lacertidae	*Pedioplanis namaquensis*	Namaqua Sand Lizard	Breeding resident
Reptilia	Lacertidae	*Pedioplanis pulchella*	Common Sand Lizard	Breeding resident
Reptilia	Lacertidae	*Tropidosaura montana*	Green-striped Mountain Lizard	Breeding resident
Reptilia	Lamprophiidae	*Boaedon capensis*	Brown House Snake	Breeding resident
Reptilia	Lamprophiidae	*Gonionotophis capensis*	Common (Cape) File Snake	Breeding resident
Reptilia	Lamprophiidae	*Gonionotophis nyassae*	Black (Nyassa) File Snake	Breeding resident
Reptilia	Lamprophiidae	*Inyoka swazicus*	Swazi Rock Snake	Breeding resident
Reptilia	Lamprophiidae	*Lamprophis aurora*	Aurora House Snake	Breeding resident
Reptilia	Lamprophiidae	*Lamprophis fuscus*	Yellow-bellied House Snake	Breeding resident
Reptilia	Lamprophiidae	*Lamprophis guttatus*	Spotted House Snake	Breeding resident
Reptilia	Lamprophiidae	*Lycodonomorphus inornatus*	Olive Water (House) Snake	Breeding resident
Reptilia	Lamprophiidae	*Lycodonomorphus laevissimus*	Dusky-bellied Water Snake	Near endemic
Reptilia	Lamprophiidae	*Lycodonomorphus obscuriventris*	Floodplain Water Snake	Breeding resident
Reptilia	Lamprophiidae	*Lycodonomorphus rufulus*	Common Brown (Lichtenstein's) Water Snake	Breeding resident
Reptilia	Lamprophiidae	*Lycophidion capense*	Cape Wolf Snake	Breeding resident
Reptilia	Lamprophiidae	*Lycophidion pygmaeum*	Pygmy Wolf Snake	Endemic
Reptilia	Lamprophiidae	*Lycophidion semiannule*	Bazaruto Wolf Snake	Near endemic
Reptilia	Lamprophiidae	*Lycophidion variegatum*	Variegated Wolf Snake	Breeding resident
Reptilia	Leptotyphlopidae	*Leptotyphlops distanti*	Distant's Thread Snake	Breeding resident
Reptilia	Leptotyphlopidae	*Leptotyphlops incognitus*	Incognito Thread Snake	Breeding resident
Reptilia	Leptotyphlopidae	*Leptotyphlops nigricans*	Black Thread Snake (Schlegel's Blind Snake)	Breeding resident
Reptilia	Leptotyphlopidae	*Leptotyphlops scutifrons*	Peter's Thread Snake (Shielded Blind Snake)	Breeding resident
Reptilia	Leptotyphlopidae	*Leptotyphlops sylvicolus*	Forest Thread Snake	Endemic
Reptilia	Leptotyphlopidae	*Leptotyphlops telloi*	Tello's Thread Snake	Endemic
Reptilia	Leptotyphlopidae	*Myriopholis longicauda*	Long-tailed Thread (Blind) Snake	Breeding resident
Reptilia	Pelomedusidae	*Pelomedusa subrufa*	Marsh (Helmeted) Terrapin	Breeding resident
Reptilia	Pelomedusidae	*Pelusios castanoides*	Yellow-bellied Hinged Terrapin (Yellowbelly Mud Turtle)	Breeding resident
Reptilia	Pelomedusidae	*Pelusios rhodesianus*	Variable (Mashona) Hinged Terrapin	Breeding resident
Reptilia	Pelomedusidae	*Pelusios sinuatus*	Serrated Hinged Terrapin (East African Serrated Mud Turtle)	Breeding resident
Reptilia	Pelomedusidae	*Pelusios subniger*	Black-bellied Hinged Terrapin (East African Black Mud Turtle)	Breeding resident
Reptilia	Prosymnidae	*Prosymna bivittata*	Two-striped Shovel-snout	Breeding resident
Reptilia	Prosymnidae	*Prosymna janii*	Mozambique Shovel-snout	Near endemic
Reptilia	Prosymnidae	*Prosymna lineata*	Lined Shovel-snout	Breeding resident
Reptilia	Prosymnidae	*Prosymna stuhlmannii*	East African Shovel-snout	Breeding resident
Reptilia	Prosymnidae	*Prosymna sundevallii*	Sundevall's Shovel-snout	Breeding resident
Reptilia	Psammophiidae	*Hemirhagerrhis nototaenia*	Eastern Bark Snake	Breeding resident
Reptilia	Psammophiidae	*Psammophis angolensis*	Dwarf Sand Snake	Breeding resident
Reptilia	Psammophiidae	*Psammophis brevirostris*	Short-snouted Sand Snake	Breeding resident
Reptilia	Psammophiidae	*Psammophis crucifer*	Cross-marked Grass Snake	Breeding resident
Reptilia	Psammophiidae	*Psammophis mossambicus*	Olive Grass Snake	Breeding resident
Reptilia	Psammophiidae	*Psammophis notostictus*	Karoo Sand Snake	Breeding resident
Reptilia	Psammophiidae	*Psammophis subtaeniatus*	Stripe-bellied Sand Snake	Breeding resident
Reptilia	Psammophiidae	*Psammophylax rhombeatus*	Spotted Grass Snake (Skaapsteker)	Breeding resident
Reptilia	Psammophiidae	*Psammophylax tritaeniatus*	Striped Grass Snake (Skaapsteker)	Breeding resident
Reptilia	Psammophiidae	*Pseudaspis cana*	Mole Snake	Breeding resident
Reptilia	Psammophiidae	*Rhamphiophis rostratus*	Rufous Beaked Snake	Breeding resident
Reptilia	Pseudoxyrhophiidae	*Amplorhinus multimaculatus*	Many-spotted Snake	Breeding resident
Reptilia	Pseudoxyrhophiidae	*Duberria lutrix*	Common Slug-eater	Breeding resident
Reptilia	Pseudoxyrhophiidae	*Duberria variegata*	Variegated Slug-eater	Near endemic
Reptilia	Scincidae	*Acontias breviceps*	Short-headed Legless Skink	Near endemic
Reptilia	Scincidae	*Acontias gracilicauda*	Thin-tailed Legless Skink	Breeding resident
Reptilia	Scincidae	*Acontias meleagris*	Cape Legless Skink	Breeding resident
Reptilia	Scincidae	*Acontias percivali*	Percival's Legless Skink	Breeding resident
Reptilia	Scincidae	*Acontias plumbeus*	Giant Legless Skink	Breeding resident
Reptilia	Scincidae	*Acontias poecilus*	Variable Legless Skink	Endemic
Reptilia	Scincidae	*Cryptoblepharus africanus*	African Coral Rag (Bouton's) Skink	Breeding resident
Reptilia	Scincidae	*Mochlus sundevallii*	Sundevall's Writhing Skink	Breeding resident
Reptilia	Scincidae	*Panaspis maculicollis*	Spotted-neck Snake-eyed Skink	Breeding resident
Reptilia	Scincidae	*Panaspis wahlbergii*	Wahlberg's Snake-eyed Skink	Breeding resident
Reptilia	Scincidae	*Scelotes anguineus*	Algoa Dwarf Burrowing Skink	Endemic
Reptilia	Scincidae	*Scelotes arenicolus*	Zululand Dwarf Burrowing Skink	Endemic
Reptilia	Scincidae	*Scelotes bidigittatus*	Lowveld Dwarf Burrowing Skink	Near endemic
Reptilia	Scincidae	*Scelotes bourquini*	Bourquin's Dwarf Burrowing Skink	Endemic

Reptilia	Scincidae	*Scelotes caffer*	Cape (Peters') Dwarf Burrowing Skink	Breeding resident
Reptilia	Scincidae	*Scelotes fitzsimonsi*	FitzSimons' Dwarf Burrowing Skink	Endemic
Reptilia	Scincidae	*Scelotes guentheri*	Guenthers' Dwarf Burrowing Skink	Endemic
Reptilia	Scincidae	*Scelotes inornatus*	Durban (Smith's) Dwarf Burrowing Skink	Endemic
Reptilia	Scincidae	*Scelotes mirus*	Montane Dwarf Burrowing Skink	Near endemic
Reptilia	Scincidae	*Scelotes mossambicus*	Mozambique Dwarf Burrowing Skink	Near endemic
Reptilia	Scincidae	*Scelotes vestigifer*	Coastal Dwarf Burrowing Skink	Endemic
Reptilia	Scincidae	*Trachylepis capensis*	Cape Skink	Breeding resident
Reptilia	Scincidae	*Trachylepis depressa*	Eastern Coastal Skink	Breeding resident
Reptilia	Scincidae	*Trachylepis homalocephala*	Red-sided Skink	Breeding resident
Reptilia	Scincidae	*Trachylepis margaritifer*	Rainbow Skink	Breeding resident
Reptilia	Scincidae	*Trachylepis occidentalis*	Western Three-striped Skink	Breeding resident
Reptilia	Scincidae	*Trachylepis punctatissima*	Speckled Rock Skink	Breeding resident
Reptilia	Scincidae	*Trachylepis striata*	Striped Skink	Breeding resident
Reptilia	Scincidae	*Trachylepis sulcata*	Western Rock Skink	Breeding resident
Reptilia	Scincidae	*Trachylepis varia*	Variable Skink	Breeding resident
Reptilia	Scincidae	*Trachylepis variegata*	Variegated Skink	Breeding resident
Reptilia	Scincidae	*Typhlosaurus aurantiacus*	Golden Blind Legless Skink	Near endemic
Reptilia	Testudinidae	*Chersina angulata*	Angulate Tortoise	Breeding resident
Reptilia	Testudinidae	*Homopus areolatus*	Parrot-beaked (Beaked Cape) Tortoise	Breeding resident
Reptilia	Testudinidae	*Homopus boulengeri*	Karoo Padloper	Breeding resident
Reptilia	Testudinidae	*Homopus femoralis*	Greater Padloper	Breeding resident
Reptilia	Testudinidae	*Kinixys belliana*	Bell's Hinged Tortoise	Breeding resident
Reptilia	Testudinidae	*Kinixys natalensis*	Natal Hinged Tortoise	Endemic
Reptilia	Testudinidae	*Kinixys spekii*	Speke's Hinged Tortoise	Breeding resident
Reptilia	Testudinidae	*Psammobates tentorius*	Karoo Tent Tortoise	Breeding resident
Reptilia	Testudinidae	*Stigmochelys pardalis*	Leopard Tortoise	Breeding resident
Reptilia	Typhlopidae	*Afrotyphlops bibronii*	Bibron's Worm Snake	Breeding resident
Reptilia	Typhlopidae	*Afrotyphlops fornasinii*	Fornasini's Worm Snake	Near endemic
Reptilia	Typhlopidae	*Rhinotyphlops lalandei*	Delalande's Beaked Blind Snake	Breeding resident
Reptilia	Typhlopidae	*Rhinotyphlops schlegelii*	Schlegel's Beaked Blind Snake	Breeding resident
Reptilia	Varanidae	*Varanus albigularis*	Rock (White-throated) Monitor	Breeding resident
Reptilia	Varanidae	*Varanus niloticus*	Water (Nile) Monitor	Breeding resident
Reptilia	Viperidae	*Bitis albanica*	Albany Adder	Endemic
Reptilia	Viperidae	*Bitis arietans*	Puff Adder	Breeding resident
Reptilia	Viperidae	*Bitis atropos*	Berg Adder	Breeding resident
Reptilia	Viperidae	*Bitis caudalis*	Horned Adder	Breeding resident
Reptilia	Viperidae	*Bitis gabonica*	Gaboon Viper	Breeding resident
Reptilia	Viperidae	*Bitis inornata*	Plain Mountain Adder	Endemic
Reptilia	Viperidae	*Causus defilippii*	Snouted Night Adder	Breeding resident
Reptilia	Viperidae	*Causus rhombeatus*	Common (Rhombic) Night Adder	Breeding resident
Aves	Accipitridae	*Accipiter badius*	Shikra	Breeding resident
Aves	Accipitridae	*Accipiter melanoleucus*	Black Sparrowhawk	Breeding resident
Aves	Accipitridae	*Accipiter minullus*	Little Sparrowhawk	Breeding resident
Aves	Accipitridae	*Accipiter ovampensis*	Ovambo Sparrowhawk	Breeding resident
Aves	Accipitridae	*Accipiter rufiventris*	Rufous-chested Sparrowhawk	Breeding resident
Aves	Accipitridae	*Accipiter tachiro*	African Goshawk	Breeding resident
Aves	Accipitridae	*Aegypius tracheliotos*	Lappet-faced Vulture	Breeding resident
Aves	Accipitridae	*Aegypius occipitalis*	White-headed Vulture	Breeding resident
Aves	Accipitridae	*Aquila ayresii*	Ayres's Hawk-Eagle	Breeding resident
Aves	Accipitridae	*Aquila pennatus*	Booted Eagle	Non-breeding migrant
Aves	Accipitridae	*Aquila spilogaster*	African Hawk-Eagle	Breeding resident
Aves	Accipitridae	*Aquila nipalensis*	Steppe Eagle	Non-breeding migrant
Aves	Accipitridae	*Aquila pomarina*	Lesser Spotted Eagle	Non-breeding migrant
Aves	Accipitridae	*Aquila rapax*	Tawny Eagle	Breeding resident
Aves	Accipitridae	*Aquila verreauxii*	Verreauxs' Eagle	Breeding resident
Aves	Accipitridae	*Aquila wahlbergi*	Wahlberg's Eagle	Breeding resident
Aves	Accipitridae	*Aviceda cuculoides*	African Cuckoo Hawk	Breeding resident
Aves	Accipitridae	*Buteo rufofuscus*	Jackal Buzzard	Breeding resident
Aves	Accipitridae	*Buteo trizonatus*	Forest Buzzard	Near endemic
Aves	Accipitridae	*Buteo vulpinus*	Steppe Buzzard	Non-breeding migrant
Aves	Accipitridae	*Circaetus cinereus*	Brown Snake-Eagle	Breeding resident
Aves	Accipitridae	*Circaetus fasciolatus*	Southern Banded Snake-Eagle	Breeding resident
Aves	Accipitridae	*Circaetus pectoralis*	Black-breasted Snake-Eagle	Breeding resident
Aves	Accipitridae	*Circus aeruginosus*	Western Marsh-Harrier	Non-breeding migrant
Aves	Accipitridae	*Circus macrourus*	Pallid Harrier	Non-breeding migrant
Aves	Accipitridae	*Circus maurus*	Black Harrier	Breeding resident
Aves	Accipitridae	*Circus pygargus*	Montagu's Harrier	Non-breeding migrant

Aves	Accipitridae	*Circus ranivorus*	African Marsh-Harrier	Breeding resident
Aves	Accipitridae	*Elanus caeruleus*	Black-shouldered Kite	Breeding resident
Aves	Accipitridae	*Gypaetus barbatus*	Bearded Vulture	Breeding resident
Aves	Accipitridae	*Gypohierax angolensis*	Palm-nut Vulture	Breeding resident
Aves	Accipitridae	*Gyps africanus*	White-backed Vulture	Breeding resident
Aves	Accipitridae	*Gyps coprotheres*	Cape Vulture	Breeding resident
Aves	Accipitridae	*Haliaeetus vocifer*	African Fish Eagle	Breeding resident
Aves	Accipitridae	*Kaupifalco monogrammicus*	Lizard Buzzard	Breeding resident
Aves	Accipitridae	*Lophaetus occipitalis*	Long-crested Eagle	Breeding resident
Aves	Accipitridae	*Macheiramphus alcinus*	Bat Hawk	Breeding resident
Aves	Accipitridae	*Melierax canorus*	Southern Pale Chanting Goshawk	Breeding resident
Aves	Accipitridae	*Melierax gabar*	Gabar Goshawk	Breeding resident
Aves	Accipitridae	*Melierax metabates*	Dark Chanting Goshawk	Breeding resident
Aves	Accipitridae	*Milvus migrans*	Black Kite	Breeding resident
Aves	Accipitridae	*Necrosyrtes monachus*	Hooded Vulture	Breeding resident
Aves	Accipitridae	*Pernis apivorus*	European Honey-Buzzard	Non-breeding migrant
Aves	Accipitridae	*Polemaetus bellicosus*	Martial Eagle	Breeding resident
Aves	Accipitridae	*Polyboroides typus*	African Harrier-Hawk	Breeding resident
Aves	Accipitridae	*Stephanoaetus coronatus*	African Crowned Eagle	Breeding resident
Aves	Accipitridae	*Terathopius ecaudatus*	Bateleur	Breeding resident
Aves	Alaudidae	*Calandrella cinerea*	Red-capped Lark	Breeding resident
Aves	Alaudidae	*Calendulauda africanoides*	Fawn-coloured Lark	Breeding resident
Aves	Alaudidae	*Calendulauda sabota*	Sabota Lark	Breeding resident
Aves	Alaudidae	*Certhilauda semitorquata*	Eastern Long-billed Lark	Breeding resident
Aves	Alaudidae	*Chersomanes albofasciata*	Spike-heeled Lark	Breeding resident
Aves	Alaudidae	*Eremopterix leucotis*	Chestnut-backed Sparrowlark	Breeding resident
Aves	Alaudidae	*Eremopterix verticalis*	Grey-backed Sparrowlark	Breeding resident
Aves	Alaudidae	*Galerida magnirostris*	Large-billed Lark	Breeding resident
Aves	Alaudidae	*Heteromirafra ruddi*	Rudd's Lark	Breeding resident
Aves	Alaudidae	*Mirafra africana*	Rufous-naped Lark	Breeding resident
Aves	Alaudidae	*Mirafra apiata*	Cape Clapper Lark	Breeding resident
Aves	Alaudidae	*Mirafra cheniana*	Melodious Lark	Breeding resident
Aves	Alaudidae	*Mirafra fasciolata*	Eastern Clapper Lark	Breeding resident
Aves	Alaudidae	*Mirafra passerina*	Monotonous Lark	Breeding resident
Aves	Alaudidae	*Mirafra rufocinnamomea*	Flappet Lark	Breeding resident
Aves	Alaudidae	*Pinarocorys nigricans*	Dusky Lark	Non-breeding migrant
Aves	Alaudidae	*Spizocorys conirostris*	Pink-billed Lark	Breeding resident
Aves	Alcedinidae	*Alcedo cristata*	Malachite Kingfisher	Breeding resident
Aves	Alcedinidae	*Alcedo semitorquata*	Half-collared Kingfisher	Breeding resident
Aves	Alcedinidae	*Ispidina picta*	African Pygmy-Kingfisher	Breeding resident
Aves	Anatidae	*Alopochen aegyptiaca*	Egyptian Goose	Breeding resident
Aves	Anatidae	*Anas capensis*	Cape Teal	Breeding resident
Aves	Anatidae	*Anas erythrorhyncha*	Red-billed Teal	Breeding resident
Aves	Anatidae	*Anas hottentota*	Hottentot Teal	Breeding resident
Aves	Anatidae	*Anas smithii*	Cape Shoveler	Breeding resident
Aves	Anatidae	*Anas sparsa*	African Black Duck	Breeding resident
Aves	Anatidae	*Anas undulata*	Yellow-billed Duck	Breeding resident
Aves	Anatidae	*Netta erythrophthalma*	Southern Pochard	Breeding resident
Aves	Anatidae	*Nettapus auritus*	African Pygmy-Goose	Breeding resident
Aves	Anatidae	*Oxyura maccoa*	Maccoa Duck	Breeding resident
Aves	Anatidae	*Plectropterus gambensis*	Spur-winged Goose	Breeding resident
Aves	Anatidae	*Sarkidiornis melanotos*	Comb Duck	Breeding resident
Aves	Anatidae	*Tadorna cana*	South African Shelduck	Breeding resident
Aves	Anhingidae	*Anhinga rufa*	African Darter	Breeding resident
Aves	Apodidae	*Apus affinis*	Little Swift	Breeding resident
Aves	Apodidae	*Apus apus*	Common Swift	Non-breeding migrant
Aves	Apodidae	*Apus barbatus*	African Black Swift	Breeding resident
Aves	Apodidae	*Apus caffer*	White-rumped Swift	Breeding resident
Aves	Apodidae	*Apus horus*	Horus Swift	Breeding resident
Aves	Apodidae	*Cypsiurus parvus*	African Palm-Swift	Breeding resident
Aves	Apodidae	*Tachymarptis melba*	Alpine Swift	Breeding resident
Aves	Ardeidae	*Ardea cinerea*	Grey Heron	Breeding resident
Aves	Ardeidae	*Ardea goliath*	Goliath Heron	Breeding resident
Aves	Ardeidae	*Ardea melanocephala*	Black-headed Heron	Breeding resident
Aves	Ardeidae	*Ardea purpurea*	Purple Heron	Breeding resident
Aves	Ardeidae	*Ardeola rufiventris*	Rufous-bellied Heron	Breeding resident
Aves	Ardeidae	*Ardeola ralloides*	Squacco Heron	Breeding resident
Aves	Ardeidae	*Botaurus stellaris*	Eurasian Bittern	Non-breeding migrant

Aves	Ardeidae	*Bubulcus ibis*	Cattle Egret	Breeding resident
Aves	Ardeidae	*Butorides striata*	Green-backed Heron	Breeding resident
Aves	Ardeidae	*Egretta intermedia*	Yellow-billed Egret	Breeding resident
Aves	Ardeidae	*Egretta alba*	Great Egret	Breeding resident
Aves	Ardeidae	*Egretta ardesiaca*	Black Heron	Breeding resident
Aves	Ardeidae	*Egretta garzetta*	Little Egret	Breeding resident
Aves	Ardeidae	*Gorsachius leuconotus*	White-backed Night-Heron	Breeding resident
Aves	Ardeidae	*Ixobrychus minutus*	Little Bittern	Breeding resident
Aves	Ardeidae	*Ixobrychus sturmii*	Dwarf Bittern	Breeding resident
Aves	Ardeidae	*Nycticorax nycticorax*	Black-crowned Night-Heron	Breeding resident
Aves	Bucerotidae	*Bycanistes bucinator*	Trumpeter Hornbill	Breeding resident
Aves	Bucerotidae	*Tockus alboterminatus*	Crowned Hornbill	Breeding resident
Aves	Bucerotidae	*Tockus erythrorhynchus*	Red-billed Hornbill	Breeding resident
Aves	Bucerotidae	*Tockus leucomelas*	Southern Yellow-billed Hornbill	Breeding resident
Aves	Bucerotidae	*Tockus nasutus*	African Grey Hornbill	Breeding resident
Aves	Bucorvidae	*Bucorvus leadbeateri*	Southern Ground-Hornbill	Breeding resident
Aves	Burhinidae	*Burhinus capensis*	Spotted Thick-knee	Breeding resident
Aves	Burhinidae	*Burhinus vermiculatus*	Water Thick-knee	Breeding resident
Aves	Campephagidae	*Campephaga flava*	Black Cuckooshrike	Breeding resident
Aves	Campephagidae	*Coracina caesia*	Grey Cuckooshrike	Breeding resident
Aves	Campephagidae	*Coracina pectoralis*	White-breasted Cuckooshrike	Breeding resident
Aves	Caprimulgidae	*Caprimulgus europaeus*	European Nightjar	Non-breeding migrant
Aves	Caprimulgidae	*Caprimulgus fossii*	Square-tailed Nightjar	Breeding resident
Aves	Caprimulgidae	*Caprimulgus natalensis*	Swamp Nightjar	Breeding resident
Aves	Caprimulgidae	*Caprimulgus pectoralis*	Fiery-necked Nightjar	Breeding resident
Aves	Caprimulgidae	*Caprimulgus rufigena*	Rufous-cheeked Nightjar	Breeding resident
Aves	Caprimulgidae	*Caprimulgus tristigma*	Freckled Nightjar	Breeding resident
Aves	Centropodidae	*Centropus burchellii*	Burchell's Coucal	Breeding resident
Aves	Centropodidae	*Centropus grillii*	Black Coucal	Breeding resident
Aves	Cerylidae	*Ceryle rudis*	Pied Kingfisher	Breeding resident
Aves	Cerylidae	*Megaceryle maximus*	Giant Kingfisher	Breeding resident
Aves	Chaetopidae	*Chaetops aurantius*	Drakensberg Rock-jumper	Near endemic
Aves	Charadriidae	*Charadrius asiaticus*	Caspian Plover	Non-breeding migrant
Aves	Charadriidae	*Charadrius hiaticula*	Common Ringed Plover	Non-breeding migrant
Aves	Charadriidae	*Charadrius leschenaultii*	Greater Sand Plover	Non-breeding migrant
Aves	Charadriidae	*Charadrius marginatus*	White-fronted Plover	Breeding resident
Aves	Charadriidae	*Charadrius mongolus*	Lesser Sand Plover	Non-breeding migrant
Aves	Charadriidae	*Charadrius pallidus*	Chestnut-banded Plover	Breeding resident
Aves	Charadriidae	*Charadrius pecuarius*	Kittlitz's Plover	Breeding resident
Aves	Charadriidae	*Charadrius tricollaris*	Three-banded Plover	Breeding resident
Aves	Charadriidae	*Pluvialis squatarola*	Grey Plover	Non-breeding migrant
Aves	Charadriidae	*Vanellus albiceps*	White-crowned Lapwing	Breeding resident
Aves	Charadriidae	*Vanellus armatus*	Blacksmith Lapwing	Breeding resident
Aves	Charadriidae	*Vanellus coronatus*	Crowned Lapwing	Breeding resident
Aves	Charadriidae	*Vanellus crassirostris*	Long-toed Lapwing	Breeding resident
Aves	Charadriidae	*Vanellus lugubris*	Senegal Lapwing	Breeding resident
Aves	Charadriidae	*Vanellus melanopterus*	Black-winged Lapwing	Breeding resident
Aves	Charadriidae	*Vanellus senegallus*	African Wattled Lapwing	Breeding resident
Aves	Ciconiidae	*Anastomus lamelligerus*	African Openbill	Breeding resident
Aves	Ciconiidae	*Ciconia abdimii*	Abdim's Stork	Breeding resident
Aves	Ciconiidae	*Ciconia ciconia*	White Stork	Non-breeding migrant
Aves	Ciconiidae	*Ciconia episcopus*	Woolly-necked Stork	Breeding resident
Aves	Ciconiidae	*Ciconia nigra*	Black Stork	Breeding resident
Aves	Ciconiidae	*Ephippiorhynchus senegalensis*	Saddle-billed Stork	Breeding resident
Aves	Ciconiidae	*Leptoptilos crumeniferus*	Marabou Stork	Breeding resident
Aves	Ciconiidae	*Mycteria ibis*	Yellow-billed Stork	Breeding resident
Aves	Cisticolidae	*Apalis flavida*	Yellow-breasted Apalis	Breeding resident
Aves	Cisticolidae	*Apalis ruddi*	Rudd's Apalis	Breeding resident
Aves	Cisticolidae	*Apalis thoracica*	Bar-throated Apalis	Breeding resident
Aves	Cisticolidae	*Calamonastes stierlingi*	Stierling's Wren-Warbler	Breeding resident
Aves	Cisticolidae	*Camaroptera brachyura*	Green-backed Camaroptera	Breeding resident
Aves	Cisticolidae	*Cisticola aberrans*	Lazy Cisticola	Breeding resident
Aves	Cisticolidae	*Cisticola aridulus*	Desert Cisticola	Breeding resident
Aves	Cisticolidae	*Cisticola ayresii*	Wing-snapping Cisticola	Breeding resident
Aves	Cisticolidae	*Cisticola chiniana*	Rattling Cisticola	Breeding resident
Aves	Cisticolidae	*Cisticola cinnamomeus*	Pale-crowned Cisticola	Breeding resident
Aves	Cisticolidae	*Cisticola erythrops*	Red-faced Cisticola	Breeding resident
Aves	Cisticolidae	*Cisticola fulvicapilla*	Neddicky	Breeding resident
Aves	Cisticolidae	*Cisticola galactotes*	Rufous-winged Cisticola	Breeding resident
Aves	Cisticolidae	*Cisticola juncidis*	Zitting Cisticola	Breeding resident

Aves	Cisticolidae	*Cisticola lais*	Wailing Cisticola	Breeding resident
Aves	Cisticolidae	*Cisticola natalensis*	Croaking Cisticola	Breeding resident
Aves	Cisticolidae	*Cisticola subruficapilla*	Grey-backed Cisticola	Breeding resident
Aves	Cisticolidae	*Cisticola textrix*	Cloud Cisticola	Breeding resident
Aves	Cisticolidae	*Cisticola tinniens*	Levaillant's Cisticola	Breeding resident
Aves	Cisticolidae	*Malcorus pectoralis*	Rufous-eared Warbler	Breeding resident
Aves	Cisticolidae	*Phragmacia substriata*	Namaqua Warbler	Breeding resident
Aves	Cisticolidae	*Prinia hypoxantha*	Drakensberg Prinia	Near endemic
Aves	Cisticolidae	*Prinia maculosa*	Karoo Prinia	Breeding resident
Aves	Cisticolidae	*Prinia subflava*	Tawny-flanked Prinia	Breeding resident
Aves	Coliidae	*Colius colius*	White-backed Mousebird	Breeding resident
Aves	Coliidae	*Colius striatus*	Speckled Mousebird	Breeding resident
Aves	Coliidae	*Urocolius indicus*	Red-faced Mousebird	Breeding resident
Aves	Columbidae	*Aplopelia larvata*	Lemon Dove	Breeding resident
Aves	Columbidae	*Columba arquatrix*	African Olive-Pigeon	Breeding resident
Aves	Columbidae	*Columba delegorguei*	Eastern Bronze-naped Pigeon	Breeding resident
Aves	Columbidae	*Columba guinea*	Speckled (Rock) Pigeon	Breeding resident
Aves	Columbidae	*Oena capensis*	Namaqua Dove	Breeding resident
Aves	Columbidae	*Streptopelia capicola*	Cape Turtle Dove	Breeding resident
Aves	Columbidae	*Streptopelia decipiens*	African Mourning Dove	Breeding resident
Aves	Columbidae	*Streptopelia semitorquata*	Red-eyed Dove	Breeding resident
Aves	Columbidae	*Streptopelia senegalensis*	Laughing Dove	Breeding resident
Aves	Columbidae	*Treron calvus*	African Green-Pigeon	Breeding resident
Aves	Columbidae	*Turtur chalcospilos*	Emerald-spotted Wood-Dove	Breeding resident
Aves	Columbidae	*Turtur tympanistria*	Tambourine Dove	Breeding resident
Aves	Coraciidae	*Coracias caudatus*	Lilac-breasted Roller	Breeding resident
Aves	Coraciidae	*Coracias garrulus*	European Roller	Non-breeding migrant
Aves	Coraciidae	*Coracias naevius*	Purple Roller	Breeding resident
Aves	Coraciidae	*Eurystomus glaucurus*	Broad-billed Roller	Breeding resident
Aves	Corvidae	*Corvus albicollis*	White-necked Raven	Breeding resident
Aves	Corvidae	*Corvus albus*	Pied Crow	Breeding resident
Aves	Corvidae	*Corvus capensis*	Cape Crow	Breeding resident
Aves	Cuculidae	*Ceuthmochares aereus*	Green Malkoha	Breeding resident
Aves	Cuculidae	*Chrysococcyx caprius*	Diderick Cuckoo	Breeding resident
Aves	Cuculidae	*Chrysococcyx cupreus*	African Emerald Cuckoo	Breeding resident
Aves	Cuculidae	*Chrysococcyx klaas*	Klaas's Cuckoo	Breeding resident
Aves	Cuculidae	*Clamator glandarius*	Great Spotted Cuckoo	Breeding resident
Aves	Cuculidae	*Clamator jacobinus*	Jacobin Cuckoo	Breeding resident
Aves	Cuculidae	*Clamator levaillantii*	Levaillant's Cuckoo	Breeding resident
Aves	Cuculidae	*Cuculus canorus*	Common Cuckoo	Non-breeding migrant
Aves	Cuculidae	*Cuculus clamosus*	Black Cuckoo	Breeding resident
Aves	Cuculidae	*Cuculus gularis*	African Cuckoo	Breeding resident
Aves	Cuculidae	*Cuculus solitarius*	Red-chested Cuckoo	Breeding resident
Aves	Cuculidae	*Pachycoccyx audeberti*	Thick-billed Cuckoo	Breeding resident
Aves	Dacelonidae	*Halcyon albiventris*	Brown-hooded Kingfisher	Breeding resident
Aves	Dacelonidae	*Halcyon chelicuti*	Striped Kingfisher	Breeding resident
Aves	Dacelonidae	*Halcyon leucocephala*	Grey-headed Kingfisher	Breeding resident
Aves	Dacelonidae	*Halcyon senegalensis*	Woodland Kingfisher	Breeding resident
Aves	Dacelonidae	*Halcyon senegaloides*	Mangrove Kingfisher	Breeding resident
Aves	Dendrocygnidae	*Dendrocygna bicolor*	Fulvous Duck	Breeding resident
Aves	Dendrocygnidae	*Dendrocygna viduata*	White-faced Duck	Breeding resident
Aves	Dendrocygnidae	*Thalassornis leuconotus*	White-backed Duck	Breeding resident
Aves	Dicruridae	*Dicrurus adsimilis*	Fork-tailed Drongo	Breeding resident
Aves	Dicruridae	*Dicrurus ludwigii*	Square-tailed Drongo	Breeding resident
Aves	Dromadidae	*Dromas ardeola*	Crab Plover	Non-breeding migrant
Aves	Estrildidae	*Amadina erythrocephala*	Red-headed Finch	Breeding resident
Aves	Estrildidae	*Coccopygia melanotis*	Swee Waxbill	Breeding resident
Aves	Estrildidae	*Estrilda astrild*	Common Waxbill	Breeding resident
Aves	Estrildidae	*Estrilda perreini*	Grey Waxbill	Breeding resident
Aves	Estrildidae	*Granatina granatinus*	Violet-eared Waxbill	Breeding resident
Aves	Estrildidae	*Hypargos margaritatus*	Pink-throated Twinspot	Breeding resident
Aves	Estrildidae	*Lagonosticta rhodopareia*	Jameson's Firefinch	Breeding resident
Aves	Estrildidae	*Lagonosticta rubricata*	African Firefinch	Breeding resident
Aves	Estrildidae	*Lagonosticta senegala*	Red-billed Firefinch	Breeding resident
Aves	Estrildidae	*Mandingoa nitidula*	Green Twinspot	Breeding resident
Aves	Estrildidae	*Ortygospiza atricollis*	African Quailfinch	Breeding resident
Aves	Estrildidae	*Pytilia melba*	Green-winged Pytilia	Breeding resident
Aves	Estrildidae	*Spermestes bicolor*	Red-backed Mannikin	Breeding resident

Aves	Estrildidae	*Spermestes cucullatus*	Bronze Mannikin	Breeding resident
Aves	Estrildidae	*Spermestes fringilloides*	Magpie Mannikin	Breeding resident
Aves	Estrildidae	*Sporaeginthus subflavus*	Orange-breasted Waxbill	Breeding resident
Aves	Estrildidae	*Uraeginthus angolensis*	Blue Waxbill	Breeding resident
Aves	Eurylaimidae	*Smithornis capensis*	African Broadbill	Breeding resident
Aves	Falconidae	*Falco amurensis*	Amur Falcon	Non-breeding migrant
Aves	Falconidae	*Falco biarmicus*	Lanner Falcon	Breeding resident
Aves	Falconidae	*Falco concolor*	Sooty Falcon	Non-breeding migrant
Aves	Falconidae	*Falco dickinsoni*	Dickinson's Kestrel	Breeding resident
Aves	Falconidae	*Falco naumanni*	Lesser Kestrel	Non-breeding migrant
Aves	Falconidae	*Falco peregrinus*	Peregrine Falcon	Breeding resident
Aves	Falconidae	*Falco rupicoloides*	Greater Kestrel	Breeding resident
Aves	Falconidae	*Falco rupicolus*	Rock Kestrel	Breeding resident
Aves	Falconidae	*Falco subbuteo*	Eurasian Hobby	Non-breeding migrant
Aves	Falconidae	*Falco vespertinus*	Red-footed Falcon	Non-breeding migrant
Aves	Fringillidae	*Crithagra symonsi*	Drakensberg Siskin	Breeding resident
Aves	Fringillidae	*Crithagra albogularis*	White-throated Canary	Breeding resident
Aves	Fringillidae	*Crithagra atrogularis*	Black-throated Canary	Breeding resident
Aves	Fringillidae	*Crithagra citrinipectus*	Lemon-breasted Canary	Breeding resident
Aves	Fringillidae	*Crithagra flaviventris*	Yellow Canary	Breeding resident
Aves	Fringillidae	*Crithagra gularis*	Streaky-headed Seedeater	Breeding resident
Aves	Fringillidae	*Crithagra mozambicus*	Yellow-fronted Canary	Breeding resident
Aves	Fringillidae	*Crithagra scotops*	Forest Canary	Near endemic
Aves	Fringillidae	*Crithagra sulphuratus*	Brimstone Canary	Breeding resident
Aves	Fringillidae	*Emberiza capensis*	Cape Bunting	Breeding resident
Aves	Fringillidae	*Emberiza flaviventris*	Golden-breasted Bunting	Breeding resident
Aves	Fringillidae	*Emberiza impetuani*	Lark-like Bunting	Breeding resident
Aves	Fringillidae	*Emberiza tahapisi*	Cinnamon-breasted Bunting	Breeding resident
Aves	Fringillidae	*Serinus alario*	Black-headed Canary	Breeding resident
Aves	Fringillidae	*Serinus canicollis*	Cape Canary	Breeding resident
Aves	Glareolidae	*Cursorius rufus*	Burchell's Courser	Breeding resident
Aves	Glareolidae	*Cursorius temminckii*	Temminck's Courser	Breeding resident
Aves	Glareolidae	*Glareola pratincola*	Collared Pratincole	Breeding resident
Aves	Glareolidae	*Rhinoptilus africanus*	Doublebanded Courser	Breeding resident
Aves	Glareolidae	*Rhinoptilus chalcopterus*	Bronze-winged Courser	Breeding resident
Aves	Gruidae	*Anthropoides paradiseus*	Blue Crane	Breeding resident
Aves	Gruidae	*Balearica regulorum*	Grey Crowned Crane	Breeding resident
Aves	Gruidae	*Bugeranus carunculatus*	Wattled Crane	Breeding resident
Aves	Haematopodidae	*Haematopus moquini*	African Black Oystercatcher	Breeding resident
Aves	Haematopodidae	*Haematopus ostrelegus*	Eurasian Oystercatcher	Non-breeding migrant
Aves	Heliornithidae	*Podica senegalensis*	African Finfoot	Breeding resident
Aves	Hirundinidae	*Delichon urbicum*	Common House-Martin	Non-breeding migrant
Aves	Hirundinidae	*Hirundo abyssinica*	Lesser Striped Swallow	Breeding resident
Aves	Hirundinidae	*Hirundo albigularis*	White-throated Swallow	Breeding resident
Aves	Hirundinidae	*Hirundo atrocaerulea*	Blue Swallow	Breeding resident
Aves	Hirundinidae	*Hirundo cucullata*	Greater Striped Swallow	Breeding resident
Aves	Hirundinidae	*Hirundo dimidiata*	Pearl-breasted Swallow	Breeding resident
Aves	Hirundinidae	*Hirundo fuligula*	Rock Martin	Breeding resident
Aves	Hirundinidae	*Hirundo rustica*	Barn Swallow	Non-breeding migrant
Aves	Hirundinidae	*Hirundo semirufa*	Red-breasted Swallow	Breeding resident
Aves	Hirundinidae	*Hirundo senegalensis*	Mosque Swallow	Breeding resident
Aves	Hirundinidae	*Hirundo smithii*	Wire-tailed Swallow	Breeding resident
Aves	Hirundinidae	*Hirundo spilodera*	South African Cliff-Swallow	Breeding resident
Aves	Hirundinidae	*Psalidoprocne holomelaena*	Black Saw-wing	Breeding resident
Aves	Hirundinidae	*Pseudhirundo griseopyga*	Grey-rumped Swallow	Breeding resident
Aves	Hirundinidae	*Riparia cincta*	Banded Martin	Breeding resident
Aves	Hirundinidae	*Riparia paludicola*	Brown-throated Martin	Breeding resident
Aves	Hirundinidae	*Riparia riparia*	Sand Martin	Non-breeding migrant
Aves	Indicatoridae	*Indicator indicator*	Greater Honeyguide	Breeding resident
Aves	Indicatoridae	*Indicator minor*	Lesser Honeyguide	Breeding resident
Aves	Indicatoridae	*Indicator variegatus*	Scaly-throated Honeyguide	Breeding resident
Aves	Indicatoridae	*Prodotiscus regulus*	Brown-backed Honeybird	Breeding resident
Aves	Jacanidae	*Actophilornis africanus*	African Jacana	Breeding resident
Aves	Jacanidae	*Microparra capensis*	Lesser Jacana	Breeding resident
Aves	Laniidae	*Corvinella melanoleuca*	Magpie Shrike	Breeding resident
Aves	Laniidae	*Eurocephalus anguitimens*	Southern White-crowned Shrike	Breeding resident
Aves	Laniidae	*Lanius collaris*	Common Fiscal	Breeding resident

Aves	Laniidae	*Lanius collurio*	Red-backed Shrike	Non-breeding migrant
Aves	Laniidae	*Lanius minor*	Lesser Grey Shrike	Non-breeding migrant
Aves	Laridae	*Chlidonias hybrida*	Whiskered Tern	Breeding resident
Aves	Laridae	*Chlidonias leucopterus*	White-winged Tern	Non-breeding migrant
Aves	Laridae	*Chlidonias niger*	Black Tern	Non-breeding migrant
Aves	Laridae	*Larus cirrocephalus*	Grey-headed Gull	Breeding resident
Aves	Laridae	*Larus dominicanus*	Kelp Gull	Breeding resident
Aves	Laridae	*Larus fuscus*	Lesser Black-backed Gull	Non-breeding migrant
Aves	Laridae	*Sterna caspia*	Caspian Tern	Breeding resident
Aves	Laridae	*Sterna albifrons*	Little Tern	Non-breeding migrant
Aves	Laridae	*Sterna balaenarum*	Damara Tern	Breeding resident
Aves	Laridae	*Sterna bengalensis*	Lesser Crested-tern	Non-breeding migrant
Aves	Laridae	*Sterna bergii*	Swift Tern	Breeding resident
Aves	Laridae	*Sterna dougallii*	Roseate Tern	Breeding resident
Aves	Laridae	*Sterna hirundo*	Common Tern	Non-breeding migrant
Aves	Laridae	*Sterna sandvicensis*	Sandwich Tern	Non-breeding migrant
Aves	Lybiidae	*Lybius torquatus*	Black-collared Barbet	Breeding resident
Aves	Lybiidae	*Pogoniulus bilineatus*	Yellow-rumped Tinkerbird	Breeding resident
Aves	Lybiidae	*Pogoniulus chrysoconus*	Yellow-fronted Tinkerbird	Breeding resident
Aves	Lybiidae	*Pogoniulus pusillus*	Red-fronted Tinkerbird	Breeding resident
Aves	Lybiidae	*Stactolaema leucotis*	White-eared Barbet	Breeding resident
Aves	Lybiidae	*Stactolaema olivacea*	Green Barbet	Breeding resident
Aves	Lybiidae	*Trachyphonus vaillantii*	Crested Barbet	Breeding resident
Aves	Lybiidae	*Tricholaema leucomelas*	Acacia Pied Barbet	Breeding resident
Aves	Malaconotidae	*Batis capensis*	Cape Batis	Breeding resident
Aves	Malaconotidae	*Batis fratrum*	Woodwards' Batis	Breeding resident
Aves	Malaconotidae	*Batis molitor*	Chinspot Batis	Breeding resident
Aves	Malaconotidae	*Batis pririt*	Pririt Batis	Breeding resident
Aves	Malaconotidae	*Dryoscopus cubla*	Black-backed Puffback	Breeding resident
Aves	Malaconotidae	*Laniarius ferrugineus*	Southern Boubou	Breeding resident
Aves	Malaconotidae	*Malaconotus blanchoti*	Grey-headed Bush-Shrike	Breeding resident
Aves	Malaconotidae	*Nilaus afer*	Brubru	Breeding resident
Aves	Malaconotidae	*Platysteira peltata*	Black-throated Wattle-eye	Breeding resident
Aves	Malaconotidae	*Prionops plumatus*	White-crested Helmet-Shrike	Breeding resident
Aves	Malaconotidae	*Prionops retzii*	Retz's Helmet-Shrike	Breeding resident
Aves	Malaconotidae	*Tchagra australis*	Brown-crowned Tchagra	Breeding resident
Aves	Malaconotidae	*Tchagra senegalus*	Black-crowned Tchagra	Breeding resident
Aves	Malaconotidae	*Tchagra tchagra*	Southern Tchagra	Breeding resident
Aves	Malaconotidae	*Telophorus olivaceus*	Olive Bush-Shrike	Breeding resident
Aves	Malaconotidae	*Telophorus sulfureopectus*	Orange-breasted Bush-Shrike	Breeding resident
Aves	Malaconotidae	*Telophorus zeylonus*	Bokmakierie	Breeding resident
Aves	Malaconotidae	*Telophorus viridis*	Gorgeous Bush-Shrike	Breeding resident
Aves	Megaluridae	*Bradypterus baboecala*	Little Rush-Warbler	Breeding resident
Aves	Megaluridae	*Bradypterus barratti*	Barratt's Warbler	Near endemic
Aves	Megaluridae	*Bradypterus sylvaticus*	Knysna Warbler	Near endemic
Aves	Megaluridae	*Schoenicola brevirostris*	Broad-tailed Warbler	Breeding resident
Aves	Meropidae	*Merops apiaster*	European Bee-eater	Non-breeding migrant
Aves	Meropidae	*Merops bullockoides*	White-fronted Bee-eater	Breeding resident
Aves	Meropidae	*Merops hirundineus*	Swallow-tailed Bee-eater	Breeding resident
Aves	Meropidae	*Merops nubicoides*	Southern Carmine Bee-eater	Breeding resident
Aves	Meropidae	*Merops persicus*	Blue-cheeked Bee-eater	Non-breeding migrant
Aves	Meropidae	*Merops pusillus*	Little Bee-eater	Breeding resident
Aves	Monarchidae	*Terpsiphone viridis*	African Paradise-Flycatcher	Breeding resident
Aves	Monarchidae	*Trochocercus cyanomelas*	Blue-mantled Crested-Flycatcher	Breeding resident
Aves	Motacillidae	*Anthus chloris*	Yellow-breasted Pipit	Near endemic
Aves	Motacillidae	*Anthus brachyurus*	Short-tailed Pipit	Breeding resident
Aves	Motacillidae	*Anthus caffer*	Bushveld Pipit	Breeding resident
Aves	Motacillidae	*Anthus cinnamomeus*	African Pipit	Breeding resident
Aves	Motacillidae	*Anthus crenatus*	African Rock Pipit	Breeding resident
Aves	Motacillidae	*Anthus hoeschi*	Mountain Pipit	Breeding resident
Aves	Motacillidae	*Anthus leucophrys*	Plain-backed Pipit	Breeding resident
Aves	Motacillidae	*Anthus lineiventris*	Striped Pipit	Breeding resident
Aves	Motacillidae	*Anthus similis*	Long-billed Pipit	Breeding resident
Aves	Motacillidae	*Anthus vaalensis*	Buffy Pipit	Breeding resident
Aves	Motacillidae	*Macronyx ameliae*	Rosy-throated Longclaw	Breeding resident
Aves	Motacillidae	*Macronyx capensis*	Cape Longclaw	Breeding resident
Aves	Motacillidae	*Macronyx croceus*	Yellow-throated Longclaw	Breeding resident
Aves	Motacillidae	*Motacilla aguimp*	African Pied Wagtail	Breeding resident
Aves	Motacillidae	*Motacilla capensis*	Cape Wagtail	Breeding resident
Aves	Motacillidae	*Motacilla clara*	Mountain Wagtail	Breeding resident

Aves	Motacillidae	*Motacilla flava*	Yellow Wagtail	Non-breeding migrant
Aves	Muscicapidae	*Bradornis infuscatus*	Chat Flycatcher	Breeding resident
Aves	Muscicapidae	*Bradornis pallidus*	Pale Flycatcher	Breeding resident
Aves	Muscicapidae	*Cercomela familiaris*	Familiar Chat	Breeding resident
Aves	Muscicapidae	*Cercomela schlegelii*	Karoo Chat	Breeding resident
Aves	Muscicapidae	*Cercomela sinuata*	Sickle-winged Chat	Breeding resident
Aves	Muscicapidae	*Cercotrichas coryphoeus*	Karoo Scrub-Robin	Breeding resident
Aves	Muscicapidae	*Cercotrichas leucophrys*	White-browed Scrub-Robin	Breeding resident
Aves	Muscicapidae	*Cercotrichas quadrivirgata*	Bearded Scrub-Robin	Breeding resident
Aves	Muscicapidae	*Cercotrichas signata*	Brown Scrub-Robin	Breeding resident
Aves	Muscicapidae	*Cossypha caffra*	Cape Robin-Chat	Breeding resident
Aves	Muscicapidae	*Cossypha dichroa*	Chorister Robin-Chat	Near endemic
Aves	Muscicapidae	*Cossypha heuglini*	White-browed Robin-Chat	Breeding resident
Aves	Muscicapidae	*Cossypha humeralis*	White-throated Robin-Chat	Breeding resident
Aves	Muscicapidae	*Cossypha natalensis*	Red-capped Robin-Chat	Breeding resident
Aves	Muscicapidae	*Melaenornis pammelaina*	Southern Black Flycatcher	Breeding resident
Aves	Muscicapidae	*Monticola explorator*	Sentinel Rock-Thrush	Breeding resident
Aves	Muscicapidae	*Monticola rupestris*	Cape Rock-Thrush	Breeding resident
Aves	Muscicapidae	*Muscicapa adusta*	African Dusky Flycatcher	Breeding resident
Aves	Muscicapidae	*Muscicapa caerulescens*	Ashy Flycatcher	Breeding resident
Aves	Muscicapidae	*Muscicapa striata*	Spotted Flycatcher	Non-breeding migrant
Aves	Muscicapidae	*Myioparus plumbeus*	Grey Tit-Flycatcher	Breeding resident
Aves	Muscicapidae	*Myrmecocichla formicivora*	Ant-eating Chat	Breeding resident
Aves	Muscicapidae	*Oenanthe bifasciata*	Buff-streaked Chat	Near endemic
Aves	Muscicapidae	*Oenanthe monticola*	Mountain Wheatear	Breeding resident
Aves	Muscicapidae	*Oenanthe pileata*	Capped Wheatear	Breeding resident
Aves	Muscicapidae	*Pogonocichla stellata*	White-starred Robin	Breeding resident
Aves	Muscicapidae	*Psophocichla litsitsirupa*	Groundscraper Thrush	Breeding resident
Aves	Muscicapidae	*Saxicola torquata*	African Stonechat	Breeding resident
Aves	Muscicapidae	*Sigelus silens*	Fiscal Flycatcher	Breeding resident
Aves	Muscicapidae	*Thamnolaea cinnamomeiventris*	Mocking Cliff-Chat	Breeding resident
Aves	Muscicapidae	*Turdus libonyanus*	Kurrichane Thrush	Breeding resident
Aves	Muscicapidae	*Turdus olivaceus*	Olive Thrush	Breeding resident
Aves	Muscicapidae	*Turdus smithi*	Karoo Thrush	Breeding resident
Aves	Muscicapidae	*Zoothera gurneyi*	Orange Ground-Thrush	Breeding resident
Aves	Muscicapidae	*Zoothera guttata*	Spotted Ground-Thrush	Breeding resident
Aves	Musophagidae	*Corythaixoides concolor*	Grey Go-away-bird	Breeding resident
Aves	Musophagidae	*Gallirex porphyreolophus*	Purple-crested Turaco	Breeding resident
Aves	Musophagidae	*Tauraco corythaix*	Knysna Turaco	Near endemic
Aves	Musophagidae	*Tauraco livingstonii*	Livingstone's Turaco	Breeding resident
Aves	Nectarinidae	*Chalcomitra amethystina*	Amethyst Sunbird	Breeding resident
Aves	Nectarinidae	*Chalcomitra senegalensis*	Scarlet-chested Sunbird	Breeding resident
Aves	Nectarinidae	*Cinnyris afer*	Greater Double-collared Sunbird	Breeding resident
Aves	Nectarinidae	*Cinnyris bifasciata*	Purple-banded Sunbird	Breeding resident
Aves	Nectarinidae	*Cinnyris mariquensis*	Marico Sunbird	Breeding resident
Aves	Nectarinidae	*Cinnyris neergardi*	Neergaard's Sunbird	Breeding resident
Aves	Nectarinidae	*Cinnyris talatala*	White-bellied Sunbird	Breeding resident
Aves	Nectarinidae	*Cinnyris chalybeus*	Southern Double-collared Sunbird	Breeding resident
Aves	Nectarinidae	*Cinnyris fuscus*	Dusky Sunbird	Breeding resident
Aves	Nectarinidae	*Cyanomitra olivacea*	Olive Sunbird	Breeding resident
Aves	Nectarinidae	*Cyanomitra veroxii*	Grey Sunbird	Breeding resident
Aves	Nectarinidae	*Hedydipna collaris*	Collared Sunbird	Breeding resident
Aves	Nectarinidae	*Nectarinia famosa*	Malachite Sunbird	Breeding resident
Aves	Numididae	*Guttera edouardi*	Crested Guineafowl	Breeding resident
Aves	Numididae	*Numida meleagris*	Helmeted Guineafowl	Breeding resident
Aves	Oriolidae	*Oriolus larvatus*	Black-headed Oriole	Breeding resident
Aves	Oriolidae	*Oriolus oriolus*	Eurasian Golden Oriole	Non-breeding migrant
Aves	Otididae	*Afrotis afra*	Southern Black Korhaan	Breeding resident
Aves	Otididae	*Afrotis afraoides*	Northern Black Korhaan	Breeding resident
Aves	Otididae	*Ardeotis kori*	Kori Bustard	Breeding resident
Aves	Otididae	*Eupodotis caerulescens*	Blue Korhaan	Breeding resident
Aves	Otididae	*Eupodotis senegalensis*	White-bellied Korhaan	Breeding resident
Aves	Otididae	*Eupodotis vigorsii*	Karoo Korhaan	Breeding resident
Aves	Otididae	*Lissotis melanogaster*	Black-bellied Bustard	Breeding resident
Aves	Otididae	*Lophotis ruficrista*	Red-crested Korhaan	Breeding resident
Aves	Otididae	*Neotis denhami*	Denham's Bustard	Breeding resident
Aves	Otididae	*Neotis ludwigii*	Ludwig's Bustard	Breeding resident
Aves	Pandionidae	*Pandion haliaetus*	Osprey	Breeding resident

Aves	Paridae	*Anthoscopus caroli*	Grey Penduline-Tit	Breeding resident
Aves	Paridae	*Anthoscopus minutus*	Cape Penduline-Tit	Breeding resident
Aves	Paridae	*Parus afer*	Grey Tit	Breeding resident
Aves	Paridae	*Parus niger*	Southern Black Tit	Breeding resident
Aves	Passeridae	*Passer diffusus*	Southern Grey-headed Sparrow	Breeding resident
Aves	Passeridae	*Passer melanurus*	Cape Sparrow	Breeding resident
Aves	Passeridae	*Petronia superciliaris*	Yellow-throated Petronia	Breeding resident
Aves	Pelecanidae	*Pelecanus onocrotalus*	Great White Pelican	Breeding resident
Aves	Pelecanidae	*Pelecanus rufescens*	Pink-backed Pelican	Breeding resident
Aves	Phalacrocoracidae	*Phalacrocorax africanus*	Reed Cormorant	Breeding resident
Aves	Phalacrocoracidae	*Phalacrocorax capensis*	Cape Cormorant	Breeding resident
Aves	Phalacrocoracidae	*Phalacrocorax lucidus*	White-breasted Cormorant	Breeding resident
Aves	Phasianidae	*Coturnix adansonii*	Blue Quail	Breeding resident
Aves	Phasianidae	*Coturnix coturnix*	Common Quail	Breeding resident
Aves	Phasianidae	*Coturnix delegorguei*	Harlequin Quail	Breeding resident
Aves	Phasianidae	*Dendroperdix sephaena*	Crested Francolin	Breeding resident
Aves	Phasianidae	*Peliperdix coqui*	Coqui Francolin	Breeding resident
Aves	Phasianidae	*Pternistis afer*	Red-necked Spurfowl	Breeding resident
Aves	Phasianidae	*Pternistis natalensis*	Natal Spurfowl	Breeding resident
Aves	Phasianidae	*Pternistis swainsonii*	Swainson's Spurfowl	Breeding resident
Aves	Phasianidae	*Scleroptila africanus*	Grey-winged Francolin	Breeding resident
Aves	Phasianidae	*Scleroptila levaillantii*	Red-winged Francolin	Breeding resident
Aves	Phasianidae	*Scleroptila shelleyi*	Shelley's Francolin	Breeding resident
Aves	Phoenicopteridae	*Phoenicopterus minor*	Lesser Flamingo	Breeding resident
Aves	Phoenicopteridae	*Phoenicopterus ruber*	Greater Flamingo	Breeding resident
Aves	Phoeniculidae	*Phoeniculus purpureus*	Green Wood-Hoopoe	Breeding resident
Aves	Picidae	*Campethera abingoni*	Golden-tailed Woodpecker	Breeding resident
Aves	Picidae	*Campethera bennettii*	Bennett's Woodpecker	Breeding resident
Aves	Picidae	*Campethera notata*	Knysna Woodpecker	Near endemic
Aves	Picidae	*Dendropicos griseocephalus*	Olive Woodpecker	Breeding resident
Aves	Picidae	*Dendropicos namaquus*	Bearded Woodpecker	Breeding resident
Aves	Picidae	*Dendropicos fuscescens*	Cardinal Woodpecker	Breeding resident
Aves	Picidae	*Geocolaptes olivaceus*	Ground Woodpecker	Breeding resident
Aves	Picidae	*Jynx ruficollis*	Red-throated Wryneck	Breeding resident
Aves	Ploceidae	*Amblyospiza albifrons*	Thick-billed Weaver	Breeding resident
Aves	Ploceidae	*Anaplectes melanotis*	Red-headed Weaver	Breeding resident
Aves	Ploceidae	*Bubalornis niger*	Red-billed Buffalo-Weaver	Breeding resident
Aves	Ploceidae	*Euplectes afer*	Yellow-crowned Bishop	Breeding resident
Aves	Ploceidae	*Euplectes albonotatus*	White-winged Widowbird	Breeding resident
Aves	Ploceidae	*Euplectes ardens*	Red-collared Widowbird	Breeding resident
Aves	Ploceidae	*Euplectes axillaris*	Fan-tailed Widowbird	Breeding resident
Aves	Ploceidae	*Euplectes capensis*	Yellow Bishop	Breeding resident
Aves	Ploceidae	*Euplectes orix*	Southern Red Bishop	Breeding resident
Aves	Ploceidae	*Euplectes progne*	Long-tailed Widowbird	Breeding resident
Aves	Ploceidae	*Plocepasser mahali*	White-browed Sparrow-Weaver	Breeding resident
Aves	Ploceidae	*Ploceus bicolor*	Dark-backed Weaver	Breeding resident
Aves	Ploceidae	*Ploceus capensis*	Cape Weaver	Breeding resident
Aves	Ploceidae	*Ploceus cucullatus*	Village Weaver	Breeding resident
Aves	Ploceidae	*Ploceus intermedius*	Lesser Masked-Weaver	Breeding resident
Aves	Ploceidae	*Ploceus ocularis*	Spectacled Weaver	Breeding resident
Aves	Ploceidae	*Ploceus subaureus*	Yellow Weaver	Breeding resident
Aves	Ploceidae	*Ploceus velatus*	Southern Masked-weaver	Breeding resident
Aves	Ploceidae	*Ploceus xanthops*	Golden Weaver	Breeding resident
Aves	Ploceidae	*Ploceus xanthopterus*	Southern Brown-throated Weaver	Breeding resident
Aves	Ploceidae	*Quelea erythrops*	Red-headed Quelea	Breeding resident
Aves	Ploceidae	*Quelea quelea*	Red-billed Quelea	Breeding resident
Aves	Ploceidae	*Sporopipes squamifrons*	Scaly-feathered Finch	Breeding resident
Aves	Podicipedidae	*Podiceps cristatus*	Great Crested Grebe	Breeding resident
Aves	Podicipedidae	*Podiceps nigricollis*	Black-necked Grebe	Breeding resident
Aves	Podicipedidae	*Tachybaptus ruficollis*	Little Grebe	Breeding resident
Aves	Promeropidae	*Promerops cafer*	Cape Sugarbird	Breeding resident
Aves	Promeropidae	*Promerops gurneyi*	Gurney's Sugarbird	Near endemic
Aves	Psittacidae	*Poicephalus cryptoxanthus*	Brown-headed Parrot	Breeding resident
Aves	Psittacidae	*Poicephalus robustus*	Cape Parrot	Near endemic
Aves	Pteroclidae	*Pterocles bicinctus*	Double-banded Sandgrouse	Breeding resident
Aves	Pteroclidae	*Pterocles namaqua*	Namaqua Sandgrouse	Breeding resident
Aves	Pycnonotidae	*Andropadus importunus*	Sombre Greenbul	Breeding resident
Aves	Pycnonotidae	*Chlorocichla flaviventris*	Yellow-bellied Greenbul	Breeding resident
Aves	Pycnonotidae	*Nicator gularis*	Eastern Nicator	Breeding resident

Aves	Pycnonotidae	*Phyllastrephus flavostriatus*	Yellow-streaked Greenbul	Breeding resident
Aves	Pycnonotidae	*Phyllastrephus terrestris*	Terrestrial Brownbul	Breeding resident
Aves	Pycnonotidae	*Pycnonotus capensis*	Cape Bulbul	Breeding resident
Aves	Pycnonotidae	*Pycnonotus nigricans*	African Red-eyed Bulbul	Breeding resident
Aves	Pycnonotidae	*Pycnonotus tricolor*	Dark-capped Bulbul	Breeding resident
Aves	Rallidae	*Amaurornis flavirostris*	Black Crake	Breeding resident
Aves	Rallidae	*Crecopsis egregia*	African Crake	Breeding resident
Aves	Rallidae	*Crex crex*	Corncrake	Non-breeding migrant
Aves	Rallidae	*Filica cristata*	Red-knobbed Coot	Breeding resident
Aves	Rallidae	*Gallinula angulata*	Lesser Moorhen	Breeding resident
Aves	Rallidae	*Gallinula chloropus*	Common Moorhen	Breeding resident
Aves	Rallidae	*Porphyrio porphyrio*	African Purple Swamphen	Breeding resident
Aves	Rallidae	*Porphyrula alleni*	Allen's Gallinule	Breeding resident
Aves	Rallidae	*Porzana porzana*	Spotted Crake	Non-breeding migrant
Aves	Rallidae	*Porzana pusilla*	Baillon's Crake	Breeding resident
Aves	Rallidae	*Rallus caerulescens*	African Rail	Breeding resident
Aves	Rallidae	*Sarothrura affinis*	Striped Flufftail	Breeding resident
Aves	Rallidae	*Sarothrura ayresi*	White-winged Flufftail	Breeding resident
Aves	Rallidae	*Sarothrura elegans*	Buff-spotted Flufftail	Breeding resident
Aves	Rallidae	*Sarothrura rufa*	Red-chested Flufftail	Breeding resident
Aves	Recurvirostridae	*Himantopus himantopus*	Black-winged Stilt	Breeding resident
Aves	Recurvirostridae	*Recurvirostra avosetta*	Pied Avocet	Breeding resident
Aves	Rhinopomastidae	*Rhinopomastus cyanomelas*	Common Scimitarbill	Breeding resident
Aves	Rostratulidae	*Rostratula benghalensis*	Greater Painted-snipe	Breeding resident
Aves	Sagittariidae	*Sagittarius serpentarius*	Secretarybird	Breeding resident
Aves	Scolopacidae	*Actitis hypoleucos*	Common Sandpiper	Non-breeding migrant
Aves	Scolopacidae	*Arenaria interpres*	Ruddy Turnstone	Non-breeding migrant
Aves	Scolopacidae	*Calidris alba*	Sanderling	Non-breeding migrant
Aves	Scolopacidae	*Calidris canutus*	Red Knot	Non-breeding migrant
Aves	Scolopacidae	*Calidris ferruginea*	Curlew Sandpiper	Non-breeding migrant
Aves	Scolopacidae	*Calidris minuta*	Little Stint	Non-breeding migrant
Aves	Scolopacidae	*Gallinago nigripennis*	African Snipe	Breeding resident
Aves	Scolopacidae	*Limicola falcinellus*	Broad-billed Sandpiper	Non-breeding migrant
Aves	Scolopacidae	*Limosa lapponica*	Bar-tailed Godwit	Non-breeding migrant
Aves	Scolopacidae	*Limosa limosa*	Black-tailed Godwit	Non-breeding migrant
Aves	Scolopacidae	*Numenius arquata*	Eurasian Curlew	Non-breeding migrant
Aves	Scolopacidae	*Numenius phaeopus*	Common Whimbrel	Non-breeding migrant
Aves	Scolopacidae	*Philomachus pugnax*	Ruff	Non-breeding migrant
Aves	Scolopacidae	*Tringa glareola*	Wood Sandpiper	Non-breeding migrant
Aves	Scolopacidae	*Tringa nebularia*	Common Greenshank	Non-breeding migrant
Aves	Scolopacidae	*Tringa ochropus*	Green Sandpiper	Non-breeding migrant
Aves	Scolopacidae	*Tringa stagnatilis*	Marsh Sandpiper	Non-breeding migrant
Aves	Scolopacidae	*Tringa totanus*	Common Redshank	Non-breeding migrant
Aves	Scolopacidae	*Xenus cinereus*	Terek Sandpiper	Non-breeding migrant
Aves	Scopidae	*Scopus umbretta*	Hamerkop	Breeding resident
Aves	Strigidae	*Asio capensis*	Marsh Owl	Breeding resident
Aves	Strigidae	*Bubo africanus*	Spotted Eagle-Owl	Breeding resident
Aves	Strigidae	*Bubo capensis*	Cape Eagle-Owl	Breeding resident
Aves	Strigidae	*Bubo lacteus*	Verreaux's Eagle-Owl	Breeding resident
Aves	Strigidae	*Glaucidium capense*	African Barred Owlet	Breeding resident
Aves	Strigidae	*Glaucidium perlatum*	Pearl-spotted Owlet	Breeding resident
Aves	Strigidae	*Otus senegalensis*	African Scops-Owl	Breeding resident
Aves	Strigidae	*Ptilopsis granti*	Southern White-faced Scops-Owl	Breeding resident
Aves	Strigidae	*Scotopelia peli*	Pel's Fishing Owl	Breeding resident
Aves	Strigidae	*Strix woodfordii*	African Wood-Owl	Breeding resident
Aves	Struthionidae	*Struchio camelus*	Common Ostrich	Breeding resident
Aves	Sturnidae	*Buphagus africanus*	Yellow-billed Oxpecker	Breeding resident
Aves	Sturnidae	*Buphagus erythrorhynchus*	Red-billed Oxpecker	Breeding resident
Aves	Sturnidae	*Cinnyricinclus leucogaster*	Violet-backed Starling	Breeding resident
Aves	Sturnidae	*Creatophora cinerea*	Wattled Starling	Breeding resident
Aves	Sturnidae	*Lamprotornis australis*	Burchell's Starling	Breeding resident
Aves	Sturnidae	*Lamprotornis chalybaeus*	Greater Blue-eared Starling	Breeding resident
Aves	Sturnidae	*Lamprotornis corruscus*	Black-bellied Starling	Breeding resident
Aves	Sturnidae	*Lamprotornis nitens*	Cape Glossy Starling	Breeding resident
Aves	Sturnidae	*Onychognathus morio*	Red-winged Starling	Breeding resident
Aves	Sturnidae	*Onychognathus nabouroup*	Pale-winged Starling	Breeding resident
Aves	Sturnidae	*Spreo bicolor*	Pied Starling	Breeding resident
Aves	Sylviidae	*Acrocephalus arundinaceus*	Great Reed-Warbler	Non-breeding migrant
Aves	Sylviidae	*Acrocephalus baeticatus*	African Reed-Warbler	Breeding resident
Aves	Sylviidae	*Acrocephalus gracilirostris*	Lesser Swamp-Warbler	Breeding resident

Aves	Sylviidae	*Acrocephalus palustris*	Marsh Warbler	Non-breeding migrant
Aves	Sylviidae	*Acrocephalus schoenobaenus*	Sedge Warbler	Non-breeding migrant
Aves	Sylviidae	*Chloropeta natalensis*	Dark-capped Yellow Warbler	Breeding resident
Aves	Sylviidae	*Eremomela gregalis*	Karoo Eremomela	Breeding resident
Aves	Sylviidae	*Eremomela icteropygialis*	Yellow-bellied Eremomela	Breeding resident
Aves	Sylviidae	*Eremomela scotops*	Green-caped Eremomela	Breeding resident
Aves	Sylviidae	*Eremomela usticollis*	Burnt-necked Eremomela	Breeding resident
Aves	Sylviidae	*Hippolais icterina*	Icterine Warbler	Non-breeding migrant
Aves	Sylviidae	*Hippolais olivetorum*	Olive-tree Warbler	Non-breeding migrant
Aves	Sylviidae	*Parisoma layardi*	Layard's Tit-Babbler	Breeding resident
Aves	Sylviidae	*Parisoma subcaeruleum*	Chestnut-vented Tit-Babbler	Breeding resident
Aves	Sylviidae	*Phylloscopus ruficapilla*	Yellow-throated Woodland-Warbler	Breeding resident
Aves	Sylviidae	*Phylloscopus trochilus*	Willow Warbler	Non-breeding migrant
Aves	Sylviidae	*Sphenoeacus afer*	Cape Grassbird	Breeding resident
Aves	Sylviidae	*Stenostira scita*	Fairy Flycatcher	Breeding resident
Aves	Sylviidae	*Sylvia borin*	Garden Warbler	Non-breeding migrant
Aves	Sylviidae	*Sylvia communis*	Common Whitethroat	Non-breeding migrant
Aves	Sylviidae	*Sylvietta rufescens*	Long-billed Crombec	Breeding resident
Aves	Threskiornithidae	*Bostrychia hagedash*	Hadeda Ibis	Breeding resident
Aves	Threskiornithidae	*Geronticus calvus*	Southern Bald Ibis	Breeding resident
Aves	Threskiornithidae	*Platalea alba*	African Spoonbill	Breeding resident
Aves	Threskiornithidae	*Plegadis falcinellus*	Glossy Ibis	Breeding resident
Aves	Threskiornithidae	*Threskiornis aethiopicus*	African Sacred Ibis	Breeding resident
Aves	Timaliidae	*Lioptilus nigricapillus*	Bush Blackcap	Near endemic
Aves	Timaliidae	*Turdoides jardineii*	Arrow-marked Babbler	Breeding resident
Aves	Trogonidae	*Apaloderma narina*	Narina Trogon	Breeding resident
Aves	Turnicidae	*Turnix nanus*	Black-rumped Buttonquail	Breeding resident
Aves	Turnicidae	*Turnix sylvaticus*	Kurrichane Buttonquail	Breeding resident
Aves	Tytonidae	*Tyto alba*	Barn Owl	Breeding resident
Aves	Tytonidae	*Tyto capensis*	African Grass-Owl	Breeding resident
Aves	Upupidae	*Upupa africana*	African Hoopoe	Breeding resident
Aves	Viduidae	*Anomalospiza imberbis*	Cuckoo Finch	Breeding resident
Aves	Viduidae	*Vidua chalybeata*	Village Indigobird	Breeding resident
Aves	Viduidae	*Vidua funerea*	Dusky Indigobird	Breeding resident
Aves	Viduidae	*Vidua macroura*	Pin-tailed Whydah	Breeding resident
Aves	Viduidae	*Vidua paradisaea*	Long-tailed Paradise-Whydah	Breeding resident
Aves	Viduidae	*Vidua purpurascens*	Purple Indigobird	Breeding resident
Aves	Zosteropidae	*Zosterops pallidus*	Orange River White-eye	Breeding resident
Aves	Zosteropidae	*Zosterops senegalensis*	African Yellow White-eye	Breeding resident
Aves	Zosteropidae	*Zosterops virens*	Cape White-eye	Breeding resident
Mammalia	Bathyergidae	*Cryptomys hottentotus*	African Mole-Rat	Breeding resident
Mammalia	Bathyergidae	*Georychus capensis*	Cape Mole-Rat	Breeding resident
Mammalia	Bovidae	*Aepyceros melampus*	Impala	Breeding resident
Mammalia	Bovidae	*Alcelaphus buselaphus*	Red Hartebeest	Breeding resident
Mammalia	Bovidae	*Alcelaphus lichtensteinii*	Lichtenstein's Hartebeest	Breeding resident
Mammalia	Bovidae	*Antidorcas marsupialis*	Springbok	Breeding resident
Mammalia	Bovidae	*Cephalophus natalensis*	Red Duiker	Breeding resident
Mammalia	Bovidae	*Connochaetes gnou*	Black Wildebeest	Breeding resident
Mammalia	Bovidae	*Connochaetes taurinus*	Blue Wildebeest	Breeding resident
Mammalia	Bovidae	*Damaliscus lunatus*	Tsessebe	Breeding resident
Mammalia	Bovidae	*Damaliscus pygargus phillipsi*	Blesbok	Breeding resident
Mammalia	Bovidae	*Kobus ellipsiprymnus*	Waterbuck	Breeding resident
Mammalia	Bovidae	*Neotragus moschatus*	Suni	Breeding resident
Mammalia	Bovidae	*Oreotragus oreotragus*	Klipspringer	Breeding resident
Mammalia	Bovidae	*Ourebia ourebi*	Oribi	Breeding resident
Mammalia	Bovidae	*Pelea capreolus*	Grey Rhebok	Breeding resident
Mammalia	Bovidae	*Philantomba monticola*	Blue Duiker	Breeding resident
Mammalia	Bovidae	*Raphicerus campestris*	Steenbok	Breeding resident
Mammalia	Bovidae	*Raphicerus melanotis*	Cape Grysbok	Breeding resident
Mammalia	Bovidae	*Raphicerus sharpei*	Sharpe's Grysbok	Breeding resident
Mammalia	Bovidae	*Redunca arundinum*	Southern Reedbuck	Breeding resident
Mammalia	Bovidae	*Redunca fulvorufula*	Mountain Reedbuck	Breeding resident
Mammalia	Bovidae	*Sylvicapra grimmia*	Common (Grey) Duiker	Breeding resident
Mammalia	Bovidae	*Syncerus caffer*	African Buffalo	Breeding resident
Mammalia	Bovidae	*Taurotragus oryx*	Eland	Breeding resident
Mammalia	Bovidae	*Tragelaphus angasii*	Nyala	Breeding resident
Mammalia	Bovidae	*Tragelaphus scriptus*	Bushbuck	Breeding resident
Mammalia	Bovidae	*Tragelaphus strepsiceros*	Greater Kudu	Breeding resident
Mammalia	Canidae	*Canis adustus*	Side-striped Jackal	Breeding resident
Mammalia	Canidae	*Canis mesomelas*	Black-backed Jackal	Breeding resident

Mammalia	Canidae	*Lycaon pictus*	African Wild Dog	Breeding resident
Mammalia	Canidae	*Otocyon megalotis*	Bat-eared Fox	Breeding resident
Mammalia	Canidae	*Vulpes chama*	Cape Fox	Breeding resident
Mammalia	Cercopithecidae	*Cercopithecus albogularis*	Sykes' (Samango) Monkey	Breeding resident
Mammalia	Cercopithecidae	*Chlorocebus pygerythrus*	Vervet Monkey	Breeding resident
Mammalia	Cercopithecidae	*Papio hamadryas*	Chacma Baboon	Breeding resident
Mammalia	Chrysochloridae	*Amblysomus hottentotus*	Hottentot Golden Mole	Near endemic
Mammalia	Chrysochloridae	*Amblysomus marleyi*	Marley's Golden Mole	Endemic
Mammalia	Chrysochloridae	*Calcochloris obtusirostris*	Yellow Golden Mole	Breeding resident
Mammalia	Chrysochloridae	*Chlorotalpa sclateri*	Sclater's Golden Mole	Breeding resident
Mammalia	Chrysochloridae	*Chrysospalax trevelyani*	Giant Golden Mole	Endemic
Mammalia	Chrysochloridae	*Chrysospalax villosus*	Rough-haired Golden Mole	Breeding resident
Mammalia	Chrysochloridae	*Neamblysomus julianae*	Juliana's Golden Mole	Breeding resident
Mammalia	Elephantidae	*Loxodonta africana*	African Savanna Elephant	Breeding resident
Mammalia	Emballonuridae	*Taphozous mauritianus*	Mauritian Tomb Bat	Breeding resident
Mammalia	Equidae	*Equus quagga*	Plains (Burchell's) Zebra	Breeding resident
Mammalia	Equidae	*Equus zebra zebra*	Cape Mountain Zebra	Breeding resident
Mammalia	Erinaceidae	*Atelerix frontalis*	Southern African Hedgehog	Breeding resident
Mammalia	Felidae	*Acinonyx jubatus*	Cheetah	Breeding resident
Mammalia	Felidae	*Caracal caracal*	Caracal	Breeding resident
Mammalia	Felidae	*Felis nigripes*	Black-footed Cat	Breeding resident
Mammalia	Felidae	*Felis silvestris*	African Wild Cat	Breeding resident
Mammalia	Felidae	*Leptailurus serval*	Serval	Breeding resident
Mammalia	Felidae	*Panthera leo*	Lion	Breeding resident
Mammalia	Felidae	*Panthera pardus*	Leopard	Breeding resident
Mammalia	Galagidae	*Galago moholi*	South African Galago	Breeding resident
Mammalia	Galagidae	*Otolemur crassicaudatus*	Greater Galago	Breeding resident
Mammalia	Giraffidae	*Giraffa camelopardalis*	Giraffe	Breeding resident
Mammalia	Herpestidae	*Atilax paludinosus*	Marsh (Water) Mongoose	Breeding resident
Mammalia	Herpestidae	*Cynictis penicillata*	Yellow Mongoose	Breeding resident
Mammalia	Herpestidae	*Galerella pulverulenta*	Cape Grey Mongoose	Breeding resident
Mammalia	Herpestidae	*Galerella sanguinea*	Slender Mongoose	Breeding resident
Mammalia	Herpestidae	*Helogale parvula*	Dwarf Mongoose	Breeding resident
Mammalia	Herpestidae	*Herpestes ichneumon*	Large Grey Mongoose	Breeding resident
Mammalia	Herpestidae	*Ichneumia albicauda*	White-tailed Mongoose	Breeding resident
Mammalia	Herpestidae	*Mungos mungo*	Banded Mongoose	Breeding resident
Mammalia	Herpestidae	*Paracynictis selousi*	Selous' Mongoose	Breeding resident
Mammalia	Herpestidae	*Rhynchogale melleri*	Meller's Mongoose	Breeding resident
Mammalia	Herpestidae	*Suricata suricatta*	Suricate (Meerkat)	Breeding resident
Mammalia	Hippopotamidae	*Hippopotamus amphibius*	Hippopotamus	Breeding resident
Mammalia	Hipposideridae	*Cloeotis percivali*	Short-eared Trident Bat	Breeding resident
Mammalia	Hipposideridae	*Hipposideros caffer*	Sundevall's roundleaf Bat	Breeding resident
Mammalia	Hyaenidae	*Crocuta crocuta*	Spotted Hyaena	Breeding resident
Mammalia	Hyaenidae	*Parahyaena brunnea*	Brown Hyaena	Breeding resident
Mammalia	Hyaenidae	*Proteles cristatus*	Aardwolf	Breeding resident
Mammalia	Hystricidae	*Hystrix africaeaustralis*	Cape Porcupine	Breeding resident
Mammalia	Leporidae	*Lepus saxatilis*	Scrub Hare	Breeding resident
Mammalia	Leporidae	*Pronolagus crassicaudatus*	Natal Red Rock Rabbit	Near endemic
Mammalia	Leporidae	*Pronolagus rupestris*	Smith's Red Rock Rabbit	Breeding resident
Mammalia	Leporidae	*Pronolagus saundersiae*	Hewitt's Red Rock Rabbit	Breeding resident
Mammalia	Macroscelididae	*Elephantulus brachyrhynchus*	Short-snouted Elephant-Shrew	Breeding resident
Mammalia	Macroscelididae	*Elephantulus edwardii*	Cape Rock Elephant-Shrew	Breeding resident
Mammalia	Macroscelididae	*Elephantulus myurus*	Eastern Rock Elephant-Shrew	Breeding resident
Mammalia	Macroscelididae	*Elephantulus rupestris*	Western Rock Elephant-Shrew	Breeding resident
Mammalia	Macroscelididae	*Macroscelides proboscideus*	Round-eared Elephant-Shrew	Breeding resident
Mammalia	Macroscelididae	*Petrodromus tetradactylus*	Four-toed Elephant-Shrew	Breeding resident
Mammalia	Manidae	*Manis temminckii*	Ground Pangolin	Breeding resident
Mammalia	Molossidae	*Chaerephon ansorgei*	Ansorge's Free-tailed Bat	Breeding resident
Mammalia	Molossidae	*Chaerephon pumila*	Little Free-tailed Bat	Breeding resident
Mammalia	Molossidae	*Mops condylurus*	Angolan Free-tailed Bat	Breeding resident
Mammalia	Molossidae	*Mops midas*	Midas Free-tailed Bat	Breeding resident
Mammalia	Molossidae	*Mormopterus acetabulosus*	Natal Free-tailed bat	Breeding resident
Mammalia	Molossidae	*Otomops martiensseni*	Large-eared Free-tailed Bat	Breeding resident
Mammalia	Molossidae	*Tadarida aegyptiaca*	Egyptian Free-tailed Bat	Breeding resident
Mammalia	Muridae	*Aethomys chrysophilus*	Red Veld Rat	Breeding resident
Mammalia	Muridae	*Aethomys ineptus*	Tete Veld Rat	Breeding resident
Mammalia	Muridae	*Cricetomys gambianus*	Gambian Giant Rat	Breeding resident
Mammalia	Muridae	*Dasymys incomtus*	African Marsh Rat	Breeding resident

Mammalia	Muridae	*Dasymys rufulus*	West African Marsh Rat	Breeding resident
Mammalia	Muridae	*Dendromus melanotis*	Grey Climbing Mouse	Breeding resident
Mammalia	Muridae	*Dendromus mesomelas*	Brants'Climbing Mouse	Breeding resident
Mammalia	Muridae	*Dendromus mystacalis*	Chestnut Climbing Mouse	Breeding resident
Mammalia	Muridae	*Desmodillus auricularis*	Cape Short-tailed Gerbil	Breeding resident
Mammalia	Muridae	*Gerbillurus paeba*	Hairy-footed Gerbil	Breeding resident
Mammalia	Muridae	*Grammomys cometes*	Mozambique Thicket Rat	Breeding resident
Mammalia	Muridae	*Grammomys dolichurus*	Woodland Thicket Rat	Breeding resident
Mammalia	Muridae	*Grammomys macmillani*	Macmillan's Thicket Rat	Breeding resident
Mammalia	Muridae	*Lemniscomys rosalia*	Single-striped Grass Mouse	Breeding resident
Mammalia	Muridae	*Malacothrix typica*	Gerbil Mouse	Breeding resident
Mammalia	Muridae	*Mastomys coucha*	Southern Multimammate Mouse	Breeding resident
Mammalia	Muridae	*Mastomys natalensis*	Natal Multimammate Mouse	Breeding resident
Mammalia	Muridae	*Micaelamys granti*	Grant's Rock Mouse	Breeding resident
Mammalia	Muridae	*Micaelamys namaquensis*	Namaqua Rock Mouse	Breeding resident
Mammalia	Muridae	*Mus minutoides*	Pygmy Mouse	Breeding resident
Mammalia	Muridae	*Mus neavei*	Neave's Pygmy Mouse	Breeding resident
Mammalia	Muridae	*Mystromys albicaudatus*	White-tailed Mouse	Breeding resident
Mammalia	Muridae	*Otomys angoniensis*	Angoni Vlei Rat	Breeding resident
Mammalia	Muridae	*Otomys irroratus*	Vlei Rat	Breeding resident
Mammalia	Muridae	*Otomys laminatus*	Laminate Vlei Rat	Near endemic
Mammalia	Muridae	*Otomys sloggetti*	Sloggett's Vlei Rat	Breeding resident
Mammalia	Muridae	*Otomys unisulcatus*	Bush Vlei Rat	Breeding resident
Mammalia	Muridae	*Parotomys brantsii*	Brant's Whistling Rat	Breeding resident
Mammalia	Muridae	*Rhabdomys pumilio*	Four-striped Grass Mouse	Breeding resident
Mammalia	Muridae	*Saccostomus campestris*	Pouched Mouse	Breeding resident
Mammalia	Muridae	*Steatomys krebsii*	Krebs's Fat Mouse	Breeding resident
Mammalia	Muridae	*Steatomys pratensis*	Fat Mouse	Breeding resident
Mammalia	Muridae	*Tatera brantsii*	Highveld Gerbil	Breeding resident
Mammalia	Muridae	*Tatera leucogaster*	Bushveld Gerbil	Breeding resident
Mammalia	Muridae	*Thallomys nigricauda*	Black-tailed Tree Rat	Breeding resident
Mammalia	Mustelidae	*Aonyx capensis*	African (Cape) Clawless Otter	Breeding resident
Mammalia	Mustelidae	*Ictonyx striatus*	Striped Polecat	Breeding resident
Mammalia	Mustelidae	*Lutra maculicollis*	Spotted-necked Otter	Breeding resident
Mammalia	Mustelidae	*Mellivora capensis*	Honey Badger (Ratel)	Breeding resident
Mammalia	Mustelidae	*Poecilogale albinucha*	African Striped (White-naped) Weasel	Breeding resident
Mammalia	Myoxidae	*Graphiurus murinus*	Woodland Dormouse	Breeding resident
Mammalia	Myoxidae	*Graphiurus ocularis*	Spectacled Dormouse	Breeding resident
Mammalia	Nycteridae	*Nycteris hispida*	Hairy Slit-faced Bat	Breeding resident
Mammalia	Nycteridae	*Nycteris thebaica*	Egyptian Slit-faced Bat	Breeding resident
Mammalia	Orycteropodidae	*Orycteropus afer*	Aardvark (Antbear)	Breeding resident
Mammalia	Pedetidae	*Pedetes capensis*	Springhare / Springhaas	Breeding resident
Mammalia	Procaviidae	*Dendrohyrax arboreus*	Tree Hyrax (Tree Dassie)	Breeding resident
Mammalia	Procaviidae	*Procavia capensis*	Rock Hyrax (Rock Dassie)	Breeding resident
Mammalia	Pteropodidae	*Eidolon helvum*	Straw-coloured Fruit Bat	Non-breeding migrant
Mammalia	Pteropodidae	*Epomophorus gambianus*	Gambian Epauletted Fruit Bat	Breeding resident
Mammalia	Pteropodidae	*Epomophorus wahlbergi*	Wahlberg's Epauletted Fruit Bat	Breeding resident
Mammalia	Pteropodidae	*Rousettus aegyptiacus*	Egyptian Rousette	Breeding resident
Mammalia	Rhinocerotidae	*Ceratotherium simum*	White (Square-lipped) Rhinoceros	Breeding resident
Mammalia	Rhinocerotidae	*Diceros bicornis*	Black (Hook-lipped) Rhinoceros	Breeding resident
Mammalia	Rhinolophidae	*Rhinolophus blassi*	Blasius's Horseshoe Bat	Breeding resident
Mammalia	Rhinolophidae	*Rhinolophus capensis*	Cape Horseshoe Bat	Breeding resident
Mammalia	Rhinolophidae	*Rhinolophus clivosus*	Geoffroy's Horseshoe Bat	Breeding resident
Mammalia	Rhinolophidae	*Rhinolophus darlingi*	Darling's Horseshoe Bat	Breeding resident
Mammalia	Rhinolophidae	*Rhinolophus hildebrandti*	Hildebrandt's Horseshoe Bat	Breeding resident
Mammalia	Rhinolophidae	*Rhinolophus landeri*	Lander's Horseshoe Bat	Breeding resident
Mammalia	Rhinolophidae	*Rhinolophus simulator*	Bushveld Horseshoe Bat	Breeding resident
Mammalia	Rhinolophidae	*Rhinolophus swinnyi*	Swinny's Horseshoe Bat	Breeding resident
Mammalia	Sciuridae	*Paraxerus cepapi*	Tree Squirrel	Breeding resident
Mammalia	Sciuridae	*Paraxerus palliatus*	Red Bush Squirrel	Breeding resident
Mammalia	Soricidae	*Crocidura cyanea*	Reddish-Grey Musk Shrew	Breeding resident
Mammalia	Soricidae	*Crocidura flavescens*	Greater Red Musk shrew	Breeding resident
Mammalia	Soricidae	*Crocidura fuscomurina*	Tiny Musk Shrew	Breeding resident
Mammalia	Soricidae	*Crocidura hirta*	Lesser Red Musk Shrew	Breeding resident
Mammalia	Soricidae	*Crocidura maquassiensis*	Maquassie Musk Shrew	Breeding resident
Mammalia	Soricidae	*Crocidura mariquensis*	Swamp Musk Shrew	Breeding resident
Mammalia	Soricidae	*Crocidura silacea*	Lesser Grey-brown Musk Shrew	Breeding resident
Mammalia	Soricidae	*Myosorex cafer*	Dark-footed Forest Shrew	Breeding resident
Mammalia	Soricidae	*Myosorex sclateri*	Sclater's Forest Shrew	Endemic

Mammalia	Soricidae	*Myosorex varius*	Forest Shrew	Breeding resident
Mammalia	Soricidae	*Suncus infinitesimus*	Least Dwarf Shrew	Breeding resident
Mammalia	Soricidae	*Suncus lixus*	Greater Dwarf shrew	Breeding resident
Mammalia	Soricidae	*Suncus varilla*	Lesser Dwarf Shrew	Breeding resident
Mammalia	Suidae	*Phacochoerus africanus*	Common Warthog	Breeding resident
Mammalia	Suidae	*Potamochoerus larvatus*	Bushpig	Breeding resident
Mammalia	Thryonomyidae	*Thryonomys swinderianus*	Greater Canerat	Breeding resident
Mammalia	Viverridae	*Civettictis civetta*	African Civet	Breeding resident
Mammalia	Viverridae	*Genetta genetta*	Small-spotted Genet	Breeding resident
Mammalia	Viverridae	*Genetta maculata*	Common Large-spotted Genet	Breeding resident
Mammalia	Viverridae	*Genetta tigrina*	South African Large-spotted (Rusty-spotted) Genet	Breeding resident
Mammalia	Vesepertilionidae	*Eptesicus hottentotus*	Long-tailed Serotine Bat	Breeding resident
Mammalia	Vesepertilionidae	*Glauconycteris variegata*	Butterfly Bat	Breeding resident
Mammalia	Vesepertilionidae	*Hypsugo anchietae*	Anchieta's Pipistrelle	Breeding resident
Mammalia	Vesepertilionidae	*Kerivoula argentata*	Damara Woolly Bat	Breeding resident
Mammalia	Vesepertilionidae	*Kerivoula lanosa*	Lesser Woolly Bat	Breeding resident
Mammalia	Vesepertilionidae	*Miniopterus fraterculus*	Lesser Long-fingered Bat	Breeding resident
Mammalia	Vesepertilionidae	*Miniopterus schreibersii*	Schreibers' Long-fingered Bat	Breeding resident
Mammalia	Vesepertilionidae	*Myotis bocagei*	Rufous Mouse-eared Bat	Breeding resident
Mammalia	Vesepertilionidae	*Myotis tricolor*	Temminck's Hairy Bat	Breeding resident
Mammalia	Vesepertilionidae	*Myotis welwitschii*	Welwitsch's Hairy Bat	Breeding resident
Mammalia	Vesepertilionidae	*Neoromicia capensis*	Cape Serotine Bat	Breeding resident
Mammalia	Vesepertilionidae	*Neoromicia nanus*	Banana Bat	Breeding resident
Mammalia	Vesepertilionidae	*Neoromicia rendalli*	Rendall's Serotine Bat	Breeding resident
Mammalia	Vesepertilionidae	*Neoromicia zuluensis*	Aloe Serotine Bat	Breeding resident
Mammalia	Vesepertilionidae	*Nycticeinops schlieffenii*	Schlieffen's Bat	Breeding resident
Mammalia	Vesepertilionidae	*Pipistrellus hesperidus*	African Pipistrelle	Breeding resident
Mammalia	Vesepertilionidae	*Pipistrellus rusticus*	Rusty Pipistrelle	Breeding resident
Mammalia	Vesepertilionidae	*Scotoecus albofuscus*	Light-winged Lesser House Bat	Breeding resident
Mammalia	Vesepertilionidae	*Scotophilus dinganii*	African Yellow Bat	Breeding resident
Mammalia	Vesepertilionidae	*Scotophilus viridis*	Greenish Yellow Bat	Breeding resident

Note: Please see the full reference list of the article, Perera SJ, Ratnayake-Perera D, Procheş Ş. Vertebrate distributions indicate a greater Maputaland-Pondoland-Albany region of endemism. S Afr J Sci. 2011;107(7/8), Art. #462, 15 pages. doi:10.4102/sajs.v107i7/8.462, for more information.

CHAPTER 3

A biodiversity hotspot numerically revisited based on vertebrate endemism

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ABSTRACT

Aim Biodiversity hotspots are a popular approach to setting global conservation priorities, yet their delimitation is primarily intuitive. Here we focus on the Maputaland-Pondoland-Albany Hotspot (MPA) of south-eastern Africa, and use cluster analyses on vertebrate incidence data to evaluate the original delimitation of the hotspot and a subsequent expansion thereof based on qualitative analyses. Additionally, we propose a preliminary zoogeographical regionalisation for south-eastern Africa, and describe centres of endemism.

Location South-eastern Africa.

Methods We use an incidence matrix of vertebrate species endemic to south-eastern Africa (300 species, including freshwater fish) in hierarchical cluster analyses to numerically evaluate the regional delimitation. Various spatially based measures of endemism were mapped to discuss the patterns of south-east African vertebrate endemism.

Results The analyses provide an accurate expanded version to the MPA – 59% larger, but substantially (168%) higher in vertebrate endemicity; greater Pondoland-Albany (GMPA) region of vertebrate endemism. South-east Africa is recognised as a dominion in the global zoogeographical hierarchy, and provinces, districts and assemblages are described within it, together with centres of endemism and centres of narrow endemism. Herpetofaunal endemism patterns are the main determinant of the overall pattern, while patterns in freshwater fish are the most distinctive. Centres of endemism detected here also support the delimitation of the GMPA region.

Main Conclusions Cluster analyses are valuable in the accurate delimitation of regions of global conservation importance, and such methods should be used wherever fine-scale distributional data are available, even in groups other than higher plants (which were initially employed in hotspot selection and delimitation), our analyses indicating a good coincidence of the centres of endemism across taxa.

Key Words biogeographical regionalisation, cluster analysis, conservation, endemism, Maputaland-Pondoland-Albany, southern Africa, vertebrates, zoogeography

INTRODUCTION

Biodiversity hotspots (Myers *et al.*, 2000; Mittermeier *et al.*, 2004) represent a popular scheme of prioritising areas for conservation at global scale and have received the highest share of conservation funding for any such schemata (Myers, 2003). The purported selection criteria for these hotspots are floristic endemism (with the assumption of plant-vertebrate hotspot coincidence; Myers *et al.*, 2000; Kier *et al.*, 2009) and the degree to which the primary vegetation is anthropogenically transformed. The delimitation of global biodiversity hotspots has seldom been empirically tested on species distribution patterns at local scales and a few hotspots have been examined in terms of their animal endemism (e.g. California Floristic Province, Davis *et al.*, 2008; Maputaland-Pondoland-Albany, Perera *et al.*, 2011).

The Maputaland-Pondoland-Albany biodiversity hotspot (MPA) is located along the eastern coast of southern Africa from Maputo in Mozambique to Port Elizabeth in South Africa's Eastern Cape Province, extending inland to reach an altitude of 1800m a.s.l. along the Great Escarpment (Steenkamp *et al.*, 2004). It harbours at least 1,900 endemic species of higher plants (Steenkamp *et al.*, 2004) together with 62 endemic and 60 near-endemic species of vertebrates (Perera *et al.*, 2011). The boundaries of the MPA are defined by (a) the Maputaland-Pondoland region and (b) the Albany centre of floristic endemism (van Wyk and Smith, 2001), respectively delimited (a) to include the midlands/escarpment endemics together with previously identified coastal belt of the Tongaland-Pondoland regional mosaic of White (1983) and (b) to encompass the mosaic of biomes and bioregions intermingling within a region characterised by a unique bi-modal rainfall pattern (van Wyk and Smith, 2001), both the delimitations being intuitive. In a qualitative study to outline the patterns of vertebrate endemism in south-eastern Africa, also with the intention of testing the congruence of floristically demarcated boundaries of the MPA to those of its faunal assemblages, Perera *et al.* (2011) proposed a greater Maputaland-Pondoland-Albany (GMPA) region of vertebrate endemism, incorporating the south-eastern Great Escarpment besides the hotspot as defined by Conservation International (Mittermeier *et al.*, 2004). The GMPA region expanded the MPA hotspot by73% in land area while increasing its vertebrate endemism by 135%, making it a notable priority region for vertebrate conservation in south-eastern Africa.

The delineation of zoo- (bio-) geographical regions using numerical analyses on taxon incidence in *operational geographic units* (OGUs) is well established (Crovello, 1981; Kreft & Jetz, 2010; Procheş & Ramdhani, 2012; Linder *et al.*, 2012). Many such studies have involved multivariate analyses on incidence matrices for taxa in equal-area grid cells (e.g. Procheş, 2005; Kreft & Jetz, 2010, with a global geographic extent, and several studies listed in Perera *et al.*, 2011 and Linder *et al.*, 2012 particularly focusing on continental Africa or southern Africa).

As such, several quantitative biogeographical studies on southern African faunal groups have suggested zoogeographical regionalisations. Terrestrial vertebrates have been the subject of many such analyses, though none has targeted the freshwater fish fauna as yet. Incidence data (presence only or presence/absence) have been used for taxa in different equal-area grid cells, ranging from coarse grids of *c.* four-degree squares to half-degree squares for amphibians, reptiles, birds and larger mammals separately (listed in Perera *et al.*, 2011) and all terrestrial vertebrates together at one-degree square scale (Linder *et al.*, 2012). Many of these grid overlays may be too coarse to pick up patterns of narrow endemism, while an increase of resolution was not possible for many groups due to data incompleteness (Moline & Linder, 2006; Perera *et al.*, 2011). The use of ecologically predefined geographical (eco-geographical) units is an alternative (e g. Smith, 1983 and Procheş & Ramdhani, 2012 at global scale; Moline & Linder, 2006 and Born *et al.*, 2007 in southern Africa), and are preferred over grid cells to reveal biogeographical patterns by Morrone & Escalante (2002) and Moline & Linder (2006), as they are expected to correspond well with the climate, topography and geology, and hence the distributional ranges of species. This paper uses such predefined eco-geographical units in numerical analyses of endemic terrestrial and freshwater vertebrate distributions, with the aim of achieving a better understanding of vertebrate endemism patterns in the region. In doing so, we (a) evaluate the pervious qualitative delimitation of the GMPA region of vertebrate endemism, (b) propose a preliminary zoogeographical regionalisation for south-eastern Africa, and (c) discuss the patterns and centres of endemism in the region.

METHODS

Study area and operational geographic units

South-eastern Africa is delimited by natural biogeographical barriers: in the north by the arid Limpopo River valley (Clancey, 1994; *c.* 22º S at its northern most meander), and in the west by the Nelspoort interval of the southern Great Escarpment (Clark *et al.*, 2009; longitudinally along *c.* 23.5º E). Following these limits, we delineated our study region as the area south of 22º S and east of 24º E. The thirty seven zoogeographical units (ZUs) predefined for this area by Perera *et al.* (2011) were used as OGUs for the present study. Twenty-eight of these ZUs are completely encompassed by 22˚S, 24˚E latitude-longitude limits and the Indian Ocean. The western boundaries of the Knysna, Lower Karoo, Sneeuberg and Highveld-Upper Karoo units (KNY, AKR, SNB and HUK in Fig. 1), extralimital to 24˚E, were incomplete, and had to be drawn based on the distribution ranges of relevant species. The wedge-shaped intrusion of the Lower Karoo Bioregion (Mucina & Rutherford, 2006) into the Albany Centre is treated here as an artificial unit on its own, and referred as Albany Karoo (AKR in Fig. 1). Five more units (MLV, NMO, NBV, KBV and UKR in Fig. 1) extend to the north and west beyond the study area, and their extralimital boundaries are not considered here. The natural boundaries of ZUs in Perera *et al.* (2011) were reviewed to match quarter-degree square (QDS) borders, as data are available at this scale for amphibians, reptiles and birds.

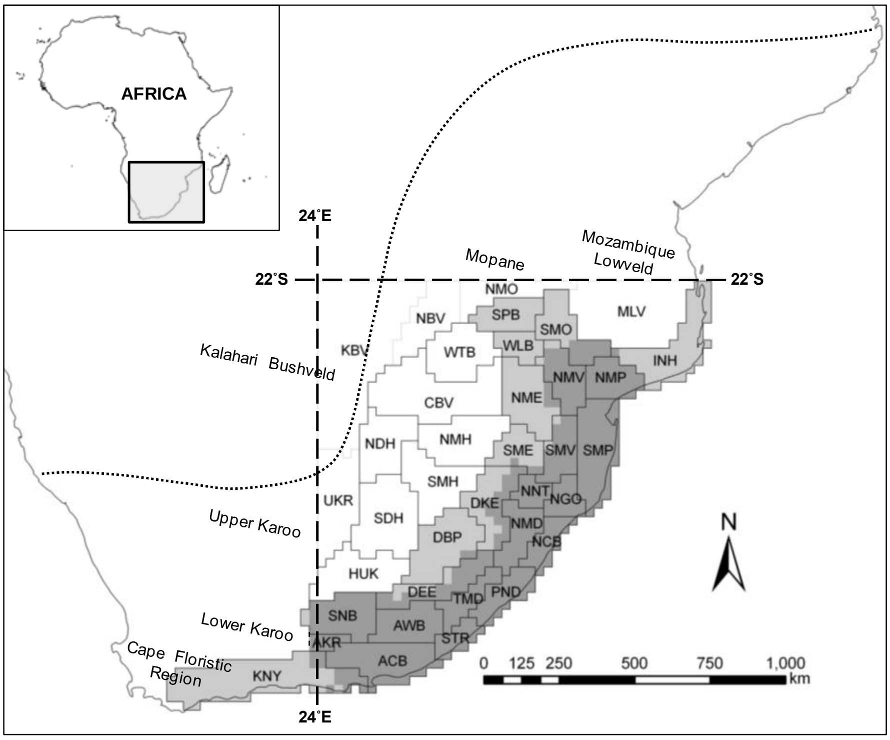


Figure 1 The study area and the operational geographic units (OGUs). Species having >50% of their extent of occurrence within the area delimited by 22˚S and 24˚E (dashed lines), were selected for analyses. No distribution ranges of species included in the study extend beyond the dotted line. The Maputaland-Pondoland-Albany hotspot of Mittermeier *et al.* (2004) is indicated in dark grey, while the areas added as parts of the greater Maputaland-Pondoland-Albany region of vertebrate endemism (Perera *et al.*, 2011) are in light grey, both as assigned to quarter-degree square borders. Zoogeographic units redrawn from Perera *et al.*, 2011 to fit quarter-degree square borders were used as OGUs in the present study: ACB - Albany Coastal Belt, AKR - Intrusion of Lower Karoo into Albany, AWB - Amatola-Winterberg, CBV - Central Bushveld, DBP - Drakensberg Plateau, DEE - Drakensberg-Eastern-Cape Escarpment, DKE - Drakensberg-KwaZulu-Natal Escarpment , HUK - Highveld-Upper Karoo, INH – Inhambane, KBV - Kalahari Bushveld, KNY – Knysna, MLV - Mozambique Lowveld, NBV - Northern Bushveld, NCB - Natal Coastal Belt, NDH - Northern Dry Highveld, NGO – Ngoye, NMD - Natal Midlands, NME - Northern Mpumalanga Escarpment, NMH - Northern Mesic Highveld, NMO - Northern Mopane, NMP - Northern Maputaland, NMV - Northern Middleveld, NNT - Northern Natal, PND – Pondoland, SDH - Southern Dry Highveld, SME - Southern Mpumalanga Escarpment, SMH - Southern Mesic Highveld, SMO - Southern Mopane, SMP - Southern Maputaland, SMV - Southern Middleveld, SNB – Sneeuberg, SPB – Soutpansberg, STR - Southern Transkei Coastal Belt, TMD - Transkei Midlands, UKR - Upper Karoo, WLB – Wolkberg, WTB – Waterberg. See text for further details.

Selection of species

All the vertebrate species endemic/near-endemic to southern Africa (south of the Cunene, Okavango and Zambezi rivers) with more than 50% of their extent of occurrence south of 22˚S and east of 24˚E were selected (see Perera at al., 2011), and referred hereafter as endemic to south-eastern Africa *sensu lato*. In order to assess vertebrate endemism in the Knysna extension of the GMPA region, species endemic here, i.e. from 24˚E westward to the Cape Floristic Region (CFR), until the Langeberg and eastern Agulhas Plains, but excluding the south-western centre of floristic endemism (Goldblatt & Manning, 2000), were also included. Thus, 300 species of vertebrates endemic to south-eastern Africa *s.l.* (31 freshwater fish, 40 amphibians, 149 reptiles, 51 birds and 29 mammals; Appendix S1) were included in the present analyses. The distribution ranges of selected species do not extend north beyond the extreme south of Malawi, central and southern Mozambique, Zimbabwe, eastern Botswana, Swaziland, South Africa, Lesotho and southern Namibia (dotted line in Fig. 1). See Perera *et al.* (2011) for the sources of data and taxonomy.

Numerical analyses

An incidence (presence/marginal presence/absence of naturally breeding populations) matrix for the 300 vertebrate species endemic to south-eastern Africa *s.l.* in thirty-seven ZUs was compiled. When scoring the incidence for species with atlas data available at QDS scale (amphibians, reptiles and birds), they were recorded as present for a given ZU, even with a single occupied QDS, as long as this QDS was not along the margin of the ZU. When scoring a species occupying only marginal QDSs for a given ZU, it was scored as present only if the species occupied more 10% of the ZU; otherwise the species was scored as marginal. A species occupying even a single or few marginal QDSs (<10% coverage of the ZU) was considered present for a ZU concerned only when (a) the species is absent in any of the neighbouring ZUs, (b) the relevant QDS is in the coastal margin of the ZU, or (c) if occupied QDSs were found along two opposite margins of the ZU. The same rules were used in scoring marginal occurrences for freshwater fish and mammals based on approximate range maps.

Species incidence matrices were subjected to phenetic cluster analyses in order to cluster ZUs and identify hierarchical relationships among them. Analyses were conducted for individual taxonomic groups of vertebrates separately viz. (1) freshwater fish, (2) amphibians, (3) reptiles, (4) birds, and (5) mammals, (6) all vertebrates combined, and for macro-ecologically combined groups such as (7) herpetofauna, (8) terrestrial vertebrates and (9) non-volant vertebrates. This way we could examine if cross-taxon congruence occurs among vertebrate groups, and also assess which group(s) of vertebrates drive(s) the overall patterns of endemism.

ZUs were clustered using Jaccard's coefficient of similarity (Jaccard, 1901), to compare each ZU with every other based on its endemic species composition, eventually producing a similarity matrix. The Jaccard's coefficient does not consider shared absences in its calculation (Jardine, 1972), hence artefacts introduced to the analysis due to under-collection in a particular area would be disregarded (Ramdhani *et al.*, 2008). Subsequently, the similarity matrix was converted into distance values by applying the agglomerative hierarchical clustering algorithm of Unweighted Pair-Group Method using Arithmetic Averages (UPGMA). The analyses were conducted using FreeTree *ver*. 0.9.1.50 (Pavlicek *et al.*, 1999). The resulting dendrograms were visualised using TreeView *ver*. 1.6.6. (Page, 1996) and used to define hierarchical relationships between different clusters of ZUs. As there is no generally accepted rule to decide which of the clusters recognised by a clustering algorithm are meaningful biogeographical entities, different authors have used various "stopping rules", to decide at which point to stop the splitting of clusters further into smaller units: e.g. set maximum number of OGUs for a cluster group (e.g. Williams *et al*., 1999); set number of cluster divisions (e.g. Kreft & Jetz, 2010); and set level of distance or dissimilarity (e.g. Procheş, 2005), also known as phenon line approach (Sneath & Sokal, 1962; Sokal & Rohlf, 1962). We employed phenon lines at arbitrary levels of dissimilarity in interpreting dendrograms, and the ArcGIS 9.3 (ESRI, 2009) was used to map the results.

For each species incidence matrix the analysis was run twice, with marginal species taken as present and absent, respectively. Considering marginal occurrences as absent was favoured over taking them as present, since false absences do not affect the results when using the UPGMA algorithm with the Jaccard's similarity coefficient. Geographically contiguous and biogeographically meaningful clusters were obtained consistently from the analyses taking marginal occurrences as absent; hence only those results are presented here.

A numerical delimitation is presented for the GMPA region of vertebrate endemism based on the overall occurrence of each ZU within the geographically contiguous cluster closest to the qualitative demarcation of the region in each of the cluster analyses for five individual taxonomic groups (consensus/maximally congruent approach; Linder *et al.*, 2012), and finally its consensus with the cluster analysis for all vertebrates combined. Core units and extensions of the numerically delimited GMPA region were hence identified, respectively, with more than 70% and 50% congruence for each ZU.

Zoogeographical regionalisation

The cluster dendrogram developed for all vertebrate species endemic to south-eastern Africa *s.l.* (combined/total evidence approach; Linder *et al.*, 2012) was used to propose a preliminary zoogeographical regionalisation for the study area. We followed the biogeographical taxonomic hierarchy as given by the International Code of Area Nomenclature (ICAN; Ebach *et al.* 2008) viz. realms, regions, dominions, provinces, and districts. In addition to that, we followed de Klerk *et al.* (2002) and Alexander *et al.* (2004) in keeping assemblages as the smallest units subordinate to the districts, as our analysis with a comparatively smaller extent of coverage (even smaller than sub-continental scale) detects finer units compared to a global or a continental analyses. All biogeographical units were detected based on phenon lines, except in the case of the Karoo Dominion, where an arbitrary decision had to be made consulting the separation between relatively mesic and arid areas in published zoogeographical regionalisations (listed in Perera *et al.*, 2011 and Linder *et al.*, 2012).

Patterns of endemism

Measures of endemism

The vertebrate species endemic to the south-east African dominion (SEAD; defined here by the phenetic cluster analysis for all vertebrates endemic to south-eastern Africa *s.l.*; comprising 28 ZUs) were used for the mapping of endemism patterns. These included 188 species (vertebrates endemic to south-eastern Africa *sensu stricto*; 19 freshwater fish, 34 amphibians, 98 reptiles, 22 birds and 15 mammals; Appendix S1; hereafter referred to as SEAD endemics). Geographical patterns were mapped for four spatially based quantitative measures of endemism calculated for each ZU: (a) the SEAD endemic species richness, (b) range-restricted species richness (narrow endemism), (c) weighted endemism and (d) the weighted endemism corrected for the area. As there is no formal definition for a range-restricted/narrow endemic species (Linder, 2001), these are defined here as species restricted to a single ZU. The weighted endemism for each ZU was calculated following Crisp *et al.* (2001), as the sum of the reciprocal of the total number of ZUs each species is found in, and normalised. The calculation for weighted endemism index can be given as, $WE = \sum 1/C$, where C is the number of ZUs each endemic occurs in. As our ZUs are not of equal area, we calculated weighted endemism corrected for the area (normalised), for each ZU by simply dividing the weighted endemism index by the number of QDSs in the respective ZU. Each of the calculated endemism parameter was mapped using ArcGIS 9.3 (ESRI, 2009) with a graduated grey scale of five classes. Classes were determined with natural breaks calculated using Jenk’s optimisation, so that the patterns inherent in the data are best revealed.

Centres of endemism

Endemism centres within the SEAD were identified following a phenetic approach (e.g. Oliver *et al.*, 1983), by identifying clusters derived from phenon lines on the phenetic cluster dendrogram for all vertebrates endemic to south-eastern Africa *s.l.*, using two levels of endemic species cut-offs to recognise two ranks of centres (as in the chorological approach of White, 1993); (a) centres of endemism (COEs; biogeographical assemblages detected based on a phenon line, as given above, with at least seven endemic vertebrate species, =regional centres of endemism *sensu* White, 1993) and (b) centres of narrow endemism (CONEs; the finest, geographically contiguous clusters of narrow ZUs (<50 QDSs when combined) or terminal ZUs to have at least four endemic vertebrate species, =local centres of endemism *sensu* White, 1993). During the identification of characteristic species in COEs, some ZUs of the relevant cluster were found not to contribute to the formation of centres in terms of harbouring centre endemics, but only clustered with the other ZUs based on the similarity of widespread species assemblage (see Procheş, 2005). Such ZUs were removed from the final demarcation of COE. Endemic species were tabulated for each centre as (a) characteristic endemics i.e. species strictly restricted within the centre (Williams *et al.*, 1996), and occupying more than two-thirds of the ZUs in the centre (when there are more than two such), and distributed over a half of centre's range (adapted from Procheş & Ramdhani, 2012), hence whose ranges roughly coincide with the boundary of the centre (=centre associated species; de Kelrk, *et al.*, 2002) and (b) narrow endemics i.e. species occupying further restricted ranges within the center.

RESULTS

Numerical recovery of the GMPA region of vertebrate endemism

The results of the cluster analyses recovering contiguous geographical clusters congruent with the qualitative delimitation of GMPA region and numerical consensus for it are summarised in Appendix S2. The relevant dendrograms are presented and geographical clusters are mapped in Fig. 2. All analyses recovered a cluster with a fairly high congruence (>64%) to the qualitative demarcation of the GMPA region, except for freshwater fish (48% congruence; Fig. 2e). The analyses for all vertebrates together (Fig. 2a), and for terrestrial vertebrates (Fig. 2b) produced clusters with 84% congruence to the qualitative demarcation of the GMPA region of endemism. This pattern reveals that the freshwater fishes have the most different zoogeography among all vertebrate classes in the study area, with greater geographical differentiation in the northern parts of the region. Reptiles, being the vertebrate class with the highest number of endemics in the area (n=149) show the highest level of numerical congruence to the qualitative GMPA demarcation (76%; Fig. 2h). The herpetofauna as a whole, with similar numerical congruence is the main determinant of the overall pattern of vertebrate endemism in the region (Fig. 2d). Even though birds show only a 68% numerical congruence (Fig. 2f), their contribution to the GMPA region of endemism seems to be significant, as their removal results in a lower congruence (see non-volant vertebrates, Fig. 2c). Patterns for amphibians and mammals alone also confirm the qualitative demarcation of the GMPA region with 68% and 72% congruence, respectively (Fig. 2g and 2i), albeit these analyses are based on smaller numbers of species (n=40, 29 respectively).

The numerically recovered GMPA region of vertebrate endemism comprises nineteen core units and three extensions (Appendix S2; Fig. 3). With the numerical refinements, the region loses the Inhambane, Southern Mopane and Northern Maputaland ZUs, while the Sneeuberg is left out of the core region, becoming an extension. The Waterberg joins the GMPA region as a new extension. The Knysna unit, originally an extension of the qualitatively defined GMPA region, is now recovered as a core unit in all analyses. However, considering its affiliation to the CFR, we still view it as an extension. In this area, forest-linked endemic elements (dominant in the east) are clearly similar to those in the GMPA region, but those extending west, not included here, are likely to be more distinctive CFR elements (see Koen & Crowe, 1987).

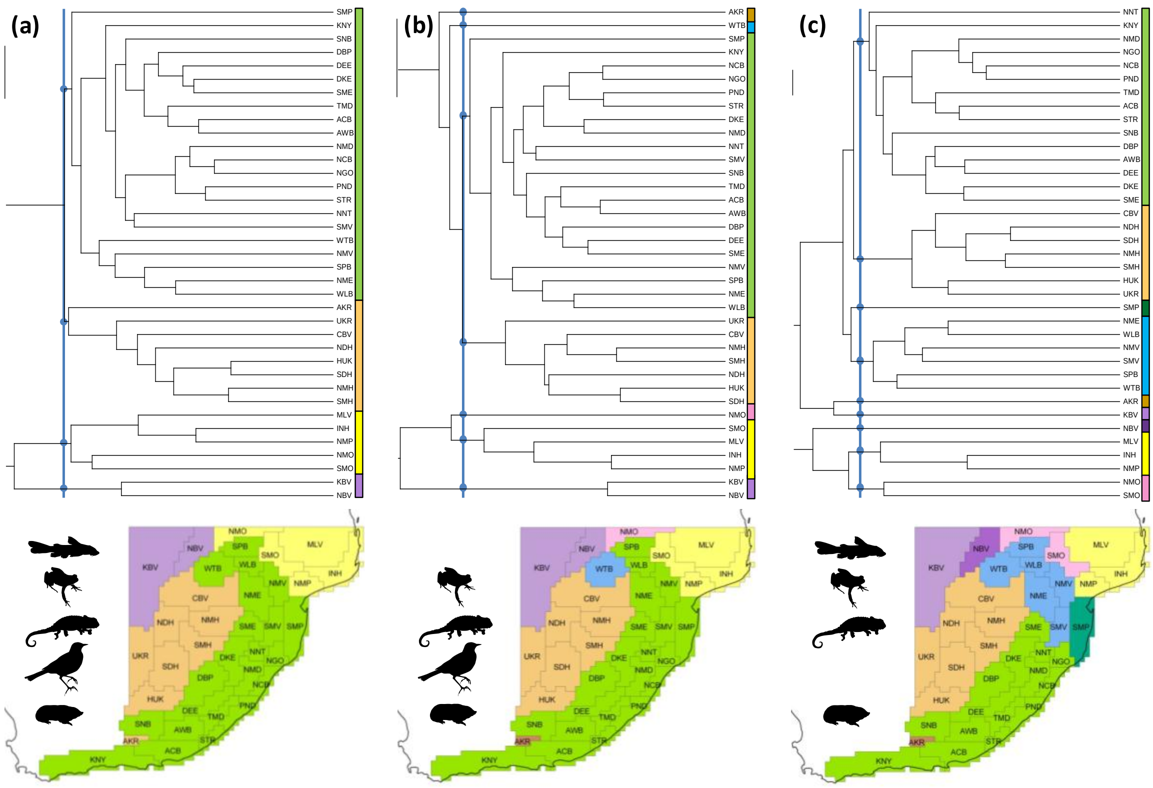


Figure 2 *Continued to the next page*

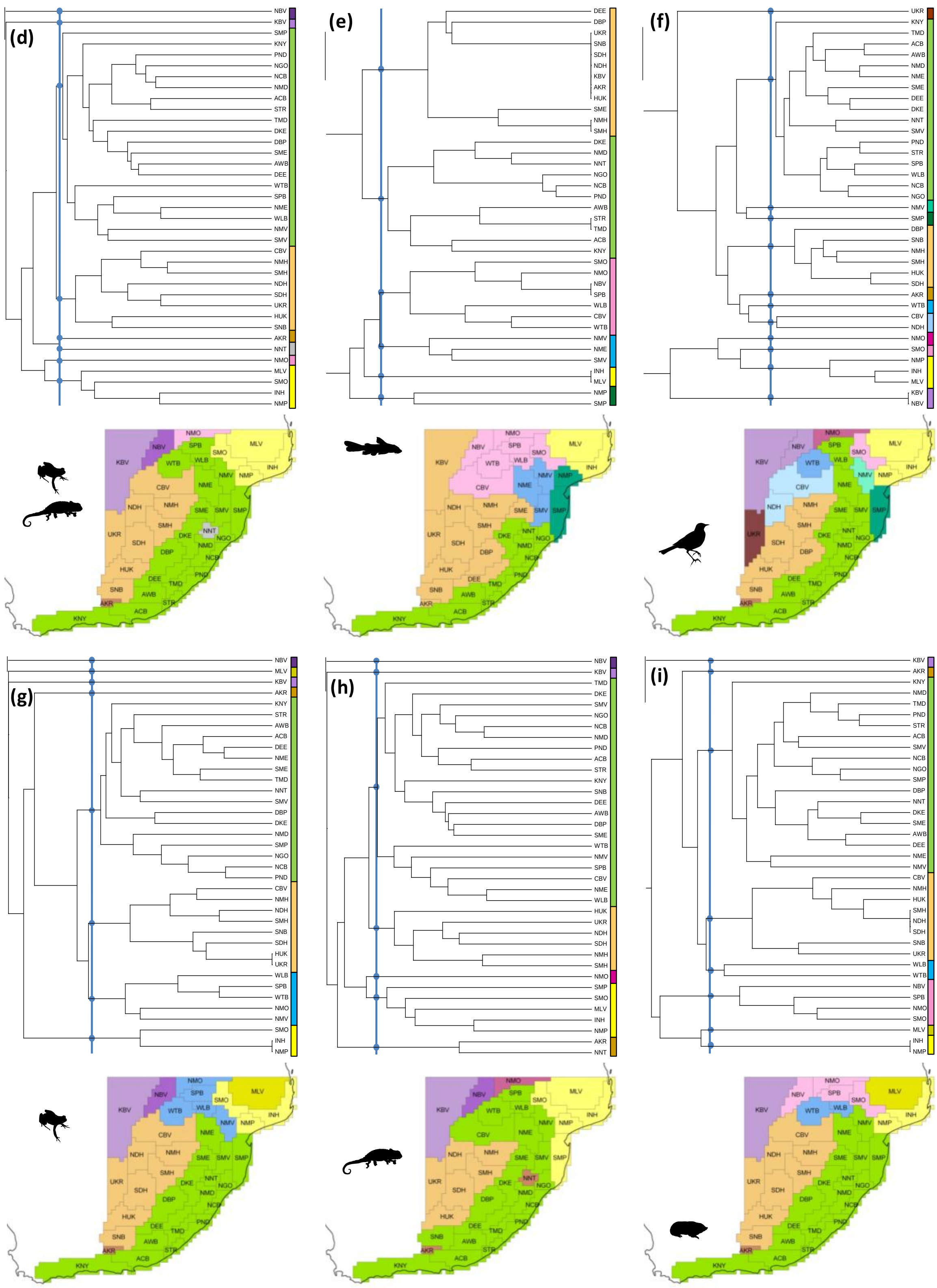


Figure 2 The results of UPGMA cluster analyses on endemic species incidence matrices for (a) all vertebrates (n=301) (b) terrestrial vertebrates (n=270), (c) non-volant vertebrates (n=250), (d) herpetofauna (n=190), (e) birds (n=51), (f) freshwater fish (n=31), (g) amphibians (n=40), (h) reptiles (n=149) and (i) mammals (n=29). Contiguous geographical clusters with maximum congruence to the qualitative delimitation of the greater Maputaland-Pondoland-Albany (GMPA) region of vertebrate

endemism, recovered from each of numerical analyses is presented with cluster dendrograms and relevant maps. Different colours denote congruent geographical clusters in different analyses, indicating clusters congruent with the qualitative delimitation of the GMPA region in light green.

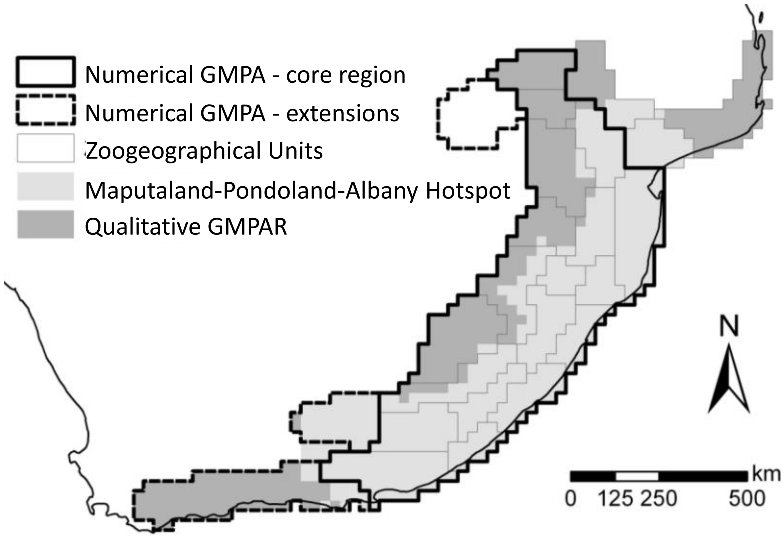
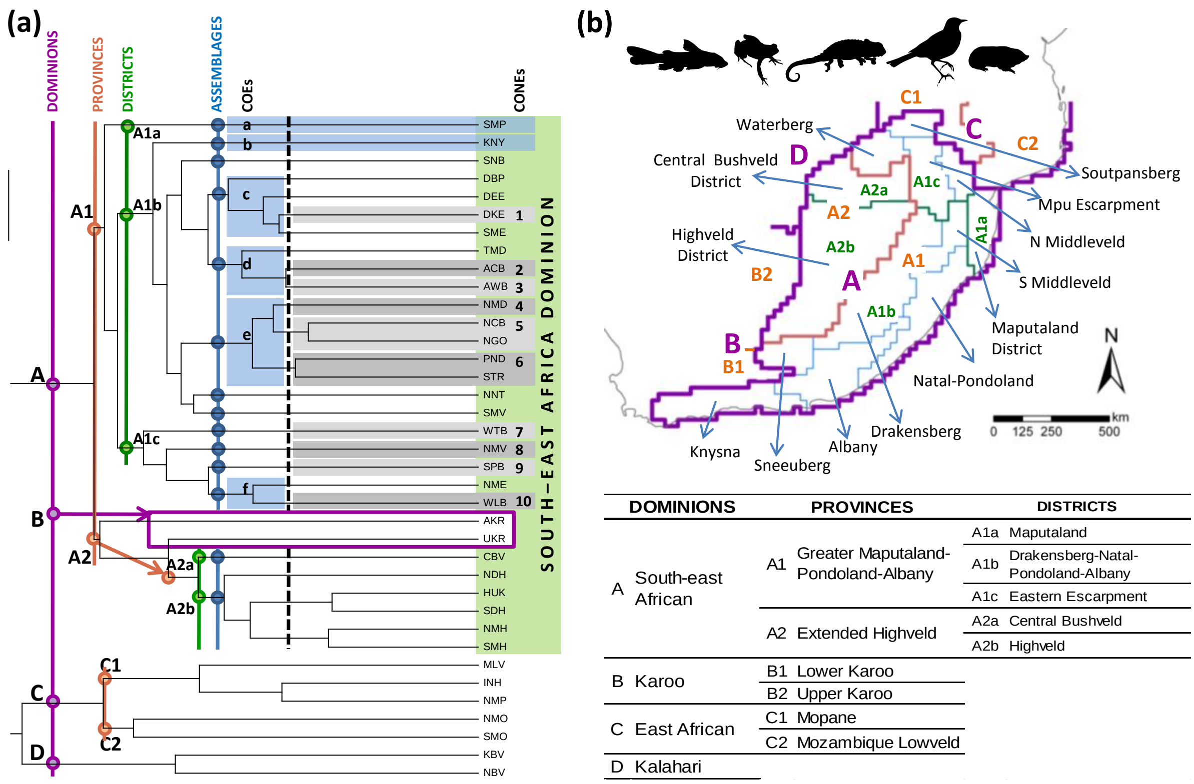


Figure 3 Numerically delimited greater Maputaland-Pondoland-Albany (GMPA) region of vertebrate endemism based on the consensus from UPGMA cluster analyses on zoogeographical units for the five incidence data matrices (vertebrate classes analysed individually) and the combined matrix for incidence of all endemic vertebrate. See Appendix S2 for the consensus calculation and text for details.

Zoogeographical regionalisation for south-eastern Africa

A preliminary zoogeographical regionalisation and its drafting based on the phenetic cluster dendrogram for south-east African endemic vertebrates *s.l.*, is given in Fig. 4. The primary split on the dendrogram produces a broad south-east African cluster presented here as a dominion (SEAD) ranging from sub-tropical to temperate latitudes separated from the more tropical east African cluster in the north-east and arid Kalahari and Karoo clusters in the west. A zoogeographical hierarchy of provinces and districts is established within the SEAD, along phenon lines at increasingly higher similarity levels; among these, the GMPA is recognised as a zoogeographical province with a clearly different vertebrate assemblage from that of the extended Highveld province.



DOMINIONS	PROVINCES	DISTRICTS
A South-east African	A1 Greater Maputaland-Pondoland-Albany	A1a Maputaland
		A1b Drakensberg-Natal-Pondoland-Albany
		A1c Eastern Escarpment
	A2 Extended Highveld	A2a Central Bushveld
		A2b Highveld
B Karoo	B1 Lower Karoo	
	B2 Upper Karoo	
C East African	C1 Mopane	
	C2 Mozambique Lowveld	
D Kalahari		

Figure 4 A proposed zoogeographical regionalisation for south-eastern Africa (a) The dendrogram of hierarchical relationships between zoogeographical units, based on the distributional data for all vertebrate species endemic to south-eastern Africa *s.l.*, using Jaccard's coefficient of similarity and the UPGMA clustering algorithm. (b) The resulting zoogeographical regionalisation; dominions, provinces and districts are listed with codes in the table below the map. All entities labelled on the map are assemblages, except for three districts (with no assemblages in them) mentioned as such. The centres of endemism (COEs) and centres of narrow endemism (CONEs) for south-east African dominion are defined by relevant phenon lines on the left of the labels (see text for their interpretation).

Vertebrate endemism within SEAD

Geographical patterns in the four measures of vertebrate endemism within the SEAD are mapped in Fig. 5. Higher vertebrate endemism along and below the escarpment, towards the south-eastern coastal belt is obvious, with peaks of endemism in Southern Maputaland [this ZU comprises most of van Wyk & Smith's (2001) Maputaland centre of floristic endemism, and is hence hereafter referred to as Maputaland], Natal, the Drakensberg-KwaZulu-Natal Escarpment, the Mpumalanga Escarpment and the Knysna ZUs. Even along the coastal belt it is observed that the endemism is comparatively low in the sub-tropical section (especially in and Eastern Cape Province, than in the KwaZulu-Natal), as compared to the more tropical coast of Maputaland in the North and the more temperate CFR (Mediterranean type vegetation) in the south. The pattern of SEAD endemic species richness (Fig. 5a), as well as the weighted endemism (Fig. 5c, d) shows that the vertebrate endemism is markedly low in the extended Highveld province, compared to that of the GMPA province. Fig. 5d shows Natal Midlands, Wolkberg and Ngoye units to have concentrations of narrowest endemics.

These patterns are further confirmed by the six COEs and ten CONEs identified through phenetic clustering, all found along or below the escarpment, and none of them in the extended Highveld province. These centres are illustrated in Fig. 6, with characteristic and narrow endemics of COEs and narrow endemics of CONEs are tabulated and in Appendix S3.

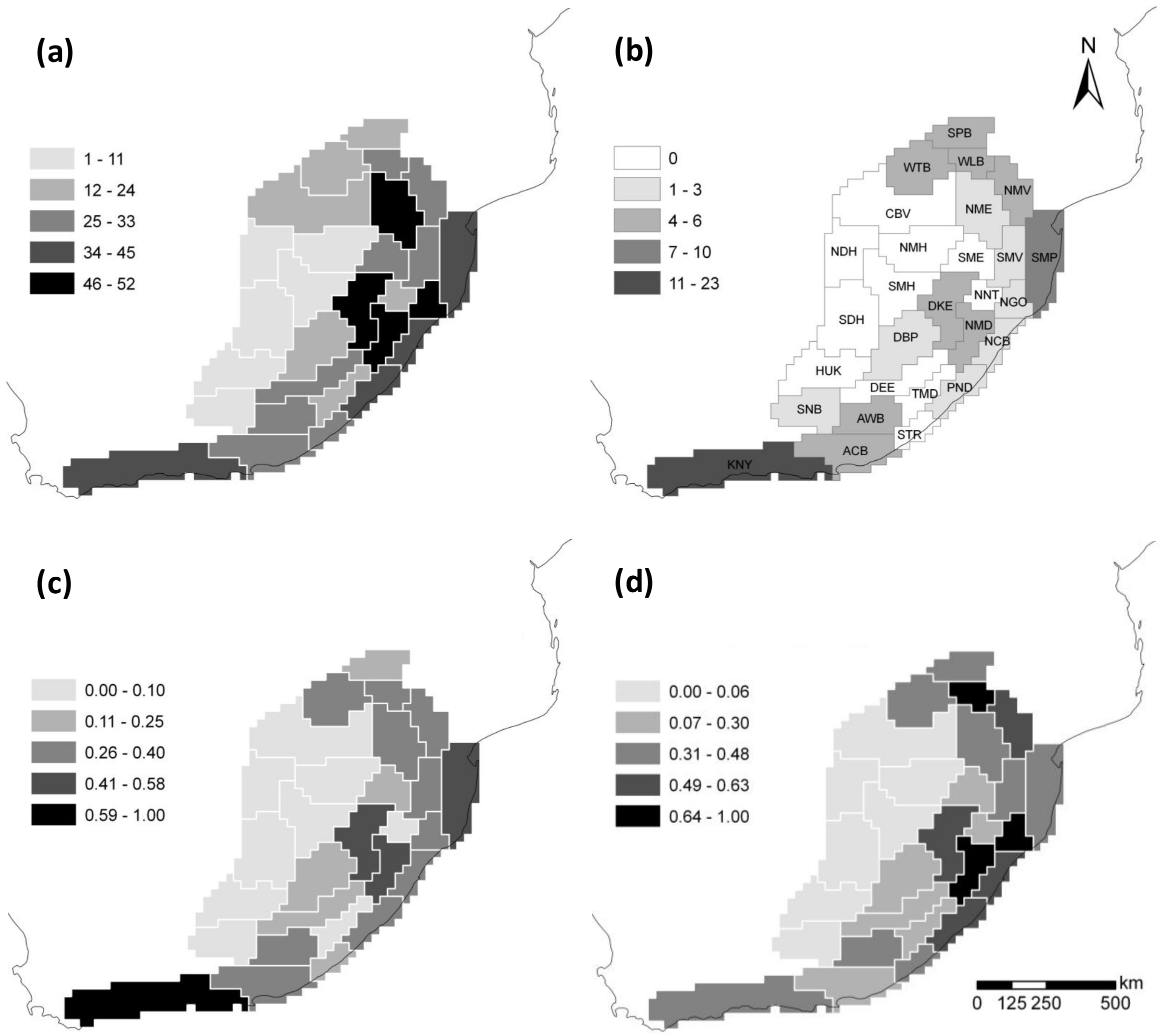


Figure 5 Patterns of vertebrate endemism within the south-east African dominion [SEAD; defined by the dendrogram in Fig. 4a, comprising 28 zoogeographical units (ZUs; acronyms in pane (b) and labelled in Fig. 1. (a) SEAD endemic species richness per ZU; (b) range-restricted species richness (narrow endemism) per ZU; (c) weighted endemism (normalised) per ZU; (d) weighted endemism corrected for the area (normalised) per ZU. Each endemism measure is illustrated by a graduated grey scale of five classes, determined by natural breaks calculated using Jenk's optimisation.

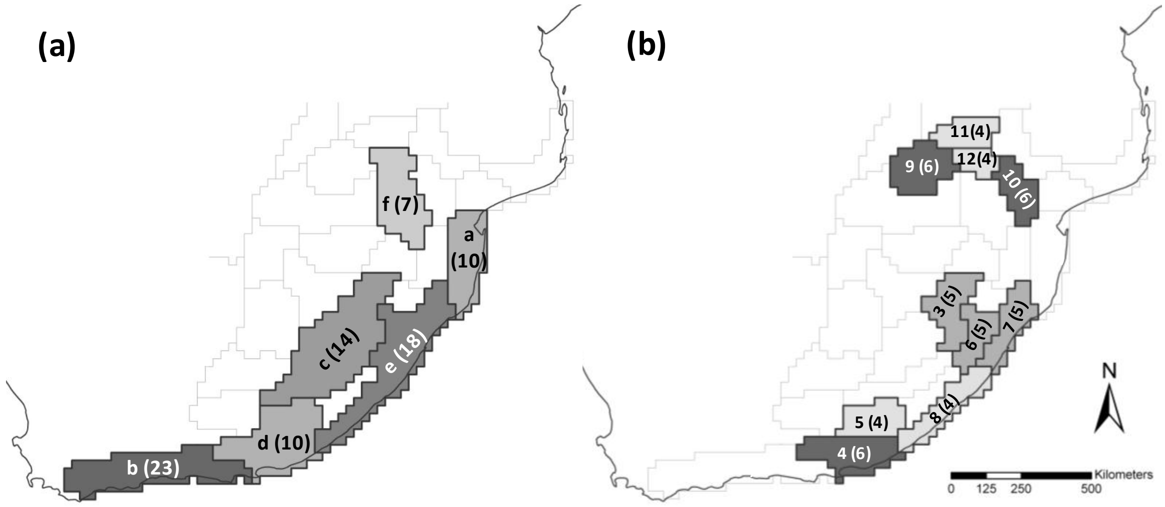


Figure 6 Centres of vertebrate endemism within the south-east African dominion identified by analysing the cluster dendrogram in Fig. 4a (a) Centres of endemism (COEs) determined by the clusters identified as biogeographical assemblages to have >7 endemic species; letters refer to COEs in Fig. 4a; a – Maputaland, b – Knysna, c – Drakensberg, d – Albany, e –Natal-Pondoland, f – Mpumalanga Escarpment, and (b) Centres of narrow endemism (CONEs), derived from the same dendrogram based on the finest, geographically contiguous clusters of narrow ZUs (<50 QDSs when combined) or terminal ZUs to have >4 narrow-endemic species; numbers refer to CONEs in Fig. 4a; 1 – Maputaland, 2 – Knysna, 3 – Drakensberg-KwaZulu-Natal Escarpment, 4 – Albany Coastal Belt, 5 – Amatola-Winterberg, 6 – Natal Midlands, 7 –Natal Coastal Belt-Ngoye, 8 –Transkei Coastal Belt, 9 – Waterberg, 10 – Northern Middleveld, 11 – Soutpansberg, 12 – Wolkberg. The number of endemics restricted to each centre is given in brackets and listed in Appendix S3.

DISCUSSION

Methods Revisited

Biogeographical analyses: from intuitive to numerical

The use of equal-area grids cells as OGUs is the ideal application in biogeographical regionalisation, as such units are free of predetermined biogeographical meaning, require a minimum of assumptions, and facilitate area calculations and robust analysis (Ramdhani *et al.*, 2008; Procheş & Ramdhani, 2012). In contrast, Morrone & Escalante (2002) and Moline & Linder (2006) favoured the use of eco-geographical units as OGUs, as those units are expected to correspond well with distributional ranges of species, thus having homogenous composition of species. One issue of using equal-area grid cells as OGUs, is the completeness of data at smaller grain sizes, that causes geographical scattering of clusters making them discontinuous (Procheş, 2005, 2008; Ramdhani *et al.*, 2008). But if the grid size is increased to correct that, there is a risk of not identifying natural boundaries of resulting biogeographical entities and missing finer patterns of endemism, that are important in conservation planning (Alexander *et al.*, 2004; Perera *et al.*, 2011). Also, the spatial homogeneity in species composition within the grid cell decreases with increasing size. Perera *et al*.'s (2011) set of ZUs for south-eastern Africa based on an intuitive/qualitative methodology, was developed to overcome both above ends of the spectrum of issues, and hence used in this study as OGUs. These were identified based on a visual analysis of distribution ranges of 495 vertebrate taxa (species, well established and disjunct sub-species, disjunct sub-species complexes and long disjunct populations) endemic to south-eastern Africa, through a chorological identification of "Endemic Vertebrate Distributions (EVDs)", defined as "*distribution ranges congruent across several endemic vertebrate taxa*" (=chorotypes *sensu* Olivero *et al.*, 2011 or biochoria *sensu* Born *et al.*, 2007 of endemic vertebrates). The ZUs were subsequently delimited based on three features of EVDs viz. core regions (where two or more endemic taxa of the same EVD coincide, =areas of endemism *sensu* Linder & Mann, 1998), overlapping margins (where two or more endemic taxa of successive EVDs coincide, =overlaps *sensu* Linder, 1983) and areas of narrow endemism (where several narrow endemic taxa of the same EVD coincide, =centres of local endemism *sensu* White, 1993). Hence these ZUs represent OGUs with more natural boundaries, also overcoming the issues of data incompleteness and uneven sampling efforts at finer scales, which resulted in virtually no discontinuous clusters in our analyses.

Endemics vs. entire faunas

Phenetic cluster analyses in most biogeographical studies have used incidence matrices for all described taxa within a higher taxonomic group in a given area (e.g. all species in an order in Procheş 2005; all species in a genus in Ramdhani *et al*., 2008). Only the species endemic to south-eastern Africa (*s.l.*) were included in the present study (*cf*. de Klerk *et al.*, 2002), (a) because these are of particular relevance to conservation in general and to the biodiversity hotspot approach in particular, and (b) to minimise any confounding effects regionally and/or continentally widespread species could have had on the identification of finer patterns within the sub-regional context. Inclusion of more widespread species in our analysis was observed to blur fine-scale patterns (data not presented here; see White 1965; de Klerk *et al.* 2002), as they inhabit most, if not all the OGUs within the study area. Thus, relatively widespread species that show evidence of relationships between OGUs have a profound influence on a cluster analysis (Alexander *et al.*, 2004). By excluding them, we have increased the possibility of identifying true evolutionary trends along the main geographic gradients in the region.

On the centres of endemism

We believe a note on the identification of COEs is in order. COEs should not be confused with the Areas of Endemism (AOEs), defined as "*areas delimited by the congruent distribution of at least two species of restricted range*" (Nelson and Platnick, 1981: p 468; also see Harold & Mooi 1994; Hausdorf, 2002). AOEs are often used as geographical templates (units) in testing hypotheses in historical biogeography (Kreft & Jetz, 2010). Instead, COEs are areas where endemic species concentrate, usually having more endemics in comparison to the surrounding areas and often termed as "hotspots" (Williams *et al.*, 1996; Linder, 2001; Crisp *et al.*, 2001; Jetz *et al.*, 2004). They are units of concern for conservation biogeography (Whittaker *et al.*, 2005), i.e. biogeographically delimited areas of conservation concern (e.g. Stattersfield *et al.*, 1998). Our two-tier hierarchy of endemism centres (COEs and CONEs) is potentially important in the prioritisation of sites for conservation. COEs are essentially fulfilling the criteria to be AOEs, but not vice-versa. Hence, out of fourteen chorologically-defined narrow AOEs for vertebrates in Perera *et al.* (2011), eight are identified here as CONEs.

South-east African zoogeography and endemism patterns

Placing south-east African regionalisation in the global context

In order to fit our results in a broader picture, patterns derived here were compared to those derived at global (Procheş & Ramdhani, 2012; Holt *et al*., 2013), and continental (Linder *et al.*, 2012) scales, following the ICAN hierarchy of biogeographical units. Hence, biogeographical entities derived by the primary dichotomies in our dendrogram were equated to dominions i.e. south-east African dominion within the southern African subregion (= region in Linder *et al.*, 2012) of the Afrotropical region and the realm (cf. Procheş & Ramdhani, 2012 and Holt *et al*., 2013, respectively), followed by provinces, districts and assemblages.

Cross-taxon congruence

Despite the minor differences in regionalisations for separate vertebrate classes, possibly caused by macro-ecological features such as average body size and dispersal ability, the results suggest that a common zoogeographical regionalisation for south-eastern Africa is possible, albeit freshwater fish distributions, governed primarily by water regimes being the most different from the overall pattern. It is evident that the amphibians and reptiles with alike physiological (poikilothermy) and ecological (limited dispersal ability) traits govern the patterns, over and above birds and (larger) mammals, characterised by the opposite traits, by virtue of the mere numbers of endemics in the region.

The distribution of centres of endemism

The greater representation of COEs along and below the Great Escarpment presumably relates to greater habitat heterogeneity, including forest patches and other fire-free refugia (Hamilton, 1976; Samways, 1990; de Klerk *et al*., 2002), in an otherwise fire prone grassland matrix. These in turn are likely to have represented refugia through the Pleistocene, thus allowing the differentiation of lineages with limited dispersal abilities into new species (with the contraction and expansion of forests), most of which would have remained endemic to the areas where they appeared. The congruence of CONEs with forest distributions along the Indian Ocean costal belt and in the Afromontane areas indicates the refugial role of forests, facilitating the diversification of forest specialists (e.g. *Bradypodion* species; Tolley *et al.*, 2008). On the other hand, forest specialists in the southern Cape are most likely recent colonisers, since forest patches in the Knysna-Tsitsikamma area are result of post-glacial expansion, and showing Afromontane affinities (Geldenhuys, 1989). This would explain the similarity between the endemic vertebrate fauna of the Cape forests and our study region, resulting in the incorporation of the Knysna unit as an extension to the GMPA region. The Knysna and Maputaland units, representing COEs (as they diverge early from the SEAD cluster) but containing no CONEs is an artefact of our OGU delimitation. The Knysna ZU was identified by Perera *et al.*, (2011) as a transitional extension of the GMPA region of endemism towards the CFR and treated as a single unit due to the lack of Knysna endemics in their study, although the unit actually contains a few local centres of floristic endemism (Goldblatt & Manning, 2000; van Wyk and Smith, 2001). Similarly, the Maputaland unit, even with fairly homogeneous vegetation, could possibly have subunits defined by local endemics, especially in the Lebombo Mountains and coastal sand forest areas.

Many of the COEs described here for vertebrates correspond to the centres of floristic endemism of van Wyk and Smith (2001). However, others are novel (e.g. Natal-Pondoland Centre instead of a narrow Pondoland Centre) or differently delimited (e.g. Mpumalanga Escarpment Centre harbouring three centres of floristic endemism - Wolkberg, Barberton and Sekhukhuneland, and the Knysna Centre harboring two - Little Karoo and the Worcester-Robertson Karoo). This may genuinely be a case of differences between plant and animal endemism, but more likely relates to the history of floristic exploration, which has known phases of explosive enthusiasm as relevant to specific areas (David Styles, *pers. comm.*). Hence, the identification of the Natal component of the Natal-Pondoland Centre of vertebrate endemism warrants a re-investigation of the area for its floristic endemism (see Perera *et al.*, 2011)

The GMPA region of vertebrate endemism from qualitative to numerical

The numerically recovered GMPA region leaves out the northern ZUs of tropical affinities from its qualitative demarcation. Nevertheless, this leaves a region spanning a substantial climatic gradient from subtropical to temperate, and an altitudinal gradient from over 3000m a.s.l. in the south-eastern

Great Escarpment to the coastal belt. It also confirms faunal extensions towards the CFR (Knysna) and the northern and southern isolates of the Great Escarpment (Waterberg and Sneeuberg mountain ranges, respectively). The removal of northern units supports the combined analysis of all terrestrial vertebrates and plants for continental Africa by Linder *et al.* (2012) where those units, together with the northern sections of Maputaland are clustered with the Zambesian Region (a broad tropical East African unit). The numerically delimitated GMPA region of vertebrate endemsim is 59% larger than the MPA hotspot, but harbouring a staggering 168% higher vertebrate endemism (166 species dominated by herptiles; 88 reptiles, 32 amphibians, 18 birds, 16 freshwater fish and 12 mammals; Appendix S1) as compared to the hotspot (62 species in total). When the Knysna endemics are removed from this list (as this transitional extension of the GMPA forms the eastern section of the CFR hotspot) it leaves 143 endemic species (see Appendix S1), which is similar to that of qualitative delimitation of the region, albeit with lesser area in the numerical GMPA. The new delimitation can be further supported with floristic evidence for a similar region (Cowling and Hilton-Taylor, 1997; see Perera *et al.*, 2011 for more details), and by a cluster incorporating the Maputaland-Pondoland region and the Drakensberg Alpine centre for the genus *Kniphofia* (Ramdhani *et al.*, 2008).

The GMPA region of endemism may not fulfil the habitat transformation criterion to be considered as a revised boundary for the MPA hotspot, but, essentially, it includes areas of high conservation priority that are missed by the current demarcation of the hotspot. Assessing the land use changes to see whether the GMPA region meets the threat criteria of biodiversity hotspot identification (i.e. >70% of primary vegetation been transformed; Myers *et al.*, 2000) is out of the scope of this study. But we believe that, depending on the degree of grazing pressure considered as a transformation of pristine vegetation (*cf.* Succulent Karoo Hotspot), there is a good chance that the entire GMPA region of endemism may meet this criterion (see map of transformed land in Botts *et al.*, 2012), and this would be an interesting point for future studies relevant to global conservation planning.

CONCLUSIONS

The GMPA region of vertebrate endemism is numerically confirmed with nineteen ZUs, and three extensions comprising an array of both broad and narrow centres of endemism, possibly influenced by the distribution of forests and the habitat heterogeneity along the Indian Ocean coastal belt and the south-eastern Great Escarpment. This region of vertebrate endemism is further validated as a legitimate zoogeographical entity by its identification as a zoogeographic province upon cluster analysis. Patterns of endemism mapped for the SEAD also illustrate high vertebrate endemicity within the GMPA region. The zoogeographical regionalization proposed here for south-eastern Africa with centres of endemism for vertebrates are intended to serve a purpose in both theoretical and conservation biogeography, until a more comprehensive multi-taxon regionalization is available involving distributional data for all species at a finer geographic grain.

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Appendix S1

Vertebrate species endemic to south-eastern Africa and to the numerically-defined greater Maputaland-Pondoland-Albany (GMPA) region of vertebrate endemism

Distribution data for the following 300 vertebrate species (south-east African endemics *sensu lato*) were selected for the numerical cluster analysis, while only the 188 species strictly endemic within the south-east African dominion (south-east African endemics *sensu stricto*; bold letters) were used for the mapping of endemism patterns.

Family	Species	Common name	GMPA Endemic Species	
			GMPA incl. all extensions	Excl. Knysna extension endemics
Pisces	*Amphilius natalensis*	Natal Mountain Catfish		
Pisces	***Barbus amatolicus***	Amatola Barb	√	√
Pisces	*Barbus anoplus*	Chubbyhead Barb		
Pisces	***Barbus brevipinnis***	Shortfin Barb	√	√
Pisces	***Barbus gurneyi***	Redtail Barb	√	√
Pisces	***Barbus motebensis***	Marico Barb		
Pisces	***Barbus pallidus***	Goldie Barb		
Pisces	***Barbus treurensis***	Treur River Barb	√	√
Pisces	***Barbus trevelyani***	Border Barb	√	√
Pisces	*Chetia brevis*	Orange-fringed Largemouth		
Pisces	*Chetia flaviventris*	Canary Kurper		
Pisces	*Chiloglanis anoterus*	Pennant-tailed Suckermouth		
Pisces	***Chiloglanis bifurcus***	Incomati Suckermouth	√	√
Pisces	*Chiloglanis emarginatus*	Phongolo Suckermouth		
Pisces	*Chiloglanis paratus*	Sawfin Suckermouth		
Pisces	*Chiloglanis swierstrai*	Lowveld Suckermouth		
Pisces	*Gilchristella aestuaria*	Estuarine Round-Herring		
Pisces	***Hypseleotris dayi***	Golden Sleeper	√	√
Pisces	*Labeo rosae*	Rednose Labeo		
Pisces	***Labeo rubromaculatus***	Tugela Labeo	√	√
Pisces	***Labeobarbus natalensis***	Scaly	√	√
Pisces	***Labeobarbus polylepis***	Smallscale Yellowfish		
Pisces	***Myxus capensis***	Freshwater Mullet	√	√
Pisces	***Pseudobarbus afer***	Eastern Cape Redfin	√	√
Pisces	***Pseudobarbus quathlambae***	Drakensberg Minnow	√	√
Pisces	***Pseudobarbus tenuis***	Slender Redfin	√	
Pisces	*Redigobius dewaali*	Checked Goby		
Pisces	***Sandelia bainsii***	Eastern Cape Rocky	√	√
Pisces	*Serranochromis meridianus*	Lowveld Largemouth		
Pisces	***Silhouettea sibayi***	Sibayi Goby	√	√
Pisces	***Varicorhinus nelspruitensis***	Incomati Chiselmouth	√	√
Amphibia	*Afrixalus aureus*	Golden Leaf-folding (Dwarf Reed)		

		Frog		
Amphibia	***Afrixalus knysnae***	Knysna Leaf-folding Frog	√	
Amphibia	***Afrixalus spinifrons***	Natal Leaf-folding (Banana) Frog	√	√
Amphibia	***Amietia dracomontana***	Drakensberg River Frog	√	√
Amphibia	*Amietia fuscigula*	Cape River Frog		
Amphibia	***Amietia umbraculata***	Maluti River Frog	√	√
Amphibia	***Amietia vertebralis***	Phofung River Frog	√	√
Amphibia	***Amietophrynus pardalis***	Eastern Leopard Toad	√	√
Amphibia	*Amietophrynus rangeri*	Raucous (Ranger's) Toad		
Amphibia	***Anhydrophryne hewitti***	Natal Chirping (Hewitt's Moss) Frog	√	√
Amphibia	***Anhydrophryne ngongoniensis***	Mistbelt Chirping (Ngoni Moss) Frog	√	√
Amphibia	***Anhydrophryne rattrayi***	Hogsback Chirping Frog	√	√
Amphibia	***Arthroleptis wahlbergi***	Bush Squeaker	√	√
Amphibia	***Breviceps bagginsi***	Bilbo's Rain Frog	√	√
Amphibia	***Breviceps fuscus***	Plain Rain Frog	√	
Amphibia	***Breviceps sopranus***	Whistling Rain Frog	√	√
Amphibia	***Breviceps sylvestirs***	Northern Forest Rain Frog	√	√
Amphibia	***Breviceps verrucosus***	Plaintive Rain Frog	√	√
Amphibia	***Cacosternum nanum***	Bronze Caco	√	√
Amphibia	***Cacosternum parvum***	Mountain Caco (Small Dainty Frog)	√	√
Amphibia	***Cacosternum poyntoni***	Poynton's Caco	√	√
Amphibia	***Cacosternum*** **sp. "a"**	Rhythmic Caco	√	√
Amphibia	***Cacosternum*** **sp. "b"**	KwaZulu Caco	√	√
Amphibia	***Cacosternum striatum***	Striped Caco	√	√
Amphibia	***Hadromophryne natalensis***	Natal Cascade (Ghost) Frog	√	√
Amphibia	***Heleophryne hewitti***	Hewitt's Ghost Frog	√	
Amphibia	***Heleophryne regis***	Southern Ghost Frog	√	
Amphibia	***Hemisus guttatus***	Spotted Shovel-nosed Frog (Snout-burrower)	√	√
Amphibia	***Hyperolius pickersgilli***	Pickersgill's Reed Frog	√	√
Amphibia	***Hyperolius semidiscus***	Yellow-striped Reed Frog	√	√
Amphibia	***Leptopelis natalensis***	Natal Tree Frog	√	√
Amphibia	***Leptopelis xenodactylus***	Long-toed Tree Frog	√	√
Amphibia	***Natalobatrachus bonebergi***	Kloof Frog	√	√
Amphibia	*Poyntonophrynus vertebralis*	Southern Pygmy Toad		
Amphibia	***Semnodactylus wealii***	Rattling (Weale's Running) Frog		
Amphibia	***Strongylopus fasciatus***	Striped Stream Frog		
Amphibia	*Strongylopus grayii*	Clicking (Gray's) Stream Frog		
Amphibia	***Strongylopus wageri***	Plain (Wager's) Stream Frog	√	√
Amphibia	*Tomopterna natalensis*	Natal Sand Frog		
Amphibia	***Vandijkophrynus amatolicus***	Amatola Toad	√	√
Reptilia	***Acontias breviceps***	Short-headed Legless Skink	√	√
Reptilia	*Acontias gracilicauda*	Thin-tailed Legless Skink		
Reptilia	*Acontias plumbeus*	Giant Legless Skink		
Reptilia	***Acontias poecilus***	Variable Legless Skink	√	√
Reptilia	***Acontophiops lineatus***	Woodbush Legless Skink	√	√

Reptilia	***Afroedura amatolica***	Amatola Flat gecko	√	√
Reptilia	***Afroedura halli***	Hall's Flat gecko	√	√
Reptilia	*Afroedura karroica*	Karoo Flat Gecko		
Reptilia	*Afroedura langi*	Lowveld flat gecko		
Reptilia	***Afroedura major***	Giant Swazi flat gecko	√	√
Reptilia	***Afroedura marleyi***	Marley's flat gecko	√	√
Reptilia	***Afroedura multiporis***	Woodbush flat gecko	√	√
Reptilia	***Afroedura nivaria***	Mountain flat gecko	√	√
Reptilia	***Afroedura pondolia***	Pondo Flat gecko	√	√
Reptilia	***Afroedura* sp. "granitica"**		√	√
Reptilia	***Afroedura* sp. "kouga"**		√	
Reptilia	***Afroedura* sp. "lebomboensis"**		√	√
Reptilia	***Afroedura* sp. "leoleonsis"**		√	√
Reptilia	***Afroedura* sp. "mariepi"**		√	√
Reptilia	*Afroedura* sp. "pienaari"			
Reptilia	***Afroedura* sp. "pongolae"**		√	√
Reptilia	***Afroedura* sp. "rondavelica"**		√	√
Reptilia	***Afroedura* sp. "rupestris"**		√	√
Reptilia	***Afroedura* sp. "soutpansbergensis"**		√	√
Reptilia	***Afroedura* sp. "waterbergensis"**		√	√
Reptilia	***Afroedura tembulica***	Tembo Flat Gecko	√	√
Reptilia	*Afrotyphlops bibronii*	Bibron's Worm Snake		
Reptilia	*Afrotyphlops fornasinii*	Fornasini's Worm Snake		
Reptilia	***Amblyodipsas concolor***	Natal Purple-glossed Snake	√	√
Reptilia	*Amblyodipsas microphthalma*	Eyeless Purple-glossed Snake		
Reptilia	*Amplorhinus multimaculatus*	Many-spotted Snake		
Reptilia	*Aparallactus nigriceps*	Mozambique Centipede-eater		
Reptilia	***Australolacerta rupicola***	Soutpansberg Rock Lizard	√	√
Reptilia	***Bitis albanica***	Albany Adder	√	√
Reptilia	*Bitis atropos*	Berg Adder		
Reptilia	***Bitis inornata***	Plain Mountain Adder	√	√
Reptilia	***Bradypodion caeruleogula***	uMlalazi dwarf chameleon	√	√
Reptilia	***Bradypodion caffer***	Pondo (Transkei) dwarf chameleon	√	√
Reptilia	***Bradypodion damaranum***	Knysna Dwarf Chameleon	√	
Reptilia	***Bradypodion dracomontanum***	Drakensberg Dwarf Chameleon	√	√
Reptilia	***Bradypodion kentanicum***	Kentani Dwarf Chameleon	√	√
Reptilia	***Bradypodion melanocephalum***	KwaZulu (Black-headed) Dwarf Chameleon	√	√
Reptilia	***Bradypodion nemorale***	Qudeni (Zululand) Dwarf Chameleon	√	√
Reptilia	***Bradypodion ngomeense***	Ngome Dwarf Chameleon	√	√
Reptilia	***Bradypodion setaroi***	Setaro's Dwarf Chameleon	√	√
Reptilia	***Bradypodion* sp. "barbatulum"**	Beardless Dwarf Chameleon	√	
Reptilia	***Bradypodion* sp. "baviaans"**	Baviaanskloof Dwarf Chameleon	√	
Reptilia	***Bradypodion* sp. "emerald"**	Emerald Dwarf Chameleon	√	√

Reptilia	***Bradypodion* sp. "groendal"**	Groendal Dwarf Chameleon	√	
Reptilia	***Bradypodion* sp. "grootvadersbosch"**		√	
Reptilia	***Bradypodion* sp. "jagersbos"**		√	
Reptilia	***Bradypodion taeniabronchum***	Smith's Dwarf Chameleon	√	
Reptilia	***Bradypodion thamnobates***	Natal Midlands Dwarf Chameleon	√	√
Reptilia	***Bradypodion transvaalense***	Transvaal (Wolkberg) Dwarf Chameleon	√	√
Reptilia	*Bradypodion ventrale*	Eastern Cape (Southern) Dwarf Chameleon		
Reptilia	***Chamaesaura aenea***	Coppery / Transvaal Grass / Snake Lizard		
Reptilia	*Chirindia langi*	Lang's Worm Lizard		
Reptilia	***Cordylus breyeri***	Waterberg Girdled Lizard	√	√
Reptilia	*Cordylus cordylus*	Cape Girdled Lizard		
Reptilia	***Cordylus giganteus***	Giant Girdled Lizard		
Reptilia	***Cordylus tasmani***	Tasman's Girdled Lizard	√	√
Reptilia	*Cordylus vandami*	Van Dam's Girdled Lizard		
Reptilia	*Cordylus vittifer*	Transvaal Girdled Lizard		
Reptilia	*Cordylus warreni*	Warren's Girdled Lizard		
Reptilia	***Cryptactites peringueyi***	Salt Marsh (Peringuey's Leaf-toed) Gecko	√	
Reptilia	***Dasypeltis inornata***	Southern Brown Egg Eater	√	√
Reptilia	*Duberria variegata*	Variegated Slug-eater		
Reptilia	***Goggia essexi***	Essex's Pygmy (Dwarf Leaf-toed) Gecko	√	√
Reptilia	***Goggia hewitti***	Hewitt's Pygmy (Dwarf Leaf-toed) Gecko	√	
Reptilia	*Hemachatus haemachatus*	Rinkhals		
Reptilia	***Homopholis mulleri***	Muller's Velvet Gecko	√	√
Reptilia	*Homopus femoralis*	Greater Padloper		
Reptilia	***Homoroselaps dorsalis***	Striped Harlequin Snake		
Reptilia	*Homoroselaps lacteus*	Spotted Harlequin Snake		
Reptilia	***Inyoka swazicus***	Swazi Rock Snake	√	√
Reptilia	***Kinixys lobatsiana***	Lobatse Hinged Tortoise		
Reptilia	***Kinixys natalensis***	Natal Hinged Tortoise	√	√
Reptilia	*Lamprophis aurora*	Aurora House Snake		
Reptilia	***Lamprophis fuscus***	Yellow-bellied House Snake	√	√
Reptilia	*Lamprophis inornatus*	Olive House Snake		
Reptilia	*Lamprophis guttatus*	Spotted House Snake		
Reptilia	*Leptotyphlops distanti*	Distant's Thread Snake		
Reptilia	***Leptotyphlops jacobseni***	Jacobsen's Thread Snake		
Reptilia	*Leptotyphlops nigricans*	Black Thread Snake (Schlegel's Blind Snake)		
Reptilia	***Leptotyphlops sylvicolus***	Forest Thread Snake	√	√
Reptilia	***Leptotyphlops telloi***	Tello's Thread Snake	√	√
Reptilia	***Lycodonomorphus laevissimus***	Dusky-bellied Water Snake	√	√
Reptilia	*Lycodonomorphus rufulus*	Common Brown (Lichtenstein's) Water Snake		
Reptilia	***Lycophidion pygmaeum***	Pygmy Wolf Snake	√	√
Reptilia	*Lycophidion semiannule*	Bazaruto Wolf Snake		

Reptilia	***Lygodactylus graniticolus***	Granite Dwarf Gecko	√	√
Reptilia	***Lygodactylus methueni***	Methuen's Dwarf Gecko	√	√
Reptilia	***Lygodactylus nigropunctatus***	Black-spotted Dwarf Gecko		
Reptilia	***Lygodactylus ocellatus***	Spotted Dwarf Gecko		
Reptilia	***Lygodactylus waterbergensis***	Waterberg Dwarf Gecko	√	√
Reptilia	***Macrelaps microlepidotus***	Natal Black Snake	√	√
Reptilia	*Monopeltis capensis*	Cape (spade-snouted) worm lizard		
Reptilia	*Monopeltis decosteri*	De Coster's (spade-snouted) worm lizard		
Reptilia	***Montaspis gilvomaculata***	Cream-spotted Mountain Sanke	√	√
Reptilia	***Ninurta coeruleopunctatus***	Blue-spotted Girdled Lizard	√	
Reptilia	*Nucras caesicaudata*	Blue-tailed Sandveld Lizard		
Reptilia	***Nucras lalandii***	Delalande's Sandveld Lizard		
Reptilia	***Nucras taeniolata***	Striped Scrub Lizard (Albany Sandveld Lizard)	√	√
Reptilia	*Pachydactylus affinis*	Transvaal (Thick-toed) Gecko		
Reptilia	*Pachydactylus maculatus*	Spotted (Thick-toed) Gecko		
Reptilia	*Pachydactylus vansoni*	Van Son's (Thick-toed) Gecko		
Reptilia	*Pedioplanis burchelli*	Burchell's Sand Lizard		
Reptilia	*Philothamnus natalensis*	East Natal Green Snake		
Reptilia	***Platysaurus guttatus***	Dwarf Flat Lizard	√	√
Reptilia	***Platysaurus lebomboensis***	Lebombo Flat Lizard	√	√
Reptilia	***Platysaurus minor***	Waterberg Flat Lizard	√	√
Reptilia	***Platysaurus monotropis***	Organge-throated Flat Lizard	√	√
Reptilia	***Platysaurus orientalis***	Sekhukhune Flat Lizard	√	√
Reptilia	***Platysaurus relictus***	Soutpansberg Flat Lizard	√	√
Reptilia	*Prosymna janii*	Mozambique Shovel-snout		
Reptilia	*Psammophis crucifer*	Cross-marked (Crossed) Grass Snake (Racer)		
Reptilia	***Pseudocordylus langi***	Lang's Crag Lizard	√	√
Reptilia	***Pseudocordylus melanotus***	Common Crag Lizard		
Reptilia	*Pseudocordylus microlepidotus*	Cape Crag Lizard		
Reptilia	***Pseudocordylus spinosus***	Spiny Crag Lizard	√	√
Reptilia	***Pseudocordylus transvaalensis***	Northern Crag Lizard	√	√
Reptilia	***Scelotes anguineus***	Algoa Dwarf Burrowing Skink	√	√
Reptilia	***Scelotes arenicolus***	Zululand Dwarf Burrowing Skink	√	√
Reptilia	*Scelotes bidigittatus*	Lowveld Dwarf Burrowing Skink		
Reptilia	***Scelotes bourquini***	Bourquin's Dwarf Burrowing Skink	√	√
Reptilia	***Scelotes fitzsimonsi***	FitzSimons' Dwarf Burrowing Skink	√	√
Reptilia	***Scelotes guentheri***	Guenthers' Dwarf Burrowing Skink	√	√
Reptilia	***Scelotes inornatus***	Durban (Smith's) Dwarf Burrowing Skink	√	√
Reptilia	*Scelotes limpopoensis*	Limpopo Dwarf Burrowing Skink		
Reptilia	***Scelotes mirus***	Montane Dwarf Burrowing Skink	√	√
Reptilia	*Scelotes mossambicus*	Mozambique Dwarf Burrowing Skink		
Reptilia	***Scelotes vestigifer***	Coastal Dwarf Burrowing Skink	√	√
Reptilia	***Tetradactylus africanus***	Eastern Long-tailed Seps (African Whip Lizard)	√	√

Reptilia	***Tetradactylus breyeri***	Breyer's Long-tailed Seps	√	√
Reptilia	***Tetradactylus eastwoodae***	Eastwood's Long-tailed Seps	√	√
Reptilia	***Tetradactylus fitzsimonsi***	FitzSimon's Long-tailed Seps	√	
Reptilia	*Tetradactylus seps*	Short-legged Seps (Five-toed Whip Lizard)		
Reptilia	*Trachylepis depressa*	Eastern Coastal Skink (Mabuya)		
Reptilia	*Trachylepis homalocephala*	Red-sided Skink (Mabuya)		
Reptilia	***Trachylepis* sp. "transvaal"**			
Reptilia	***Tropidosaura cottrelli***	Cottrell's Mountain Lizard	√	√
Reptilia	***Tropidosaura essexi***	Essex's Mountain Lizard	√	√
Reptilia	***Tropidosaura gularis***	Cape Mountain Lizard	√	
Reptilia	*Tropidosaura montana*	Green-striped Mountain Lizard		
Reptilia	*Typhlosaurus aurantiacus*	Golden Blind Legless Skink		
Reptilia	*Xenocalamus lineatus*	Striped Quill-snouted Snake		
Reptilia	*Xenocalamus transvaalensis*	Speckeled (Transvaal) Quill-snouted Snake		
Reptilia	*Zygaspis vandami*	Van Dam's Dwarf (Round-headed) Worm Lizard		
Reptilia	*Zygaspis violacea*	Violet Dwarf (Round-headed) Worm Lizard		
Aves	***Anthus chloris***	Yellow-breasted Pipit	√	√
Aves	*Anthus crenatus*	African Rock Pipit		
Aves	***Anthus hoeschi***	Mountain Pipit	√	√
Aves	*Apalis ruddi*	Rudd's Apalis		
Aves	*Bradypterus barratti*	Barratt's Warbler	√	√
Aves	***Bradypterus sylvaticus***	Knysna Warbler	√	√
Aves	***Buteo trizonatus***	Forest Buzzard	√	√
Aves	*Camaroptera brachyura*	Green-backed Camaroptera		
Aves	***Campethera notata***	Knysna Woodpecker	√	√
Aves	*Cercotrichas signata*	Brown Scrub-Robin		
Aves	***Certhilauda brevirostris***	Agulhas Long-billed Lark	√	
Aves	*Certhilauda chuana*	Short-clawed Lark		
Aves	*Certhilauda semitorquata*	Eastern Long-billed Lark		
Aves	***Chaetops aurantius***	Drakensberg Rock-jumper	√	√
Aves	***Cinnyris afra***	Greater Double-collared Sunbird		
Aves	*Cinnyris neergaardi*	Neergaard's Sunbird		
Aves	*Cisticola galactotes*	Rufous-winged Cisticola		
Aves	***Coccopygia melanotis***	Swee Waxbill		
Aves	***Cossypha dichroa***	Chorister Robin-Chat	√	√
Aves	*Cossypha humeralis*	White-throated Robin-Chat		
Aves	*Crithagra citrinipecta*	Lemon-breasted Canary		
Aves	***Crithagra scotops***	Forest Canary	√	√
Aves	***Crithagra symonsi***	Drakensberg Siskin	√	√
Aves	*Eupodotis caerulescens*	Blue Korhaan		
Aves	*Geocolaptes olivaceus*	Ground Woodpecker		
Aves	***Geronticus calvus***	Southern Bald Ibis		
Aves	***Heteromirafra ruddi***	Rudd's Lark	√	√
Aves	*Hypargos margaritatus*	Pink-throated Twinspot		

Aves	*Laniarius ferrugineus*	Southern Boubou		
Aves	***Lioptilus nigricapillus***	Bush Blackcap	√	√
Aves	*Macronyx capensis*	Cape Longclaw		
Aves	***Mirafra cheniana***	Melodious Lark		
Aves	*Monticola explorator*	Sentinel Rock-Thrush		
Aves	*Monticola rupestris*	Cape Rock-Thrush		
Aves	***Oenanthe bifasciata***	Buff-streaked Chat	√	√
Aves	*Ploceus capensis*	Cape Weaver		
Aves	***Poicephalus robustus***	Cape Parrot	√	√
Aves	***Prinia hypoxantha***	Drakensberg Prinia	√	√
Aves	*Promerops gurneyi*	Gurney's Sugarbird		
Aves	*Scleroptila africanus*	Grey-winged Francolin		
Aves	*Serinus canicollis*	Cape Canary		
Aves	*Sigelus silens*	Fiscal Flycatcher		
Aves	*Sphenoeacus afer*	Cape Grassbird		
Aves	***Spizocorys fringillaris***	Botha's Lark		
Aves	*Spreo bicolor*	Pied Starling		
Aves	***Tauraco corythaix***	Knysna Turaco	√	√
Aves	*Tchagra tchagra*	Southern Tchagra		
Aves	*Telephorus olivaceus*	Olive Bush-Shrike		
Aves	*Turdus olivaceus*	Olive Thrush		
Aves	***Turnix hottentottus***	Hottentot Buttonquail	√	
Aves	*Zosterops virens*	Cape White-eye		
Mammalia	***Amblysomus corriae***	Fynbos Golden Mole	√	
Mammalia	***Amblysomus hottentotus***	Hottentot Golden Mole	√	√
Mammalia	***Amblysomus marleyi***	Marley's Golden Mole	√	√
Mammalia	***Amblysomus robustus***	Robust Golden Mole	√	√
Mammalia	***Amblysomus septentrionalis***	Highveld Golden Mole		
Mammalia	*Calcochloris obtusirostris*	Yellow Golden Mole		
Mammalia	***Chlorotalpa duthieae***	Duthie's Golden Mole	√	
Mammalia	*Chlorotalpa sclateri*	Sclater's Golden Mole		
Mammalia	***Chrysospalax trevelyani***	Giant golden mole	√	√
Mammalia	***Chrysospalax villosus***	Rough-haired Golden Mole		
Mammalia	*Connochaetes gnou*	Black wildebeest		
Mammalia	*Crocidura flavescens*	Greater Red Musk shrew		
Mammalia	*Damaliscus pygargus*	Blesbok / Bontebok		
Mammalia	*Elephantulus myurus*	Eastern Rock Elephant Shrew		
Mammalia	*Georychus capensis*	Cape Mole-rat		
Mammalia	*Grammomys cometes*	Mozambique Thicket Rat		
Mammalia	*Myosorex cafer*	Dark-footed Forest Shrew		
Mammalia	***Myosorex longicaudatus***	Long-tailed Forest Shrew	√	
Mammalia	***Myosorex sclateri***	Sclater's Forest Shrew	√	√
Mammalia	*Myosorex varius*	Forest Shrew		
Mammalia	*Mystromys albicaudatus*	White-tailed Mouse		
Mammalia	***Neamblysomus gunningi***	Gunning's Golden Mole	√	√
Mammalia	***Neamblysomus julianae***	Juliana's Golden Mole		

Mammalia	*Otomys irroratus*	Vlei Rat		
Mammalia	***Otomys laminatus***	Laminate Vlei Rat	√	√
Mammalia	***Otomys sloggetti***	Sloggett's Vlei Rat	√	√
Mammalia	*Pelea capreolus*	Grey Rhebok		
Mammalia	***Pronolagus crassicaudatus***	Natal Red Rock Rabbit	√	√
Mammalia	*Tragelaphus angasii*	Nyala		

Appendix S2

Zoogeographical units (ZUs) of south-eastern Africa (Perera *et al.*, 2011) included and excluded from a numerically-defined greater Maputaland-Pondoland-Albany (GMPA) region of vertebrate endemism. Light grey and white separates out broad columns indicating the spatial relationship of ZUs with qualitatively defined GMPA region, while darker grey indicates their inclusion in the numerical delimitation of the GMPA as the core region and extensions.

		ZUs of south-eastern Africa and their spatial relationship with the qualitatively defined GMPA region of vertebrate endemism																																				
		ZUs Included within the GMPA region																									ZUs Marginal to GMPA region									Outside		
		ACB	AKR	AWB	DBP	DEE	DKE	INH	KNY	NCB	NGO	NMD	NME	NMP	NMV	NNT	PND	SME	SMO	SMP	SMV	SNB	SPB	STR	TMD	WLB	**% congruence**	CBV	HUK	MLV	NDH	NMH	NMO	SDH	SMH	WTB	UKR	KBV	NBV
Occurrence (Inclusion:1/exclusion:0) of each ZU in the numerically derived region closest to the qualitative GMPA, in each cluster analysis	freshwater fish	1	0	1	0	0	1	0	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	1	1	0	**48**	0	0	0	0	0	0	0	0	0	0	0	0
	amphibians	1	0	1	1	1	1	0	1	1	1	1	1	0	0	1	1	1	0	1	1	0	0	1	1	0	**68**	0	0	0	0	0	0	0	0	0	0	0	0
	reptiles	1	0	1	1	1	1	0	1	1	1	1	1	0	1	0	1	1	0	0	1	1	1	1	1	1	**76**	1	0	0	0	0	0	0	0	1	0	0	0
	birds	1	0	1	0	1	1	0	1	1	1	1	1	0	0	1	1	1	0	0	1	0	1	1	1	1	**68**	0	0	0	0	0	0	0	0	0	0	0	0
	mammals	1	0	1	1	1	1	0	1	1	1	1	1	0	1	1	1	1	0	1	1	0	0	1	1	0	**72**	0	0	0	0	0	0	0	0	0	0	0	0
Overall occurrence of each ZU within the numerically derived regions closest to qualitative GMPA in single taxon analyses (consensus approach)		1.0	0.0	1.0	0.6	0.8	1.0	0.0	1.0	1.0	1.0	1.0	0.8	0.0	0.4	0.8	1.0	1.0	0.0	0.4	0.8	0.2	0.4	1.0	1.0	0.4		0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0
Occurrence of each ZU within the numerically derived regions closest to the qualitative GMPA in the analysis for all veretebrates (combined approcah)		1	0	1	1	1	1	0	1	1	1	1	1	0	1	1	1	1	0	1	1	1	1	1	1	1	**84**	0	0	0	0	0	0	0	0	1	0	0	0
Final consensus for inlcusion in the numerically derived GMPA region (%)		**100**	0	**100**	**80**	**90**	**100**	0	**100**	**100**	**100**	**100**	**90**	0	**70**	**90**	**100**	**100**	0	**70**	**90**	**60**	**70**	**100**	**100**	**70**		10	0	0	0	0	0	0	0	**60**	0	0	0
Numerical conformation of each ZU for the GMPA (C = core region, E = extensions, O = outside)		**C**	O	**C**	**C**	**C**	**C**	O	**C**	**C**	**C**	**C**	**C**	O	**C**	**C**	**C**	**C**	O	**C**	**C**	**E**	**C**	**C**	**C**	**C**		O	O	O	O	O	O	O	O	**E**	O	O	O
Same as above for macroecologically combined groups	herpetofauna	1	0	1	1	1	1	0	1	1	1	1	1	0	1	0	1	1	0	1	1	0	1	1	1	1	**76**	0	0	0	0	0	0	0	0	1	0	0	0
	non-volant vertebrates	1	0	1	1	1	1	0	1	1	1	1	0	0	0	1	1	1	0	0	0	1	0	1	1	1	**64**	0	0	0	0	0	0	0	0	0	0	0	0
	terrestrial vertebrates	1	0	1	1	1	1	0	1	1	1	1	1	0	1	1	1	1	0	1	1	1	1	1	1	1	**84**	0	0	0	0	0	0	0	0	0	0	0	0

Appendix S3

Range-restricted species endemic to centres of narrow endemism (CONEs) and centres of endemism (COEs) within the south-east African dominion, also showing nestedness of some CONEs within COEs (see text for details).

Centres of Narrow Endemism [a]		**Centres of Endemism** [b]	
Centre & endemicity	**List of narrow endemics**	**Centre & endemicity**	**List of centre endemics ***
Waterberg (6)	**Reptilia:** *Afroedura* sp. nov. "waterbergensis", *Cordylus breyeri, Lygodactylus graniticolus, Lygodactylus waterbergensis, Platysaurus guttatus, Platysaurus minor*	Not nested within a COE	
Soutpansberg (4)	**Reptilia:** *Australolacerta rupicola, Homopholis mulleri, Platysaurus monotropis, Platysaurus relictus*	Not nested within a COE	
Wolkberg (4)	**Reptilia:** *Acontophiops lineatus, Lygodactylus methueni, Tetradactylus eastwoodae*; **Mammalia:** *Neamblysomus gunningi*	Mpumalanga Escarpment (7)	<u>Characteristic Endemics</u> **Reptilia:** *Platysaurus orientalis* <u>Narrow Endemics</u> **Reptilia:** *Afroedura* sp. nov. "leoleonsis"; **Mammalia:** *Amblysomus robustus* + 4 other narrow endemics given for the Wolkberg CONE
Northern Middleveld (6)	**Pisces:** *Barbus brevipinnis, Chiloglanis bifurcus*; **Reptilia:** *Afroedura* sp. nov. "granitica", *A.* sp. nov. "mariepi", *A.* sp. nov. "rondavelica", *A.* sp. nov. "rupestris"	Not nested within a COE	
No centres of narrow endemism detected within (see discussion)		Maputaland (10)	<u>Characteristic Endemics</u> **Amphibia:** *Breviceps sopranus*; **Reptilia:** *Lycophidion pygmaeum* <u>Narrow Endemics</u> **Pisces:** *Silhouettea sibayi*; **Reptilia:** *Bradypodion setaroi, Leptotyphlops telloi, Platysaurus lebomboensis, Scelotes arenicolus, S. fitzsimonsi, S. vestigifer*; Ma**malia:** *Amblysomus marleyi*
Drakensberg-KwaZulu-Natal Escarpment (5)	**Reptilia:** *Afroedura nivaria, Bradypodion dracomontanum, B.* sp. nov. "emerald", *Montaspis gilvomaculata, Pseudocordylus langi*	Drakensberg (14)	<u>Characteristic Endemics</u> **Aves:** *Anthus hoeschi, Crithagra symonsi*; **Amphibia:** *Amietia umbraculata* <u>Narrow Endemics</u> **Pisces:** *Pseudobarbus quathlambae*; **Amphibia:** *Amietia dracomontana, A. vertebralis*; **Reptilia:** *Afroedura halli, Tropidosaura cottrelli, T. essexi* + 5 other narrow endemics given for the Drakensberg-KwaZulu-Natal Escarpment CONE

<table>
<tr><td>Natal Midlands (5)</td><td>Amphibia: Anhydrophryne ngongoniensis, Cacosternum poyntoni, C. sp. nov. "a"; Reptilia: Bradypodion thamnobates, Scelotes bourquini</td><td rowspan="3">Natal-Pondoland (18)</td><td rowspan="3"><u>Characteristic Endemics</u>
Amphibia: Natalobatrachus bonebergi; Reptilia: Afroedura pondolia
<u>Narrow Endemics</u>
Amphibia: Breviceps bagginsi; Reptilia: Bradypodion melanocephalum
+ 14 other narrow endemics given for the Natal Midlands, Natal Coastal Belt-Ngoye & Transkei Coastal Belt CONEs</td></tr>
<tr><td>Natal Coastal Belt-Ngoye (5)</td><td>Reptilia: Bradypodion caeruleogula, B. nemorale, B. ngomeense, Scelotes guentheri, S. inornatus</td></tr>
<tr><td>Transkei Coastal Belt (4)</td><td>Reptilia: Acontias poecilus, Bradypodion caffer, B. kentanicum; Mammalia: Chrysospalax trevelyani</td></tr>
<tr><td>Albany Coastal Belt (6)</td><td>Pisces: Sandelia bainsii; Reptilia: Bitis albanica, Cordylus tasmani, Goggia essexi, Nucras taeniolata, Scelotes anguineus</td><td rowspan="2">Albany (10)</td><td rowspan="2"><u>Characteristic Endemics</u>
None
<u>Narrow Endemics</u>
10 narrow endemics given for the Albany Coastal Belt & Amatola-Winterberg CONEs</td></tr>
<tr><td>Amatola-Winterberg (4)</td><td>Pisces: Barbus trevelyani; Amphibia: Vandijkophrynus amatolicus; Reptilia: Afroedura amatolica, Afroedura tembulica</td></tr>
<tr><td colspan="2">No centres of narrow endemism detected within (see discussion)</td><td>Knysna (23)</td><td><u>Characteristic Endemics</u>
Reptilia: Tropidosaura gularis; Mammalia: Amblysomus corriae
<u>Narrow Endemics</u>
Pisces: Pseudobarbus tenuis; Amphibia: Afrixalus knysnae, Breviceps fuscus, Heleophryne hewitti, H. regis; Reptilia: Afroedura sp. nov. "kouga", Bradypodion damaranum, B. sp. nov. "barbatulum", B. sp. nov. "baviaans", B. sp. nov. "groendal", B. sp. nov. "grootvadersbosch", B. sp. nov. "jagersbos", B. taeniabronchum, Cryptactites peringueyi, Goggia hewitti, Ninurta coeruleopunctatus, Tetradactylus fitzsimonsi; Aves: Certhilauda brevirostris, Turnix hottentottus; Mammalia: Chlorotalpa duthieae, Myosorex longicaudatus</td></tr>
</table>

[a] Finest, geographically contiguous clusters of narrow ZUs (<50 QDSs when combined) of the UPGMA dendrogram or terminal ZUs with at least 4 endemic species

[b] Assemblages identified through a phenon line form the UPGMA dendrogram with at least 7 endemic species

* Characteristic Endemics: Endemic species, occupying more than two-thirds of the ZUs in the centre (when there are more than two such), and distributed over a half of centre's range, Narrow Endemics: Endemic species with a much narrower range within the centre, Species endemic to CONEs nested within a given COE are also included in the total endemicity of the COE

CHAPTER 4

A hotspot for invertebrates too: numerical analyses on the distribution of selected lineages in south-eastern Africa

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ABSTRACT

Aim To numerically analyse the zoogeography of invertebrates in south-eastern Africa, focusing on evaluating the delimitation of the Maputaland-Pondoland-Albany biodiversity hotspot (MPA), and also proposing a first invertebrate-based regionalisation for south-eastern Africa. We also discuss patterns and centres of invertebrate endemism and thence assess the MPA as a priority region for invertebrate conservation.

Location South-eastern Africa.

Methods Species incidence matrices for selected invertebrate genera in predefined zoogeographical units were subjected to two types of numerical analyses: hierarchical clustering using the unweighted pair-group method with arithmetic averages (UPGMA), and Parsimony Analyses of Endemicity (PAE). The same matrices were also used in calculating measures of endemism. UPGMA and PAE dendrograms were used for the hierarchical regionalisation, and also to determine centres and areas of endemism (COEs and AOEs), respectively. Geographical patterns for measures of endemism were mapped.

Results An MPA-similar zoogeographical entity was numerically established, with 41% endemicity, largely confirming the zoogeographical validity of the hotspot delimitation for invertebrate distributions. The zoogeographical regionalisation based on invertebrate incidence data confirms a south-east African dominion (SEAD), congruent with that for the vertebrates, in which provinces, districts and assemblages are identified. Maps of AOEs, COEs and endemism measures support a greater Maputaland-Pondoland-Albany (GMPA) region of endemism for invertebrates with 46% endemicity (more similar to the one published for vertebrates, than to the MPA). Hence, the GMPA is confirmed as a region of overall animal endemism.

Main conclusions A common zoogeographical regionalisation is feasible for both invertebrates and vertebrates in south-eastern Africa. While MPA is generally valid as a zoogeographical entity for invertebrates, GMPA region of endemism clearly represents a more defined region for conservation prioritisation, not only for invertebrates, but also for animal endemism in general, with high cross-taxon congruence.

Key Words

biogeographical regionalisation, cluster analysis, conservation, endemism, invertebrates, Maputaland-Pondoland-Albany, Parsimony Analysis of Endemicity, southern Africa, zoogeography

INTRODUCTION

Invertebrates, constituting the vast majority of eukaryotic diversity on Earth (perhaps 95% of all species), have long been underrepresented in studies of biodiversity, biogeography and conservation, primarily because most of this diversity is yet to be documented (Wilson, 1987; New, 1993; Myers, *et al.*, 2000; Baillie *et al.*, 2004; Brooks *et al.*, 2006; Lamoreux *et al.*, 2006). One of the popular global schemes for conservation prioritization, the Biodiversity Hotspots (Myers *et al.*, 2000; Mittermeier *et al.*, 2004), is not an exception. Biodiversity hotspots are primarily delimited based on the floristic endemism, under the assumption of congruent distribution patterns for both vertebrate and invertebrate animals. Such congruence of diversity/endemism centres between plants and vertebrates with invertebrates has been observed to exist for some taxa at least partially (Morrone *et al.*, 1999; Pearson and Carroll, 1998; Mittermeier *et al.*, 2004), but this is not necessarily the case for all groups (van Jaarsveld *et al.* 1998) and at different scales (Reid 1998). Congruence at fine scales tends not to be as strong as in the case of regional/global scales (Pearson and Carroll, 1999). Hence, even if accepting floristic endemism-based priority sites as a pragmatic first step towards achieving conservation objectives, their congruence with invertebrate distributions needs to be tested at the earliest availability of adequate amounts of data with an acceptably finer spatial scale of analysis, in order to fine-tune local conservation efforts. By incorporating invertebrates, one can broaden substantially the taxonomic basis of conservation planning (Kremen *et al.*, 1993). Furthermore, an invertebrate focus in biogeographical analyses at finer scales would allow the identification of centres of narrow endemism, which might not be noticed in an analysis of the flora or vertebrate fauna at the same scale, owing to the lower vagility of many invertebrate groups. Nevertheless, only few global biodiversity hotspots are tested for their invertebrate diversity and endemism (e.g. Cape Floristic Region: Pryke & Samways, 2008; West African forests, the Eastern Arc of Africa and the Western Ghats & Sri Lanka: Meier & Dikow, 2004), and to date invertebrates are seldom used in setting conservation priorities (e.g. Sfenthourakis & Legakis, 2001).

The Maputaland-Pondoland-Albany biodiversity hotspot of south-eastern Africa harbours more than 1900 species of endemic higher plants (Steenkamp, *et al.*, 2004), and has recently been explored in terms of its vertebrate endemism, recognising a Greater Maputaland-Pondoland-Albany (GMPA) region of endemism with 166 species of endemic vertebrates (Perera *et al.*, 2011; Perera *et al.*, 2013). This recognition expanded the hotspot delimitation by 59% in terms of area, to include 168% more vertebrate endemics, indicating a higher animal endemicity in its adjacent areas. Among invertebrates of the MPA a high diversity and endemism has been noted for invertebrate groups such as velvet worms (Onychophora), dung beetles (Scarabaeidae: Scarabaeinae), butterflies (especially Lycaenidae) and earthworms of Microchaetidae (Steenkamp, *et al.*, 2004).

Although it is far from complete, the understanding of invertebrate diversity and distribution in southern Africa (at least for some groups, e.g. Meier & Dikow, 2004) is better than in many parts of the world. Nevertheless, invertebrate biogeographical patterns in the region are still not well documented, except for taxon-specific discussions existing in monographs for different taxa. Hence, the already available data on invertebrate distributions need to be analysed to illustrate the overall zoogeography of the region. Since an area in south-eastern Africa greater than the MPA, having markedly higher endemicity, has already been identified based on vertebrate distributions, it is sensible to test the delimitation of the hotspot in terms of invertebrate distributions in order to acquire a more accurate delimitation on the basis of animal endemism as a whole. The invertebrate zoogeography and conservation of the relevant area, especially with emphasis on forest dwelling invertebrates has been discussed to some extent (Brinck, 1957; Stuckenberg, 1962; Endrödy-Younga, 1989; Hamer *et al*., 1997; Kotze & Samways, 1999; Davis *et al*., 2001; Herbert & Kilburn, 2004; and Deschodt & Scholtz, 2008; mostly as taxon-specific accounts; also see Endrödy-Younga, 1988; and Foord *et al.*, 2011 for savanna preferring *Anomalipus* beetles and spiders, respectively; and Endrödy-Younga, 1978 for an intuitive regionalisation of southern Africa based on Coleoptera). But a comprehensive zoogeographical regionalization with a fair representation of different taxonomic groups of invertebrates still awaits better distribution data availability at a finer resolution. Although invertebrate distribution data for the area could still be too incomplete for a fine-grain of analysis (such as quarter- or even half-degree grid cells), data are fairly thorough at the scale of eco-geographical units at least for some lineages. By using such eco-geographical units for quantitative zoogeographical analyses for such lineages, a zoogeographical regionalisation can be achieved while (a) avoiding the caveats of incompleteness of distribution data at finer grain of analysis, and (b) not losing the natural boundaries of resulting zoogeographic entities, as would be the case if a coarse equal grain of analysis (e.g. 1-2° grid cells) were to be used. Given the above background, the present study aims to contribute to the understanding of invertebrate zoogeography and patterns of endemism in south-eastern Africa, applying quantitative and objective methods at the scale of pre-defined zoogeographical units. In doing so, we (a) evaluate the delimitation of the MPA, testing whether the hotspot as it is represents a valid zoogeographical entity and/or a region of endemism for invertebrates; (b) propose a preliminary zoogeographical regionalisation for invertebrates in south-eastern Africa; (c) map and discuss patterns and centres of invertebrate endemism in the region; and these findings are used to, (d) assess the importance of the MPA as a priority region for invertebrate conservation.

MATERIAL & METHODS

Study area & operational geographic units

The study area included southern Africa south-east of 22°S and 23°E and south-west of 31°S and 23°E (Fig. 1). This includes the MPA as well as the GMPA region of vertebrate endemism (Perera *et al*., 2011, 2013) and the south-east African dominion (SEAD; Perera *et al*., 2013), proposed initially based on endemic vertebrate distributions. Furthermore, the study area encompasses the entire Cape Floristic Region (CFR) biodiversity hotspot in order to clarify the western limits of the SEAD.

Operational Geographic Units (OGUs: Fig. 1) for our numerical analyses are delimited following the zoogeographical units of south-eastern Africa (Perera *et al*., 2011) redrawn according to Quarter-Degree Square (QDS) borders . OGUs for the western section of the study area not covered by Perera *et al*. (2011) were defined based on the boundaries of Cape Floristic Region and Succulent Karoo biodiversity hotspots (Myers *et al.*, 2000; Mittermeier *et al.*, 2004) and the vegetation units (Low and Rebelo, 1996; Mucina & Rutherford, 2006).

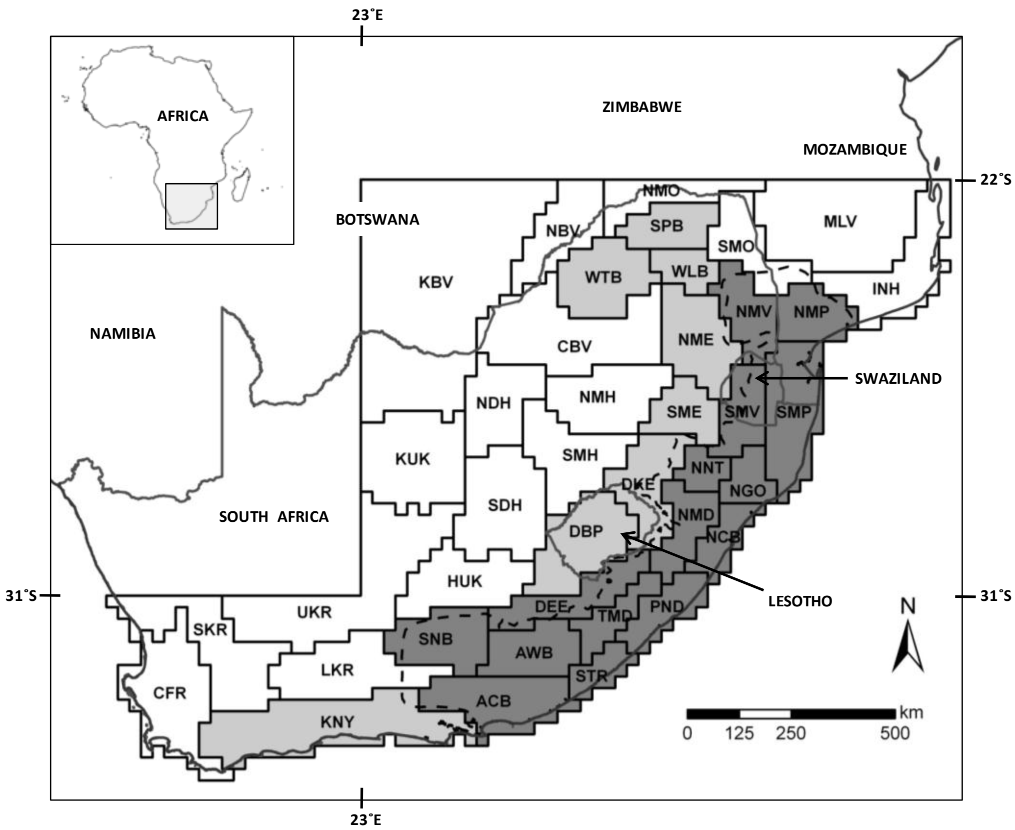

Figure 1. Study area, showing the Operational Geographic Units (OGUs) of south-eastern Africa used for the analyses. The Maputaland-Pondoland-Albany biodiversity hotspot (MPA) of Mittermeier *et al.* (2004) is demarcated by the dashed line and the OGUs considered here as MPA units are indicated in dark grey, while the areas added as parts of the greater Maputaland-Pondoland-Albany region of vertebrate endemism (Perera *et al.*, 2011) are in light grey. OGUs are labeled as: ACB – Albany Coastal Belt, AWB – Amatola-Winterberg, CBV – Central Bushveld, CFR – Cape Floristic Region except Knysna Transition Zone, DBP – Drakensberg Plateau, DEE – Drakensberg-Eastern Cape Escarpment, DKE – Drakensberg-KwaZulu-Natal Escarpment, HUK – Highveld-Upper Karoo, INH – Inhambane, KBV – Kalahari-Bushveld, KNY – Knysna Transition Zone (between the Cape Floristic Region and the Greater Maputaland-Pondoland-Albany Region), KUK – Kalahari-Upper Karoo, LKR – Lower Karoo, MLV – Mozambique Lowveld, NBV – Northern Bushveld, NCB – Natal Coastal Belt, NDH – Northern Dry Highveld, NGO – Ngoye, NMD – Natal Midlands, NME – Northern Mpumalanga Escarpment, NMH – Northern Mesic Highveld, NMO – Northern Mopane, NMP – Northern Maputaland, NMV – Northern Middleveld, NNT – Northern Natal, PND – Pondoland, SDH – Southern Dry Highveld, SKR – Succulent Karoo, SME – Southern Mpumalanga Escarpment, SMH - Southern Mesic Highveld, SMO – Southern Mopane, SMP – Southern Maputaland, SMV – Southern Middleveld, SNB – Sneeuberg, SPB – Soutpansberg, STR – Southern Transkei, TMD – Transkei Midlands, UKR – Upper Karoo, WLB – Wolkberg, WTB – Waterberg. See text for further details.

Selection of taxa

Several groups of invertebrate species (a) showing high endemicity within the study area, (b) having been collected fairly well and uniformly and with distribution records made available in monographs, and (c) monophyletic or presumed to be monophyletic, with fairly well resolved taxonomy, were selected for the present study. The selection included 78 genus-level lineages of invertebrates with 323 species, representing eight families (Appendix S1). The majority of species selected for the study (n= 234, 72.5%; 69 genera) were of Coleoptera (beetles), representing 3 families *viz.* Family Scarabaeidae: Cetoniinae chafer beetles of the tribe Cetoniini (fruit and flower chafers), represented by 57 genera in the study area (128 species; Holm & Marais, 1992), Melolonthinae chafer beetles of the genus *Rhabdopholis* (4 species; Harrison, 2004) and nine other small genera of forest dwelling Scarabaeinae dung beetles - *Aliuscanthoniola, Dwesasilvasedis, Endroedyolus, Nebulasilvius, Outenikwanus, Parvuhowdenius* and *Peckolus* (10 species; Deschodt & Scholtz, 2008), *Frankenbergerius* (7 species; Frolov & Scholtz, 2005), and *Gyronotus* (3 species; Davis *et al*., 2001); Family Tenebrionidae: darkling beetles of the genus *Anomalipus* (35 species; Endrödy-Younga, 1988); and the Family Curculionidae: weevils of the genus *Sciobius* (47 species; Schoeman, 1983). Seven genera of land snails and slugs including 75 species were also among the lineages selected, representing 4 families *viz.* Family Rhytididae: represented by four genera in the study area *Afrorhytida, Capitina, Natalina* (4, 2 and 6 species, respectively; Moussalli *et al*., 2009; Herbert & Moussalli, 2010) and *Nata* (6 species; Herbert & Kilburn, 2004; Herbert & Moussalli, 2012; D.G. Herbert, pers. obs.); Family Bulimulidae: genus *Prestonella* (2 species; Herbert, 2007; Herbert & Mitchell, 2009; D.G. Herbert, pers. obs.) and Family Chlamydephoridae: genus *Chlamydephorus* (9 species; Herbert & Kilburn, 2004; D.G. Herbert, pers. obs.) including the entire species assemblages of the respective families within the study area; and the Family Urocyclidae: representing all the species of its largest genus *Sheldonia sensu lato* (46 species; Herbert & Kilburn, 2004; Herbert & Moussalli, 2009; D.G. Herbert, pers. obs.). In addition to the above insects and molluscs, the study also included the Phylum Onychophora (velvet worms), with two genera and 14 species represented in the study area (Brinck, 1957; Hamer *et al*., 1997; Sherbon & Walker, 2004), as they are a very conspicuous and highly endemic group among invertebrates in the region. The taxonomy follows the references given for each taxon, while all the distribution records given in those references, and locality details of specimens at the KwaZulu-Natal Museum (for land snails only) were included in the study. Undescribed morpho-species authentically mentioned with distribution data in any of the above references, together with the expert opinion of DGH for land snails, were also included in the study.

Species incidence data matrix

All the species of each selected lineage that occur in southern Africa SE of 22°S and 23°E and SW of 31°S and 23°E are included, except for the those that marginally intrude the said study area with less than 10% of their distribution range within it. A species incidence matrix was prepared by scoring the presence/absence (1/0) of all selected species versus OGUs. When scoring the incidence for a given species, it was recorded as present for a given OGU, even with a single occupied QDS/record, as long as this QDS/record was not along the margin of the OGU. A species occupying only marginal QDSs for a given OGU was scored as present only if the species occupied more than 10% of the OGU. A species occupying even a single or a few marginal QDSs (with <10% coverage of the OGU) was considered present for the OGU concerned only when (a) the species was absent in the neighbouring OGU, (b) the relevant QDS was in the coastal margin of the OGU, or (c) if occupied QDSs were found along two opposite margins of the OGU.

Numerical biogeographical analyses

We used two commonly used methods in numerical biogeographical analyses, following both the phenetic approach (agglomerative hierarchical clustering using Jaccard's coefficient of similarity and the Unweighted Pair-Group Method using Arithmetic Averages clustering algorithm; hereafter UPGMA; Linder *et al.*, 2005) and the parsimony/cladistic approach (Parsimony Analysis of Endemicity; hereafter PAE; Rosen 1988; Morrone & Crisci, 1995). Both the UPGMA and PAE clustering have previously been used to determine relationships among biogeographical regions and to propose hierarchical regionalisations (Kreft & Jetz, 2010; Procheş & Ramdhani, 2012; Linder *et al*., 2012; Holt *et al*., 2013 for UPGMA, and da Silva & Oren, 1996; Morrone *et al.*, 1999; Rovito *et al.*, 2004 and Moreno Saiz *et al.*, 2012 for PAE). In addition PAE has often been used for the identification of areas of endemism (Morrone, 1994; Linder, 2001; da Silva *et al.*, 2004; Rovito *et al.*, 2004; Ramdhani *et al.*, 2008; Moreno Saiz *et al.*, 2012). Analyses using the above methods on different datasets (UPGMA and PAE for the combined database of all selected invertebrates, and UPGMA for taxonomic subsets and one macro-ecological subset of the database) were employed to (a) search for an MPA-similar zoogeographical entity and (b) propose a hierarchical zoogeographical regionalisation of the area. Nixon and Carpenter (1996) observed that simultaneous analysis of all available data maximizes cladistic parsimony, making the PAE more suitable for the analysis of the combined data set, than for the subsets thereof. Hence, while the combined database was analysed using both the UPGMA and PAE methods, its subsets are only presented as analysed using UPGMA clustering. The UPGMA analyses were conducted using FreeTree *ver*. 0.9.1.50 (Pavlicek *et al.*, 1999), and the resulting dendrograms were visualised using TreeView *ver*. 1.6.6. (Page, 1996). These were used to define hierarchical relationships between the clusters of OGUs represented by phenon lines at arbitrary levels of dissimilarity. The PAE analysis was conducted using PAUP* 4.0b10 (Swofford, 2002), where a full heuristic search was performed with tree bisection-reconnection (TBR) branch swapping, after the constant characters (species present or absent in all OGUs) and uninformative characters (autapomorphies; species found only in a single OGUs) were excluded. A strict consensus tree was constructed from all the most parsimonious trees.

Searching for an MPA similar zoogeographical entity

A zoogeographical entity similar in delimitation to the intuitively defined boundaries of the MPA was obtained through a consensus/maximum congruence approach (Linder *et al.*, 2012; Perera *et al*., 2013) using dendrograms resulting from; UPGMA and PAE analyses for the combined invertebrate incidence matrix and UPGMA clustering dendrograms for subsets of it. The geographically contiguous cluster in each dendrogram encompassing the highest number of MPA OGUs while those OGUs contribute to more than half of the cluster, are considered to be the most MPA-similar cluster in the relevant dendrogram. The consensus was achieved based on the overall occurrence of each OGU within that cluster in each dendrogram. Core units and extensions of the numerically-delimited MPA-similar zoogeographical entity for invertebrates were hence identified respectively with more than 60% and 40% occurrence in such clusters.

Zoogeographical regionalisation

Both UPGMA and PAE analyses on the combined incidence matrix for all selected invertebrates in south-eastern Africa (combined/total evidence approach; Linder *et al.*, 2012) were used to propose a preliminary zoogeographical regionalisation for the study area. While the UPGMA dendrogram was better at determining the hierarchical structure of zoogeographical entities, the PAE dendrogram provided largely congruent zoogeographical entities at the "Province" level, but not above in the hierarchy. Hence, zoogeographical provinces were delimited based on the consensus between the two analyses, whereas other levels of the hierarchy *i.e.*, dominions (above provinces), and districts and assemblages (below provinces; Perera *et al*., 2013; adapted from the International Code of Area Nomenclature; Ebach *et al.*, 2008), were determined based on phenon lines placed on the UPGMA dendrogram. In a few instances where provinces derived from the UPGMA dendrogram were not congruent with those from the PAE, phenon lines were relaxed in order to attain congruent province boundaries, thence establishing the final consensus (UPGMA-PAE) regionalisation (see Procheş & Ramdhani, 2012 for a similar approach in achieving cross-taxon congruence). OGUs that are not placed in contiguous clusters in the dendrogram were dissolved in to the adjoining and phenetically nearest assemblage.

Endemism Analyses

Areas and centres of endemism

Areas of endemism (AOEs: areas with congruent distribution of at least two species of restricted range; Nelson & Platnick, 1981; Linder, 2001) were identified through the PAE following Morrone (1994). Thus, geographically contiguous clusters of OGUs in the parsimony dendrogram with at least two endemic species are recognized as AOEs. Centres of endemism (areas where endemic species concentrate, usually having more endemics in comparison to the surrounding areas; Williams *et al.*, 1996; Linder, 2001; Crisp *et al.*, 2001; see Perera at al., 2013 for a discussion of Areas and Centres of Endemism) were derived from the UPGMA cluster dendrogram guided by phenon lines, for the south-east African dominion (SEAD; derived here from the same dendrogram; comprising 26 OGUs), where two levels of centres are presented based on increasing range size and species endemicity (see Perera *et al*., 2013): (a) centres of narrow endemism [CONE; the finest contiguous clusters of narrow OGUs (<50 QDSs when combined) or terminal OGUs, to have at least three endemic invertebrate species] and (b) centres of endemism (COE; biogeographical assemblages, that harbour at least seven endemic invertebrate species).

A hierarchical arrangement of geographic units of endemism according to range size is achieved by joining the results from both UPGMA and PAE dendrograms, where a hierarchy of CONEs, COEs, and AOEs is presented. Centre/area endemics are listed following Perera *et al*. (2013), adapted from the principles set by Williams *et al.*, 1996, de Klerk, *et al.*, 2002 and Procheş and Ramdhani 2012: characteristic endemics (i.e. endemic species, occupying more than two-thirds of OGUs in the centre/area, and distributed over a half of its range, hence whose range edges roughly coincide with the boundary of the centre/area) and narrow endemics (endemic species with a much narrower range within the centre/area).

Patterns of endemism

Geographical patterns of species richness within the whole study area and five spatially-based quantitative measures of endemism within the SEAD: (a) South-east African endemism, (b) narrow endemism, (c) weighted endemism (Crisp *et al.*, 2001), (d) weighted endemism corrected for area and (e). weighted endemism corrected for species richness (similar to corrected weighted endemism in Crisp *et al.*, 2001) were calculated for each OGU. See Perera *et al*. (2013) for definitions and the calculation of the first four measures. The weighted endemism corrected for area was found to be the most meaningful among the different variants of weighted endemism calculations for the non-equal-area OGUs used in the present study. Each of the calculated endemism parameters was mapped using ArcMap9.3 (ESRI, 2009) with a graduated grey scale for a maximum of five classes. Classes were determined with natural breaks calculated using Jenk's optimisation, so that the patterns inherent in the data are best revealed.

RESULTS

MPA as a valid zoogeographical entity for invertebrates

The dendrograms of the parsimony and phenetic cluster analyses attempting to recover the contiguous geographical cluster closest to the MPA are presented and geographical clusters are mapped in the Fig. 2. The results are summarized, and the consensus on a zoogeographical entity similar to MPA is given in the Appendix S2. An MPA-similar zoogeographical entity is recovered with an additional south-westerly extension including the Knysna OGU, but slightly narrower than the hotspot in the north (Fig. 2i), with 108 species of endemic invertebrates from selected groups (41% overall species endemicity; Appendix S1, Fig. 2k). Although the Knysna OGU is consistently recovered as a core unit of the MPA-similar zoogeographical entity, we consider it as an extension due to its transitional placement between the MPA and the Cape Floristic Region biodiversity hotspot.

The PAE dendrogram for the combined invertebrate matrix reveals the geographical cluster most congruent to the MPA (73% congruence; Fig. 2a), but with extensions towards the Drakensberg-KwaZulu-Natal Escarpment and the Knysna OGUs, beyond the hotspot as it is. In contrast, the phenetic cluster analysis on combined invertebrate matrix failed to recover a contiguous geographical cluster similar to the MPA. Instead, it recovers two paraphyletic geographical entities (out of which the highest congruence to MPA is only 33%) along the south-eastern seaboard extending inland to the Bushveld region in the north, which do however form a monophyletic and geographically contiguous cluster with the inclusion of the Highveld region (Fig. 2g). Nevertheless, UPGMA cluster dendrograms for individual taxonomic groups: velvet worms (53% congruence; Fig. 2b), land snails (67% congruence; Fig. 2c), and the weevil genus *Sciobius* (53% congruence; Fig. 2d) recover geographically contiguous clusters that are not very different from the MPA. The analysis on the darkling beetle genus *Anomalipus* results in two paraphyletic geographical entities along the south-eastern seaboard (out of which a smaller Maputaland-Natal cluster is the closest to the MPA, but with a congruence of only 33%; figure 2e), while the analysis on Scarabaeidae (selected dung beetle and chafer genera) results in a much larger zoogeographical entity combining the MPA with the Bushveld region (60 % congruence; Fig. 2f). Hence, the contributions from latter taxa are responsible for the combined invertebrate analysis not recovering a single contiguous MPA-similar zoogeographical entity. But interestingly, when an ecologically distinct subgroup of flightless, forest-dwelling dung beetles of the tribe Canthonini (13 species; Davis *et al*., 2001; Frolov & Scholtz, 2005) is combined with velvet worms and land snails, making a group of predominantly forest-dwelling invertebrates with low vagility, UPGMA cluster analysis, recovers a contiguous geographical cluster very similar to that resulting from the PAE (with 73% congruence to MPA; Fig. 2h), suggesting an important role played by forests in shaping the invertebrate endemism in the area.

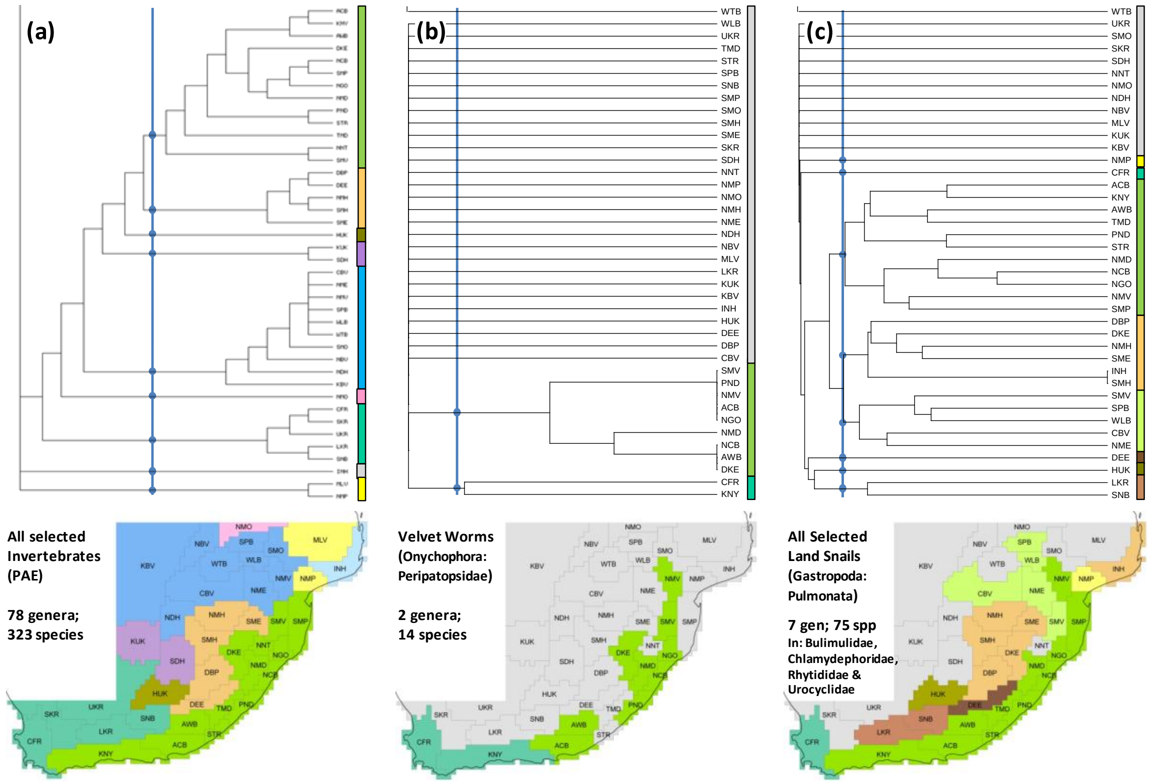

Figure 2 *Continued to the next page*

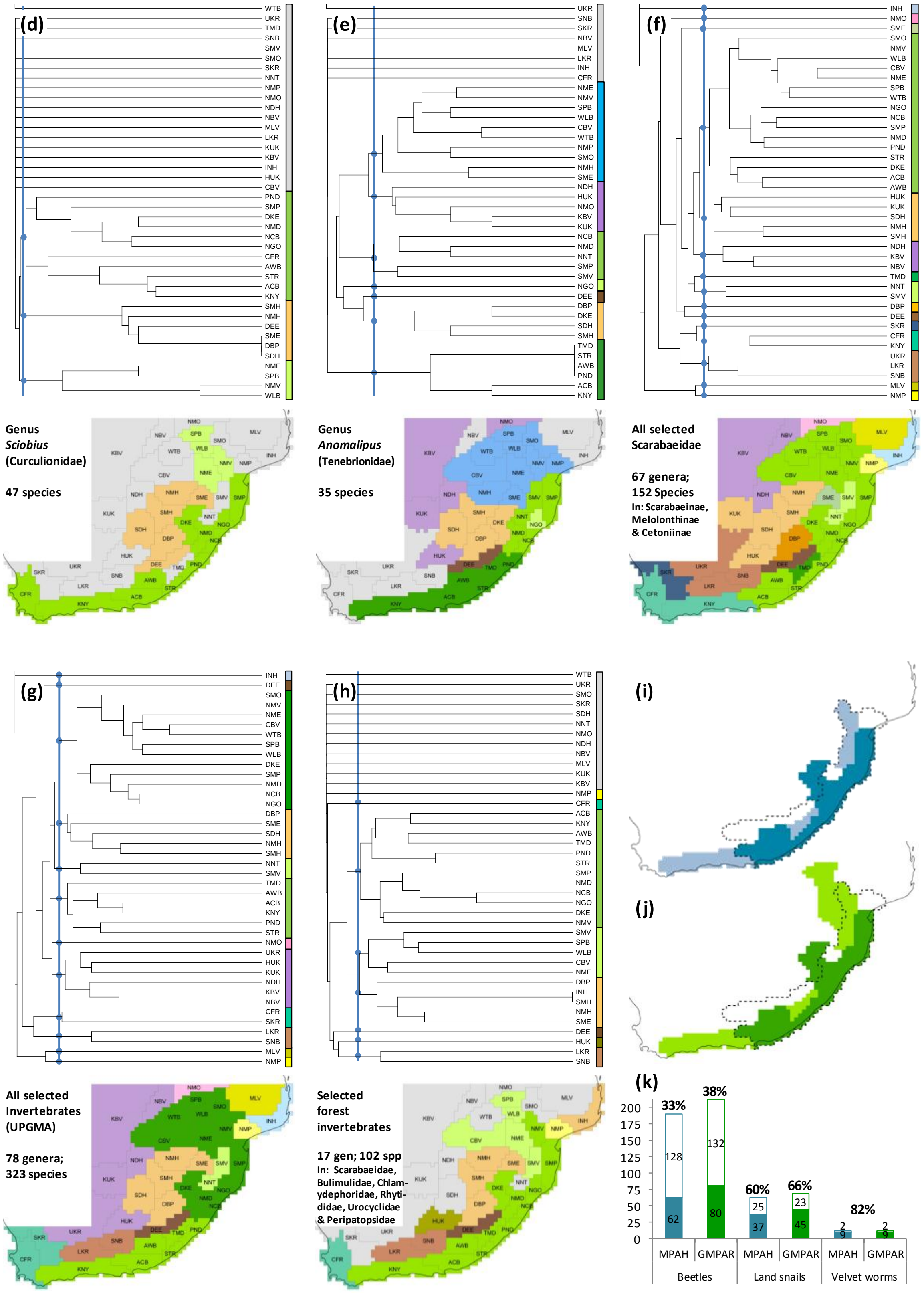

Figure 2 The resulting dendrograms and geographical clusters of numerical analyses on invertebrate species incidence matrices: (a) Parsimony analysis of endemicity for all selected invertebrate species (n=323), (b) Phenetic (UPGMA) cluster analysis (PCA) for velvet worm species (n=14), (c) PCA for land snail species (n=75), (d) PCA for weevil species in the genus *Sciobius* (n=47), (e) PCA for

darkling beetle species in the genus *Anomalipus* (n=35), (f) PCA for chafer and dung beetle species of 67 selected genera in the family Sacarabaeidae (n=152), (g) PCA for all selected invertebrate species (n=323), (h) PCA for predominantly forest-dwelling invertebrate species in 17 selected genera (n=102). (i) the numerical consensus for a zoogeographical entity similar to MPA (based on panels a-g; see Appendix S2 for calculation), and (j) proposed greater Maputaland-Pondoland-Albany (GMPA) region of invertebrate endemism (incorporating centres of narrow endemism in Fig. 6a to the zoogeographical entity similar to MPA; see text for details); darker and lighter shades indicates core area and the extensions, respectively, while the dotted line delimits the Maputaland-Pondoland-Albany biodiversity hotspot, based on zoogeographical unit borders. (k) The taxonomic composition of species assemblage in the zoogeographical entity similar to MPA (blue) and GMPA region of invertebrate endemism (green); filled and open bars indicate endemics and non-endemics, respectively, while the value above each bar denotes percentage endemism for the relevant taxa in the relevant area.

Invertebrate zoogeography of south-eastern Africa: A preliminary regionalization

A preliminary zoogeographical regionalization for invertebrates of south-eastern Africa is proposed for the first time. The drafting of the regionalisation based on phenetic and parsimony cluster dendrograms for the combined incidence matrix of the 78 selected invertebrate genera (323 species) is given in Fig. 3, where the regionalisation hierarchy is established using phenon lines on the UPGMA dendrogram (Fig. 3a), and largely congruent zoogeographical provinces identified from the PAE dendrogram (Fig. 3b,d). Phenon lines on the UPGMA dendrogram were relaxed as shown in Fig. 3a to attain congruent province boundaries in two instances, thence establishing the final consensus (UPGMA-PAE) regionalisation (Fig. 3c; Table 1). One of the early dichotomies of the UPGMA dendrogram separates a south-east African cluster recognised here as a zoogeographical dominion (South-east African dominion: SEAD; see Perera *et al*., 2013, for a justification of the “Dominion” rank) from a tropical East African cluster in the north-east, the arid Kalahari-Karoo cluster in west, and the Mediterranean-type Greater Cape cluster in the south-west. The SEAD identified here for invertebrates is almost identical to that derived for vertebrates; Perera *et al*. (2013), and supported by Endrödy-Younga’s (1978) the intuitive regionalisation of southern Africa based on Coleoptera (The Cape and Mountain Zones). The MPA-similar zoogeographical entity recognised above is comprised of two distinct provinces, the extended Maputaland-Natal and the extended Pondoland-Albany.

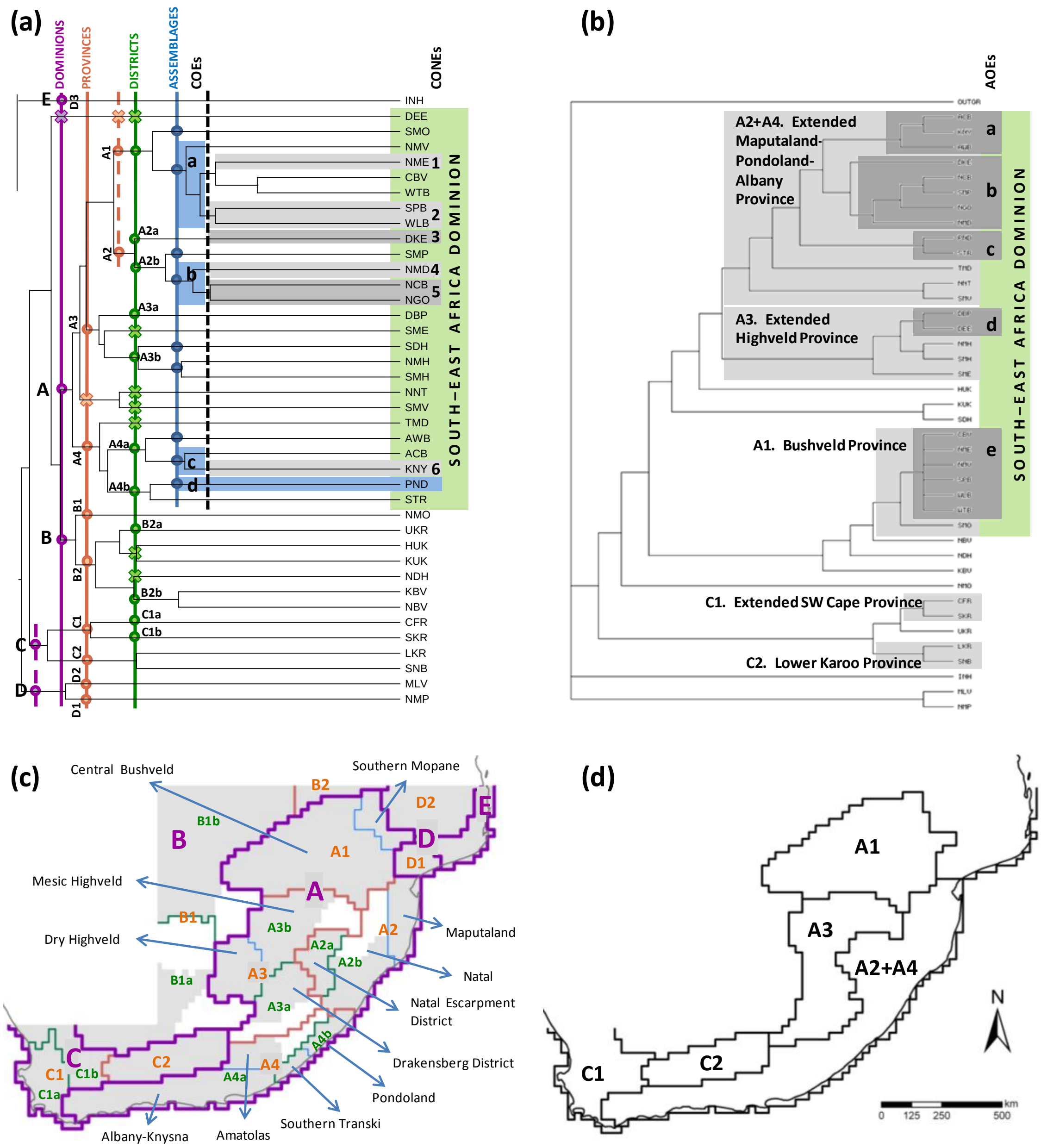

Figure 3 Drafting of the proposed zoogeographical regionalisation for south-eastern African invertebrates (a) The dendrogram of hierarchical relationships between operational geographic units (OGUs), based on the combined incidence matrix for selected invertebrate genera (n=78; 323 species), using Jaccard's coefficient of similarity and the UPGMA clustering algorithm. The hierarchy of zoogeographical entities are established along phenon lines given in different colours, except for two instances indicated by parallel dashed lines, where the dominion and province phenon lines were relaxed to attain congruent province boundaries with those derived from the PAE dendrogram given in panel (b) and mapped in panel (d). OGUs marked with × on the dendrogram show geographical scattering within the cluster and hence omitted from mapping. (c) The proposed zoogeographical regionalisation; dominions, provinces, districts and assemblages are defined by phenon lines on panel (a) given in respective colours and listed with codes in the Table 1. OGUs shown in white are not

found in contiguous clusters in the dendrogram, hence were dissolved in to the adjoining and phonetically nearest assemblage. All entities labeled on the map are assemblages unless mentioned as a district, when there are no assemblage sub divisions. Centres of endemism (COEs: a-d on panel a) and centres of narrow endemism (CONEs: 1-6 on panel a) as well as the areas of endemism (AOEs: a-e on panel b) within the south-east African dominion are defined from respective dendrograms: COEs & CONEs by phenon lines on the to the left of their labels and AOEs by identifying clusters of OGUs to harbor at least two endemic species. See Fig. 6 for their maps, Appendix S3 for their endemic species and text for methodology and definitions.

Table 1 Proposed hierarchical regionalisation for invertebrate zoogeography in south-eastern Africa (see Fig. 4c for the map and text for further details)

Dominions		Provinces		Districts		Assemblages
A	South-east African	A1	Bushveld			Southern Mopane
						Central Bushveld
		A2	Extended Maputaland-Natal	A2a	Natal Escarpment	
				A2b	Maputaland-Natal	Maputaland
						Natal
		A3	Highveld	A3a	Drakensberg	
				A3b	Highveld	Mesic Highveld
						Dry Highveld
		A4	Extended Pondoland-Albany	A4a	Extended Albany	Amatolas
						Albany-Knysna
				A4b	Extended Pondoland	Pondoland
						Southern Transkei
B	Karoo-Kalahari-Mopane	B1	Karoo-Kalahari	B1a	Upper Karoo	
				B1b	Kalahari	
		B2	Mopane			
C	Greater Cape	C1	Extended South-western Cape	C1a	South-western Cape	
				C1b	Succulent Karoo	
		C2	Lower Karoo			
D	Mozambique Lowveld	D1	Northern Maputaland			
		D2	Southern Mozambique Plains			
E	East African Coast					

Invertebrate endemism in south-eastern Africa

Invertebrate species richness for the entire study area and five spatial measures of endemism within the SEAD: (south-east African endemism, narrow endemism and weighted endemism with three variants) calculated for the combined species incidence matrix for all selected invertebrates are mapped in Fig. 4. Fig. 5 presents the geographical patterns for the species richness, and endemism measures (south-east African endemism, narrow endemism and weighted endemism corrected for area) for the individual taxonomic groups selected for the study.

A nested hierarchy of narrow to broad centres and then to the areas of endemism, respectively identified through phenetic and parsimony clustering approaches are illustrated in Fig. 6, while their characteristic and restricted endemics and the nested hierarchy are presented in the Appendix S3.

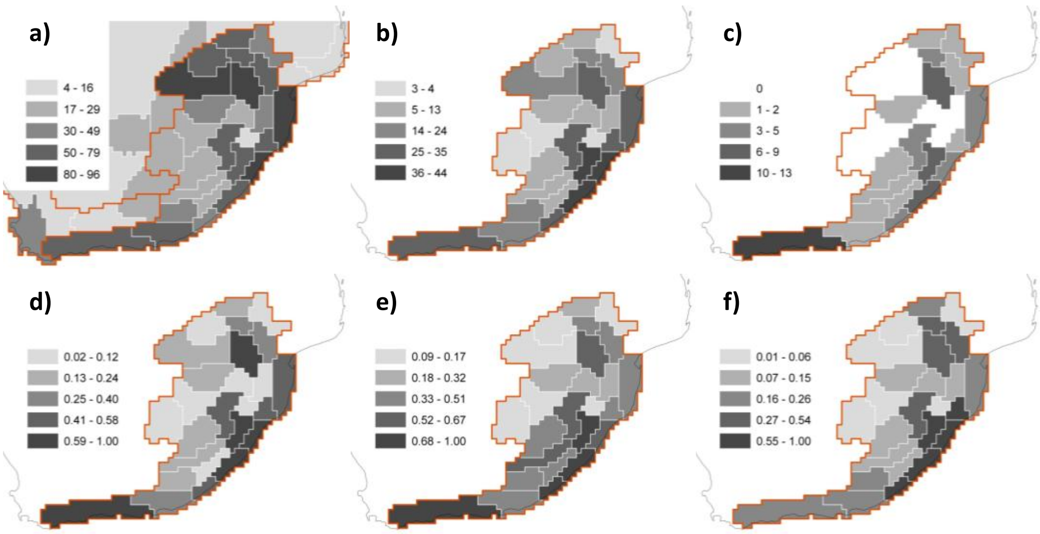

Figure 4 Patterns of species richness and various spatial measures of endemism calculated for the combined incidence matrix of all invertebrate species selected for the study: (a) species richness (SR); (b) South-east African endemism; (c) narrow endemism; (d) weighted endemism (WE); (e) WE corrected for SR; and (f) WE corrected for area. See text for details.

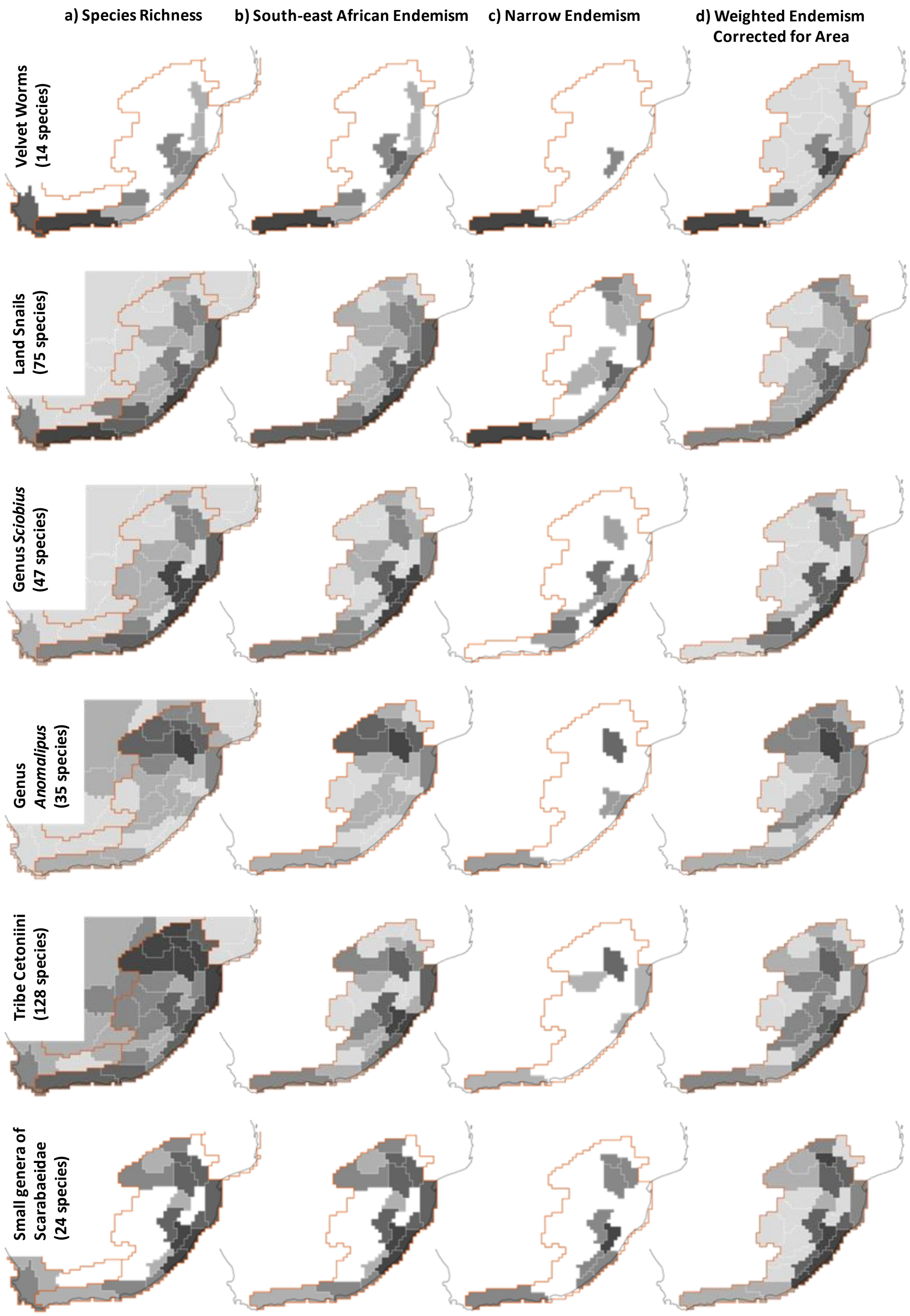

Figure 5 Patterns of species richness and various spatial measures of endemism for invertebrate groups selected for the study (a) Species richness, (b) South-east African endemism, (c) Narrow endemism, (d) Weighted endemism corrected for area; see text for details. Each measure is presented with a graduated grey scale with a maximum of five classes; darker shades indicate higher values and white indicates 0 for the first class of the respective measure

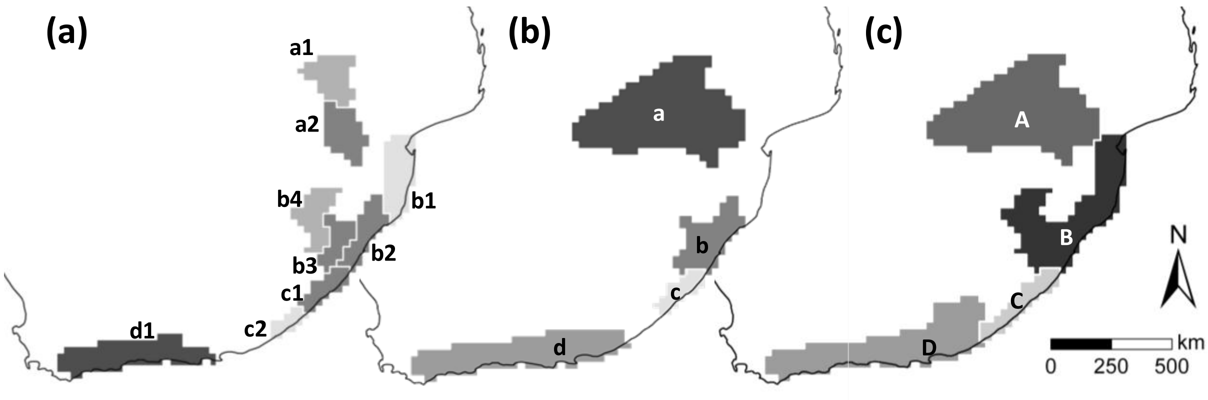

Figure 6 A nested hierarchy of centres of narrow endemism (CONEs) and centres of endemism (COEs) derived from the phenetic clustering (Fig. 4a) and the areas of endemism (AOEs) identified through parsimony clustering (Fig. 4b) of zoogeographic units for the combined invertebrate incidence matrix (323 species): (a) Centres of narrow endemism: a1 – Wolkberg-Soutpansberg, a2-Mpumalanga Escarpment , b1 – Maputaland, b2 – Natal Coastal Belt-Ngoye, b3 – Natal Midlands , b4 – Drakensberg-KwaZulu-Natal Escarpment, c1 – Pondoland, c2 – Southern Transkei Coastal Belt, and d1 – Knysna; (b) Centres of endemism: a – Central Bushveld, b – Natal, c – Pondoland, and d – Albany-Knysna; (c) Areas of endemism: A – Central Bushveld, B – Maputaland-Natal, C – Extended Pondoland, and D – Extended Albany. Centres/areas of endemism are shaded on a grey scale according to the number of endemic species in each (darker shades denotes high endemicity; see Appendix S3 for names of endemic species and text for details). See Fig. 4a for the phenon lines on the phenetic cluster dendrogram used to detect centres of endemism and narrow endemism.

A greater Maputaland-Pondoland-Albany region of endemism

Patterns and centres of invertebrate endemism detected here support the MPA-similar zoogeographical entity (Fig. 2i), confirming it also as an area rich with endemics, hence the hotspot status for invertebrates too. Nevertheless, the high endemism extends north beyond that area towards the OGUs of the eastern escarpment (Mpumalanga Escarpment, Wolkberg and Soutpansberg), especially with high levels of narrow endemism and weighted endemism, for all the study taxa (Figs. 5,6). Hence, incorporation of said OGUs to the MPA-similar zoogeographical entity designates a natural region of endemism; the GMPA region of invertebrate endemism (Fig. 2j), with 134 endemic species from selected groups (46% overall species endemicity; Appendix S1, Fig. 2k). Land snails and velvet worms exhibit a markedly high degree of endemism within the GMPA region among the invertebrate groups selected for the study, while the *Sciobius* weevils and the small flightless dung beetles of the tribe Canthonini are also high in endemics.

DISCUSSION

Revisiting the database and methods

We acknowledge the fact that our selection of species (n=323) is a small sample of the entire invertebrate fauna of the area, but the selection was random with respect to distributional patterns and fairly representative of the major endemic invertebrate groups within the study area. More importantly, selected groups have been collected comparatively well and uniformly within the study area. We did not source museum specimen localities and databases to supplement the distributional data available in published monographs due to logistical difficulties, except in the case of land snails, for which the specimen locality data in the KwaZulu-Natal Museum were included, as this collection represents a relatively uniform level of sampling for the entire study area.

Although butterflies (at least many genera within the study area if not all) comply with the selection criteria for taxa, we did not include them in the current study as the Southern African Butterfly Conservation Assessment (Animal Demography Unit, 2013) distribution database at QDS scale is currently being populated and hence would provide a more complete and finer scale database in the near future, that warrants a separate study with similar objectives on butterflies alone, owing to the fairly high number of species within the study area (Animal Demography Unit, 2013; Woodhall 2005). Other taxonomic groups of invertebrates such as scorpions (Leeming, 2003) and spiders (Griswold, 1991; Foord *et al.*, 2011) that show high endemism in the study area were not included due to (a) the unavailability of distribution data except for range maps in field guides or (b) the incomplete and heterogeneous sampling when the whole study area is concerned.

Any errors in the qualitative delimitation of the OGUs used here could be reflected in the boundaries of the proposed zoogeographical regionalisation and centres/areas of endemism. If such errors exist, they could only be corrected once the data are available at an appropriate completeness level to facilitate an analysis at a finer grain, preferably at QDS scale. Biogeographical regionalisation patterns can be unreliable when the sampling is poor or spatially heterogeneous (Rovito *et al.*, 2004), which is the case in almost all the invertebrate groups at QDS scale in the study area. Hence, we believe the zoogeographical units (Perera *et al.*, 2011) proposed for south-eastern Africa, even though derived from endemic vertebrate distributions, still represent the best OGUs for the present study. Therefore, even if the boundaries of proposed zoogeographical entities require fine-tuning, their existence is numerically proven with an objective methodology.

Recovery of an MPA-similar zoogeographical entity and the distribution of forests

Biodiversity hotspots are defined based on an endemism criterion. Hence, it would make sense to recover a zoogeographical entity similar to the MPA from the parsimony approach, rather than from the phenetic approach, provided that the PAE clusters OGUs by their shared taxa in the most parsimonious way (Morrone & Crisci, 1995), thus giving precedence to the shared and locally endemic taxa over shared and widespread taxa. The UPGMA clusters OGUs based on the complete assemblage of species and hence can be driven by either widespread or endemics species, whichever dominate the complete species assemblage. As we have included a representative sample of invertebrates in the study without major biases in terms of habitat association, taxa with more widespread and savanna-associated species and fewer endemics (Cetoniini and *Anomalipus*) have prevented the recovery of an MPA similar zoogeographical entity in the UPGMA dendrogram. Instead, they helped define a larger entity encompassing the Bushveld region. But the UPGMA analysis restricted to forest-dwelling invertebrates, reveals an MPA-similar entity for this group characterised by lower dispersal ability, that is similar to the cluster derived from PAE for the combined database. This result is evidence for the fact that the geographic pattern of invertebrate endemism in south-eastern Africa is determined by the distribution of forest patches, which is relevant both to further biogeographical hypotheses and to conservation concerns.

A regionalization for south-eastern Africa based on invertebrate zoogeography

The incongruence of diversity patterns in different invertebrate groups as evident from the differences in individual taxon regionalisations in our attempt to recover an MPA-similar zoogeographical entity, and also as observed by Kotze & Samways (1999) in forest patches in the area, makes the combined regionalisation for south-east African invertebrates a more complex one than that in the case of vertebrates (Perera *et al.*, 2013), especially along the Indian Ocean Coastal Belt. Nevertheless, the coarse geographic patterning remains the same, suggesting that a cross-taxon faunal regionalisation incorporating both invertebrates and vertebrates is feasible, despite differences in the completeness of distributional data at finer scales.

Major dichotomies in our regionalisation dendrogram represent the separation of the SEAD from neighbouring northern and western dominions, and the separation of provinces along the south-eastern seaboard from inland ones. The former is driven mainly by the climatic factors separating xeric areas from mesic ones, while the latter seems to have ecological as well as historical explanations relating to the past and present-day distribution of the forest biome. The wet vs. dry zoogeographical boundary, supporting the separation of SEAD from the Karoo-Kalahari-Mopane dominion in the presents study, is well supported by many previous biogeographical regionalisations for amphibians, reptiles, birds, bryophytes and higher plants (Crowe & Crowe, 1982; Crowe, 1990; Seymour *et al.*, 2001; de Klerk *et al.*, 2002; Alexander *et al.*, 2004; van Rooy & van Wyk, 2010, Linder *et al.*, 2012), but not for larger mammals (Turpie & Crowe, 1994), possibly due to their high dispersal ability on land. The separation of two provinces along the south-east African coastal belt (extended Maputaland-Natal and extended Pondoland-Albany) from the Highveld and Bushveld provinces can be attributed to their greater habitat heterogeneity, including forest patches and other fire-free refugia (Hamilton, 1976; Samways, 1990; de Klerk *et al*., 2002) as opposed to more homogeneous savanna in Bushveld and grassland in the Highveld. The refugial role played by forest patches during the Pleistocene climatic cycles, and progressive aridification with corresponding expansions and retractions/isolations (Hamilton, 1976; Eeley *et al.*, 1999) must have had a profound effect in shaping the present-day invertebrate zoogeography (especially of taxa with low vagility) in this area, contributing to rapid diversification and high narrow endemism (Haffer, 1969), and also leaving ancient Gondwanan geographical relicts in many small and isolated forest patches (Halffter & Matthews, 1966; Endrödy-Younga, 1989; Cambefort, 1991; Davis, 1997; Davis *et al*., 2001; Herbert & Kilburn, 2004; Herbert & Moussalli, 2010; Frolov & Scholtz, 2005; Deschodt & Scholtz, 2008; and Daniels *et al.*, 2009). The zoogeographical connection between the Knysna unit and the SEAD (through the extended Pondoland-Albany province) is in contradiction to current biodiversity hotspot delimitation; the unit spatially represents the eastern section of the Cape Floristic Region biodiversity hotspot, which is separated from the MPA at the western limits of Albany. The similarity of the invertebrate fauna (especially endemics) of the Knysna unit to that of eastern OGUs can be attributed to the post-glacial expansion of Afromontane forests to the Knysna-Tsitsikamma areas (Geldenhuys, 1989; see Perera *et al.*, 2013).

Several OGUs were inappropriately placed in the cluster dendrograms, not forming geographically contiguous clusters. This indicates geographic gaps with comparatively low species richness and endemism. Such units worth mentioning are the Northern Natal, Southern Middleveld, Southern Mpumalanga Escarpment, Drakensberg-Eastern-Cape Escarpment and the Transkei Midlands. They could represent actual biogeographical gaps of poor species recruitment or artifacts of a sampling bias towards other areas, indicating areas needing prioritised attention in the inventorying of invertebrates. Northern Natal and Transkei Midlands were also identified as gaps of vertebrate endemism (Perera *et al.*, 2011), the latter supporting the idea of a “Transkei Gap” (Vernon, 1999) – and so are less likely to be artifacts of sampling biases. Published zoogeographical regionalisations for invertebrates in the area with which to compare our results are scarce. But the intuitive endemism-based regionalisation presented for land snails in eastern South Africa (Herbert & Kilburn, 2004) has captured many similar (if finer-scale) zoogeographical entities congruent with our Natal and Pondoland assemblages.

Invertebrate endemism in south-eastern Africa

Patterns in overall invertebrate endemism follow to a great extent those observed for species richness. An increased species richness as well as endemism is always visible along the south-eastern escarpment, and on its eastern aspects towards the coastal belt, as is the case for vertebrates (Perera *et al*., 2013), higher plants (van Wyk & Smith, 2001) and bryophytes (van Rooy, 2000). Although the high species endemism is restricted to a comparatively narrower belt along the south-eastern sea-board and the adjacent escarpment, high species richness extends more inland, especially towards the Bushveld region. The Highveld region is species- as well as endemic-poor for almost all the taxonomic groups considered in this study. The Pondoland, Natal (especially the Natal Midlands), Eastern Escarpment and Knysna units are strongholds of endemism, and especially of narrow endemism, for all the study taxa. Three AOEs defined for *Sciobius* weevils by Morrone (1994) have been recovered exactly in the present study (Maputaland-Natal, Pondoland and Albany-Knysna), despite the broader taxonomic coverage and one additional AOE in Central Bushveld. Even though the COEs for invertebrates are largely congruent with those defined for vertebrates (Perera *et al.*, 2011, 2013) and plants (van Wyk & Smith, 2001), there are a few notable differences. Pondoland, a prominent centre of plant endemism, is well recovered here for invertebrates, even though it exhibited a comparatively lower endemicity for vertebrates. On the contrary, the vertebrate-based Natal centre is found to be an important centre for invertebrate endemism too, even though it is not widely acknowledged for plants. The lower degree of invertebrate endemism in Maputaland is noteworthy when compared to its high endemism for both plants and vertebrates (van Wyk, 1996). Most of the areas and centres of invertebrate endemism again overlap with the forest distribution, while a single centre is found in the savanna biome (Fig. 7b: Central Bushveld), influenced by the centre of origin and diversification for the genus *Anomalipus* (Endrödy-Younga, 1988) and two centres of narrow endemism viz. Mpumalanga escarpment and Wolkberg-Soutpansberg (Fig. 7a) coinciding with remnant forest refugia within a savanna/grassland matrix.

The greater Maputaland-Pondoland-Albany region of animal endemism

Our results indicating a GMPA region of invertebrate endemism are supported by few previous studies on invertebrate distributions. Stuckenberg's (1962) study on montane invertebrate fauna identified an Eastern Highlands Centre, mostly congruent with the core of the GMPA region, including the eastern escarpment as a sub-centre. The latter study also supported the Knysna extension, given as the Cape Centre while commenting on its transitional nature. Later, Dikow & Meier (2003) proposed two hypothetical endemism hotspots for Afrotropical robber flies (Diptera: Asilidae), one similar to the MPA hotspot and one along the eastern escarpment. Results of an endemism-based malaco-biogeographical study by Herbert & Kilburn (2004) have also identified endemism centres along the Maputaland-Natal-Pondoland coastal belt and an Mpumalanga-Swaziland (eastern escarpment) extension, supporting the GMPA region of endemism.

Moreover, the remarkable congruence of the GMPA region of invertebrate endemism to a similar region derived for vertebrates (Perera *et al*., 2013; except the Waterberg and Sneeuberg extensions) is noteworthy. We thus propose the GMPA as a common region of animal endemism with high cross-taxon congruence between vertebrate and invertebrate endemics.

CONCLUSIONS

Although the cluster analyses using both phenetic and parsimony approaches resulted in fairly similar biogeographical regionalisations (at least at the "Province" level), the present study suggests the phenetic approach is preferred for regionalisation studies due to its strength in detecting the hierarchical pattern, as compared to the parsimony approach. On the other hand, the parsimony analysis of endemicity is better at detecting those patterns driven by endemism, and especially areas of endemism. A common zoogeographical regionalisation is feasible for both invertebrates and vertebrates in south-eastern Africa, as indicated by the congruent south-east African dominion. This opens up an avenue for future studies, despite the differences in the availability of distributional data across taxa. While the Maputaland-Pondoland-Albany biodiversity hotspot is a valid zoogeographical entity for invertebrates, the greater Maputaland-Pondoland-Albany region of endemism provides an important region of conservation concern, not only for invertebrates, but a common region of animal endemism with high cross-taxon congruence. The floristic support for such a region, although indicated by several studies (e.g. Cowling and Hilton-Taylor, 1997; Küper *et al.,* 2004; van Rooy & van Wyk, 2011) is not well established. There is also a need to thoroughly document the plant component of the Natal centre of endemism. This region's place in conservation biogeography would be notable, as a zoogeographically delimited broader region of conservation concern that spans a considerable latitudinal and altitudinal gradient, while incorporating a multitude of broad to narrow centres of endemism, further fine-tuning the spatial conservation priorities. Although South Africa has incorporated many such broader priority areas in to its network of protected areas, attention is needed in rethinking the coverage of centres of narrow endemism by designating smaller protected areas that could play a major role in the conservation of the invertebrate fauna.

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BIOSKETCHES

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Appendix S1

Invertebrate species selected for the study (n=323) and their endemism within the study area, the south-east African dominion, the numerically-defined zoogeographical entity similar to the Maputaland-Pondoland-Albany biodiversity hotspot (MPA), and the greater Maputaland-Pondoland-Albany (GMPA) region of invertebrate endemism

Group	Family	Species checklist	Endemic to			
			Study Area (South-eastern Africa)	South-east African Dominian	GMPA Region of Invertebrate Endemism	MPA-similar zoogeographic entity
	Curculionidae	*Sciobius aciculatifrons*	√	√	√	√
	Curculionidae	*Sciobius angustus*	√	√	√	
	Curculionidae	*Sciobius anriae*	√	√	√	√
	Curculionidae	*Sciobius arrowi*	√	√	√	√
	Curculionidae	*Sciobius asper*	√	√	√	√
	Curculionidae	*Sciobius barkeri*	√	√	√	√
	Curculionidae	*Sciobius bistrigicollis*	√	√	√	√
	Curculionidae	*Sciobius brevicollis*	√	√	√	√
	Curculionidae	*Sciobius capeneri*	√	√	√	√
	Curculionidae	*Sciobius cinereus*	√	√	√	√
	Curculionidae	*Sciobius cognatus*	√	√	√	√
	Curculionidae	*Sciobius cultratus*	√	√	√	√
	Curculionidae	*Sciobius dealbetus*	√	√	√	√
	Curculionidae	*Sciobius endroedyi*	√	√	√	√
	Curculionidae	*Sciobius granipennis*	√	√	√	√
	Curculionidae	*Sciobius granosus*	√	√	√	√
	Curculionidae	*Sciobius griseus*	√	√	√	√
	Curculionidae	*Sciobius holmi*	√	√	√	√
	Curculionidae	*Sciobius horni*	√	√		
	Curculionidae	*Sciobius impressicollis*	√	√	√	√
	Curculionidae	*Sciobius kirsteni*	√	√	√	√
	Curculionidae	*Sciobius lateralis*	√	√	√	√
	Curculionidae	*Sciobius marginatus*	√	√	√	√
	Curculionidae	*Sciobius marshalli*	√	√	√	
	Curculionidae	*Sciobius minusculus*	√	√	√	√
	Curculionidae	*Sciobius nanus*	√	√	√	√
Beetles	Curculionidae	*Sciobius obesus*	√	√	√	

Curculionidae	*Sciobius oneilli*	√	√	√	√
Curculionidae	*Sciobius panzanus*	√	√	√	√
Curculionidae	*Sciobius peringueyi*	√	√	√	
Curculionidae	*Sciobius planipennis*	√	√	√	√
Curculionidae	*Sciobius pollinosus*	√	√		
Curculionidae	*Sciobius pondo*	√	√	√	√
Curculionidae	*Sciobius prasinus*	√	√	√	√
Curculionidae	*Sciobius pullus*	√			
Curculionidae	*Sciobius scalpularis*	√	√	√	√
Curculionidae	*Sciobius schoenlandi*	√	√		
Curculionidae	*Sciobius scholtzi*	√	√	√	√
Curculionidae	*Sciobius spatulatus*	√	√	√	√
Curculionidae	*Sciobius tenuicornis*	√	√	√	√
Curculionidae	*Sciobius thompsoni*	√	√	√	√
Curculionidae	*Sciobius tottus*	√	√	√	√
Curculionidae	*Sciobius transkeiensis*	√	√	√	√
Curculionidae	*Sciobius viduus*	√	√	√	
Curculionidae	*Sciobius viridis*	√	√		
Curculionidae	*Sciobius vittatus*	√	√	√	
Curculionidae	*Sciobius wahlbergi*	√	√	√	√
Scarabaeidae	*Acrothyrea rufofemorata*	√	√	√	√
Scarabaeidae	*Aliuscanthoniola similaris*	√	√	√	√
Scarabaeidae	*Amazula suavis*				
Scarabaeidae	*Anelaphinis rhodesiana*				
Scarabaeidae	*Anisorrhina algoensis*				
Scarabaeidae	*Anisorrhina flavomaculata*				
Scarabaeidae	*Anisorrhina serripes*	√			
Scarabaeidae	*Anisorrhina umbonata*				
Scarabaeidae	*Anoplocheilus germari*	√			
Scarabaeidae	*Anoplocheilus rusticus*				
Scarabaeidae	*Anoplocheilus variabilis*	√			
Scarabaeidae	*Anoplocheilus figuratus*				
Scarabaeidae	*Anoplocheilus globosus*	√	√		
Scarabaeidae	*Atrichelaphinis tigrina*				
Scarabaeidae	*Atrichelaphinis nigropunctulata*	√	√		
Scarabaeidae	*Atrichiana placida*				
Scarabaeidae	*Caelorrhina barthi*				
Scarabaeidae	*Caelorrhina relucens*				
Scarabaeidae	*Cheirolasia burkei*				

Scarabaeidae	*Chlorocala africana*				
Scarabaeidae	*Clinteroides permutans*				
Scarabaeidae	*Cosmiophaenia rubescens*				
Scarabaeidae	*Cyrtothyrea albomaculata*				
Scarabaeidae	*Cyrtothyrea marginalis*				
Scarabaeidae	*Cyrtothyrea rubriceps*				
Scarabaeidae	*Cyrtothyrea testaceoguttata*	√			
Scarabaeidae	*Dicronorrhina derbyana*				
Scarabaeidae	*Diplognatha gagates*				
Scarabaeidae	*Diplognatha striata*				
Scarabaeidae	*Dischista cincta*				
Scarabaeidae	*Dischista rufa*				
Scarabaeidae	*Discopeltis tricolor*				
Scarabaeidae	*Discopeltis barbertonensis*	√	√	√	
Scarabaeidae	*Discopeltis bellula*				
Scarabaeidae	*Discopeltis mashona*				
Scarabaeidae	*Dolichostethus levis*				
Scarabaeidae	*Dwesasilvasedis medinae*	√	√	√	√
Scarabaeidae	*Elaphinis cinereonebulosa*	√			
Scarabaeidae	*Elaphinis delagoensis*				
Scarabaeidae	*Elaphinis irrorata*	√			
Scarabaeidae	*Elaphinis latecostata*				
Scarabaeidae	*Elaphinis pumila*	√	√		
Scarabaeidae	*Endroedyolus paradoxus*	√	√	√	√
Scarabaeidae	*Eudicella smithii*	√	√	√	√
Scarabaeidae	*Eudicella trimeni*	√	√	√	√
Scarabaeidae	*Frankenbergerius armatus*	√	√		
Scarabaeidae	*Frankenbergerius barratti*	√	√		
Scarabaeidae	*Frankenbergerius forcipatus*	√	√		
Scarabaeidae	*Frankenbergerius gomesi*	√	√	√	
Scarabaeidae	*Frankenbergerius nanus*	√			
Scarabaeidae	*Frankenbergerius nitidus*	√			
Scarabaeidae	*Frankenbergerius opacus*	√			
Scarabaeidae	*Gnathocera hirta*				
Scarabaeidae	*Goliathus albosignatus*				
Scarabaeidae	*Gyronotus carinatus*	√	√	√	√
Scarabaeidae	*Gyronotus glabrosus*	√	√	√	
Scarabaeidae	*Gyronotus pumilus*	√	√	√	√
Scarabaeidae	*Heteroclita haworth*	√	√		

Scarabaeidae	*Heteroclita raeuperi*	√	√		
Scarabaeidae	*Hypselogenia geotrupina*				
Scarabaeidae	*Ichnestoma albomaculata*	√	√		
Scarabaeidae	*Ichnestoma cuspidata*	√			
Scarabaeidae	*Ichnestoma luridipennis*	√			
Scarabaeidae	*Ichnestoma nasula*	√	√	√	√
Scarabaeidae	*Ichnestoma petera*				
Scarabaeidae	*Ichnestoma rostrata*	√			
Scarabaeidae	*Ichnestoma stobbiai*	√	√		
Scarabaeidae	*Lamellothyrea descarpentriesi*	√	√	√	√
Scarabaeidae	*Lansbergia albonotata*				
Scarabaeidae	*Leucocelis adspersa*				
Scarabaeidae	*Leucocelis aeneicollis*	√	√		
Scarabaeidae	*Leucocelis amethystina*				
Scarabaeidae	*Leucocelis haemorrhoidalis*				
Scarabaeidae	*Leucocelis rhodesiana*				
Scarabaeidae	*Leucocelis rubra*	√			
Scarabaeidae	*Leucocelis transvaalensis*	√	√		
Scarabaeidae	*Leucocelis vitticollis*				
Scarabaeidae	*Lonchothyrea mozambica*				
Scarabaeidae	*Mausoleopsis amabilis*				
Scarabaeidae	*Mecynorrhina passerinii*				
Scarabaeidae	*Meridioclita capensis*	√	√	√	√
Scarabaeidae	*Nebulasilvius johani*	√	√	√	√
Scarabaeidae	*Nebulasilvius insularis*	√	√	√	√
Scarabaeidae	*Niphetophora carneola*				
Scarabaeidae	*Odontorrhina hispida*	√			
Scarabaeidae	*Odontorrhina krigei*	√			
Scarabaeidae	*Odontorrhina pubescens*				
Scarabaeidae	*Outenikwanus tomentosus*	√	√	√	√
Scarabaeidae	*Pachnoda cordata*				
Scarabaeidae	*Pachnoda discolor*				
Scarabaeidae	*Pachnoda sinuata*				
Scarabaeidae	*Pachnodella euparypha*				
Scarabaeidae	*Pachnodella impressa*				
Scarabaeidae	*Paraxeloma mashuna*				
Scarabaeidae	*Parelaphinis moesta*	√	√		
Scarabaeidae	*Parvuhowdenius harrisoni*	√	√	√	√
Scarabaeidae	*Peckolus alpinus*	√	√	√	√

Scarabaeidae	*Peckolus parvus*	√	√	√	√
Scarabaeidae	*Peckolus poenskopius*	√	√	√	
Scarabaeidae	*Phoxomela umbrosa*				
Scarabaeidae	*Phoxomeloides laticincta*				
Scarabaeidae	*Plaesiorrhinella picturata*				
Scarabaeidae	*Plaesiorrhinella plana*				
Scarabaeidae	*Plaesiorrhinella trivittata*				
Scarabaeidae	*Polybaphes balteata*				
Scarabaeidae	*Polybaphes subfasciata*	√	√		
Scarabaeidae	*Polystalactica furfurosa*				
Scarabaeidae	*Polystalactica perroudi*				
Scarabaeidae	*Porphyronota carnifex*				
Scarabaeidae	*Porphyronota hebreae*				
Scarabaeidae	*Porphyronota maculatissima*				
Scarabaeidae	*Pseudoclinteria cincticollis*				
Scarabaeidae	*Pseudoclinteria infuscata*				
Scarabaeidae	*Raceloma jansoni*	√	√		
Scarabaeidae	*Raceloma natalensis*	√	√	√	√
Scarabaeidae	*Rhabdopholis albostriata*	√	√	√	√
Scarabaeidae	*Rhabdopholis costipennis*	√	√	√	√
Scarabaeidae	*Rhabdopholis margaretae*	√	√	√	
Scarabaeidae	*Rhabdopholis robertsi*	√	√		
Scarabaeidae	*Rhabdotis albinigra*				
Scarabaeidae	*Rhabdotis aulica*				
Scarabaeidae	*Rhabdotis intermedia*				
Scarabaeidae	*Rhabdotis semipunctata*				
Scarabaeidae	*Rhabdotis sobrina*				
Scarabaeidae	*Rhinocoeta armata*				
Scarabaeidae	*Rhinocoeta cornuta*				
Scarabaeidae	*Rhinocoeta limbaticollis*	√	√		
Scarabaeidae	*Rhinocoeta sanguinipes*				
Scarabaeidae	*Rhinocoeta turbida*				
Scarabaeidae	*Scythropesthes bicolor*	√	√		
Scarabaeidae	*Stethodesma stachiani*				
Scarabaeidae	*Taurhina splendens*				
Scarabaeidae	*Tephraea dichroa*				
Scarabaeidae	*Tephraea leucomelona*				
Scarabaeidae	*Tephraea morosa*				
Scarabaeidae	*Tephraea simonsi*				

Scarabaeidae	*Tmesorrhina viridicyanea*				
Scarabaeidae	*Trichocephala brincki*				
Scarabaeidae	*Trichostetha albopicta*	√			
Scarabaeidae	*Trichostetha barbertonensis*	√	√	√	
Scarabaeidae	*Trichostetha capensis*	√			
Scarabaeidae	*Trichostetha coetzeri*	√			
Scarabaeidae	*Trichostetha dukei*	√			
Scarabaeidae	*Trichostetha fascicularis*				
Scarabaeidae	*Trichostetha signata*				
Scarabaeidae	*Uloptera planata*				
Scarabaeidae	*Xeloma aspersa*				
Scarabaeidae	*Xeloma atra*				
Scarabaeidae	*Xeloma laprosa*				
Scarabaeidae	*Xeloma maura*				
Scarabaeidae	*Xeloma tomentosa*	√			
Scarabaeidae	*Xiphoscellis schuckardi*				
Tenebrionidae	*Anomalipus acutangulus*				
Tenebrionidae	*Anomalipus adesmoides*	√	√	√	√
Tenebrionidae	*Anomalipus affinis*	√	√	√	
Tenebrionidae	*Anomalipus capensis*	√	√	√	√
Tenebrionidae	*Anomalipus carinatus*				
Tenebrionidae	*Anomalipus coriaceus*	√	√	√	
Tenebrionidae	*Anomalipus decosteri*	√	√	√	√
Tenebrionidae	*Anomalipus dentipes*	√	√	√	√
Tenebrionidae	*Anomalipus elephas*				
Tenebrionidae	*Anomalipus endroedii*	√	√	√	
Tenebrionidae	*Anomalipus expansicollis*	√			
Tenebrionidae	*Anomalipus fahraei*	√			
Tenebrionidae	*Anomalipus frater*	√	√		
Tenebrionidae	*Anomalipus granocostatus*	√	√	√	
Tenebrionidae	*Anomalipus haackei*				
Tenebrionidae	*Anomalipus kaszabi*	√	√	√	
Tenebrionidae	*Anomalipus kochi*	√	√		
Tenebrionidae	*Anomalipus kolbei*	√	√		
Tenebrionidae	*Anomalipus lieselottae*				
Tenebrionidae	*Anomalipus maritimus*	√	√	√	√
Tenebrionidae	*Anomalipus mastodon*	√			
Tenebrionidae	*Anomalipus meles*	√	√		
Tenebrionidae	*Anomalipus multilineatus*	√			

	Tenebrionidae	*Anomalipus mustela*	√	√		
	Tenebrionidae	*Anomalipus nemoralis*	√	√		
	Tenebrionidae	*Anomalipus oertzeni*	√	√		
	Tenebrionidae	*Anomalipus parallelus*	√	√		
	Tenebrionidae	*Anomalipus pauxillus*	√	√		
	Tenebrionidae	*Anomalipus planus*	√	√		
	Tenebrionidae	*Anomalipus schulzeae*	√	√	√	
	Tenebrionidae	*Anomalipus sculpturatus*	√	√		
	Tenebrionidae	*Anomalipus seriatus*	√	√		
	Tenebrionidae	*Anomalipus ultimus*	√	√		
	Tenebrionidae	*Anomalipus urus*	√	√		
	Tenebrionidae	*Anomalipus variolosus*	√	√	√	√
Land snails	Bulimulidae	*Prestonella bowkeri*	√			
	Bulimulidae	*Prestonella nuptialis*	√			
	Chlamydephoridae	*Chlamydephorus bruggeni*	√	√		
	Chlamydephoridae	*Chlamydephorus burnupi*	√	√		
	Chlamydephoridae	*Chlamydephorus dimidius*	√	√	√	√
	Chlamydephoridae	*Chlamydephorus gibbonsi*	√	√	√	√
	Chlamydephoridae	*Chlamydephorus lawrencei*	√	√	√	√
	Chlamydephoridae	*Chlamydephorus parva*	√	√	√	√
	Chlamydephoridae	*Chlamydephorus purcelli*	√			
	Chlamydephoridae	*Chlamydephorus sexangulus*	√	√	√	√
	Chlamydephoridae	*Chlamydephorus watsoni*	√	√	√	√
	Rhytididae	*Afrorhytida burseyae*	√	√		
	Rhytididae	*Afrorhytida knysnaensis*	√			
	Rhytididae	*Afrorhytida kraussi*	√	√	√	√
	Rhytididae	*Afrorhytida trimeni*	√	√	√	√
	Rhytididae	*Capitina calcicola*	√			
	Rhytididae	*Capitina schaerfiae*	√	√	√	√
	Rhytididae	*Nata dumeticola*				
	Rhytididae	*Nata* sp. "Albany"	√			
	Rhytididae	*Nata* sp. "Van Stadens"	√	√	√	√
	Rhytididae	*Nata tarachodes*	√			
	Rhytididae	*Nata vernicosa*	√			
	Rhytididae	*Nata viridescens*	√	√		
	Rhytididae	*Natalina beyrichi*	√	√	√	√
	Rhytididae	*Natalina cafra*	√	√	√	√
	Rhytididae	*Natalina inhluzana*	√	√	√	√
	Rhytididae	*Natalina quekettiana*	√	√		

Rhytididae	*Natalina reenenensis*	√	√	√	√
Rhytididae	*Natalina wesseliana*	√			
Urocyclidae	*Sheldonia aloicola*	√	√	√	√
Urocyclidae	*Sheldonia ampliata*	√	√	√	√
Urocyclidae	*Sheldonia arnotti*	√			
Urocyclidae	*Sheldonia asthenes*	√			
Urocyclidae	*Sheldonia bicolor*	√	√	√	√
Urocyclidae	*Sheldonia burnupi*	√	√	√	√
Urocyclidae	*Sheldonia caledonensis*	√			
Urocyclidae	*Sheldonia capsula*	√			
Urocyclidae	*Sheldonia chrysoprasina*	√	√		
Urocyclidae	*Sheldonia cingulata*	√	√	√	√
Urocyclidae	*Sheldonia cornea*	√	√	√	
Urocyclidae	*Sheldonia cotyledonis*	√			
Urocyclidae	*Sheldonia crawfordi*	√			
Urocyclidae	*Sheldonia fuscicolor*	√	√		
Urocyclidae	*Sheldonia hudsoniae*	√	√	√	√
Urocyclidae	*Sheldonia inuncta*	√	√	√	√
Urocyclidae	*Sheldonia knysnaensis*	√	√	√	√
Urocyclidae	*Sheldonia leucospira*	√	√	√	√
Urocyclidae	*Sheldonia lightfooti*	√	√	√	√
Urocyclidae	*Sheldonia maseruensis*	√	√		
Urocyclidae	*Sheldonia melvilli*	√	√	√	√
Urocyclidae	*Sheldonia natalensis*	√			
Urocyclidae	*Sheldonia perfragilis*	√	√	√	
Urocyclidae	*Sheldonia perlevis*	√	√	√	√
Urocyclidae	*Sheldonia phytostylus*	√			
Urocyclidae	*Sheldonia poeppigii*	√	√		
Urocyclidae	*Sheldonia pondoensis*	√	√	√	√
Urocyclidae	*Sheldonia pumilio*	√	√	√	
Urocyclidae	*Sheldonia puzeyi*	√	√	√	√
Urocyclidae	*Sheldonia russofulgens*	√	√	√	√
Urocyclidae	*Sheldonia* sp. "Bashee"	√	√	√	√
Urocyclidae	*Sheldonia* sp. "Graskop"	√	√	√	√
Urocyclidae	*Sheldonia* sp. "KZN-Mpumalanga"	√	√	√	
Urocyclidae	*Sheldonia* sp. "Mkambati"	√	√	√	√
Urocyclidae	*Sheldonia* sp. "Prentjiesberg"	√	√		
Urocyclidae	*Sheldonia* sp. "Sibaya"	√	√	√	√

	Urocyclidae	*Sheldonia* sp. “southern Transkei”	√	√	√	√
	Urocyclidae	*Sheldonia* sp. “Soutpansberg”	√	√	√	
	Urocyclidae	*Sheldonia* sp. “St Lucia”	√	√	√	√
	Urocyclidae	*Sheldonia* sp. “Wolkberg”	√	√	√	
	Urocyclidae	*Sheldonia symmetrica*	√	√		
	Urocyclidae	*Sheldonia transvaalensis*	√	√	√	
	Urocyclidae	*Sheldonia trotteriana*	√			
	Urocyclidae	*Sheldonia vandenbroeckii*	√	√	√	
	Urocyclidae	*Sheldonia vitalis*	√	√	√	√
	Urocyclidae	*Sheldonia zonamydra*	√	√	√	√
Velvet worms	Peripatopsidae	*Opisthopatus cinctipes*	√	√	√	√
	Peripatopsidae	*Opisthopatus roseus*	√	√	√	√
	Peripatopsidae	*Peripatopsis alba*	√			
	Peripatopsidae	*Peripatopsis balfouri*	√			
	Peripatopsidae	*Peripatopsis capensis*	√			
	Peripatopsidae	*Peripatopsis clevigera*	√	√	√	√
	Peripatopsidae	*Peripatopsis leonina*	√			
	Peripatopsidae	*Peripatopsis moseleyi*	√	√	√	√
	Peripatopsidae	*Peripatopsis sedgwicki*	√	√	√	√
	Peripatopsidae	*Peripatopsis* sp. "Grootvadersbosch"	√	√	√	√
	Peripatopsidae	*Peripatopsis* sp. "Knysna"	√	√	√	√
	Peripatopsidae	*Peripatopsis* sp. "Tsitsikamma"	√	√	√	√
	Peripatopsidae	*Peripatopsis* sp. "Wilderness"	√	√	√	√
	Peripatopsidae	*Peripatopsis stelliporata*	√			
	Total species	323	229	181	134	108

Appendix S2

Operational Geographic Units (OGUs; after Zoogeographical Units of south-eastern Africa; Perera *et al.*, 2011) providing consensus for a zoogeographically-derived region similar to the Maputaland-Pondoland-Albany biodiversity hotspot (MPA). Light grey and white separates out broad columns indicating the spatial relationship of OGUs with the MPA, while darker grey indicates their inclusion in the numerical delimitation of MPA-similar zoogeographic entity as the core region and extensions

		Operational Geographic Units (OGUs) of south-eastern Africa and their spatial relationship with the Maputaland-Pondoland-Albany hotspot (MPA)																																								
		OGUs, more than half of which are included in the MPA hotspot															**% congruence**	OGUs marginal to the MPA hotspot										OGUs completely outside the MPA hotspot														
		ACB	AWB	DEE	NCB	NGO	NMD	NMP	NMV	NNT	PND	SMP	SMV	SNB	STR	TMD		DBP	DKE	HUK	INH	KNY	LKR	NME	SME	SMO	WLB	CBV	CFR	KBV	KUK	MLV	NBV	NDH	NMH	NMO	SDH	SKR	SMH	SPB	UKR	WTB
Occurrence (Inclusion:1/exclusion:0) of each OGU in numerically derived region closest to MPA hotspot, in each cluster analysis	Velvet worms	1	1	0	1	1	1	0	1	0	1	0	1	0	0	0	**53**	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Land snails	1	1	0	1	1	1	0	1	0	1	1	0	0	1	1	**67**	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Weevils of genus *Sciobius*	1	1	0	1	1	1	0	0	0	1	1	0	0	1	0	**53**	0	1	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	Anomalipus	0	0	0	1	0	1	0	0	1	0	1	1	0	0	0	**33**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	dung beetles of family	1	1	0	1	1	1	0	1	0	1	1	0	0	1	0	**60**	0	1	0	0	0	0	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1
	phenetic clustering	1	1	0	0	0	0	0	0	0	1	0	0	0	1	1	**33**	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	parsimony analysis	1	1	0	1	1	1	0	0	1	1	1	1	0	1	1	**73**	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Overall consensus for each OGU within the numerically derived MPA-similar zoogeographical cluster in each analysis (%)		86	86	0	86	71	86	0	43	29	86	71	43	0	71	43		0	57	0	0	57	0	14	0	14	14	14	14	0	0	0	0	0	0	0	0	0	0	14	0	14
Confirmation of each OGU for an MPA-similar zoogeogra-phical cluster (C = core region, E = extensions, O = outside)		**C**	**C**	0	**C**	**C**	**C**	0	**E**	0	**C**	**C**	**E**	0	**C**	**E**		0	**C**	0	0	**C**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Same as above for	Macroecologically combined group of forest invertebrates	1	1	0	1	1	1	0	1	1	1	1	0	0	1	1	**73**	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix S3

Range-restricted species endemic to areas of endemism (AOEs), centres of endemism (COEs) and centres of narrow endemism (CONEs) within the south-east African dominion, also showing their nested hierarchy (see text for details)

<table>
<tr><th colspan="2">Centres of Narrow Endemism [a]</th><th colspan="2">Centres of Endemism [b]</th><th colspan="2">Areas of Endemism [c]</th></tr>
<tr><th>Centre & endemicity</th><th>List of narrow endemics</th><th>Centre & endemicity</th><th>List of centre endemics *</th><th>Area & endemicity</th><th>List of area endemics *</th></tr>
<tr><td>Mpumalanga Escarpment (8)</td><td>Beetles: Anomalipus coriaceus, A. endroedii, A. schulzeae, Discopeltis barbertonensis, Peckolus poenskopius, Sciobius vittatus, Trichostetha barbertonensis; Land Snails: Sheldonia vandenbroeckii</td><td rowspan="2">Bushveld (27)</td><td rowspan="2"><u>Characteristic Endemics</u>
Beetles: Anomalipus planus

<u>Restricted Endemics</u>
Beetles: Anomalipus kaszabi, A. mustela, A. nemoralis, A. oertzeni, A. seriatus, Atrichelaphinis nigropunctulata, Discopeltis barbertonensis, Frankenbergerius gomesi, Peckolus alpinus, Rhabdopholis robertsi, Sciobius angustus, S. peringueyi, S. viduus; Land Snails: Sheldonia sp. “Graskop”; + 13 other endemics given as restricted to the Mpumalanga Escarpment & Wolkberg-Soutpansberg CONEs</td><td rowspan="2">Bushveld (27)</td><td rowspan="2">Same as the Bushveld Centre of Endemism</td></tr>
<tr><td>Wolkberg-Soutpansberg (5)</td><td>Beetles: Gyronotus glabrosus; Land Snails: Sheldonia perfragilis, S. pumilio, S. sp. “Soutpansberg”, S. sp. “Wolkberg”</td></tr>
<tr><td>Maputaland (3)</td><td>Beetles: Lamellothyrea descarpentrie; Land snails: Sheldonia sp. “Sibaya”, S. sp. “St Lucia”</td><td colspan="2">Not nested within a Centre of Endemism</td><td rowspan="4">Maputaland-Natal (36)</td><td rowspan="4"><u>Characteristic Endemics</u>
Beetles: Sciobius bistrigicollis, S. brevicollis, S. wahlbergi

<u>Restricted Endemics</u>
Beetles: Gyronotus carinatus, Sciobius arrowi, S. cognatus, S. cultratus, S. prasinus, S. spatulatus; Land snails: Sheldonia inuncta; + 26 other endemics given as restricted to the Maputaland, Natal Midlands, Natal Coastal Belt-Ngoye & Drakensberg-KwaZulu-Natal Escarpment CONEs</td></tr>
<tr><td>Natal Midlands (9)</td><td>Beetles: Anomalipus adesmoides, Nebulasilvius insularis, N. johani, Parvuhowdenius harrisoni, Sciobius panzanus; Land Snails: Natalina inhluzana, Sheldonia bicolor, S. burnupi; Velvet worms: Opisthopatus roseus</td><td rowspan="2">Natal (20)</td><td rowspan="2"><u>Characteristic Endemics</u>
None

<u>Restricted Endemics</u>
Beetles: Sciobius arrowi; + 19 other narrow endemics given for the Natal Midlands & Natal Coastal Belt-Ngoye CONEs</td></tr>
<tr><td>Natal Coastal Belt-Ngoye (10)</td><td>Beetles: Anomalipus maritimus, Ichnestoma nasula, Sciobius anriae, S. barkeri, S. holmi, S. marginatus, S. tenuicornis; Land Snails: Sheldonia ampliata, S. melvilli, S. russofulgens</td></tr>
<tr><td>Drakensberg-KwaZulu-Natal Escarpment (4)</td><td>Beetles: Peckolus parvus, Sciobius aciculatifrons, S. kirsteni; Land Snails: Natalina reenenensis</td><td colspan="2">Not nested within a Centre of Endemism</td></tr>
<tr><td>Pondoland (9)</td><td>Beetles: Aliuscanthoniola similaris, Sciobius endroedyi, S. granipennis, S. lateralis, S. planipennis, S. pondo, S. scholtzi, S. transkeiensis; Land Snails: Sheldonia sp. n. C [cf. puzeyi]</td><td>Pondoland (9)</td><td>Same as the Pondoland Centre of Narrow Endemism</td><td rowspan="2">Extended Pondoland (18)</td><td rowspan="2"><u>Characteristic Endemics</u>
Land Snails: Natalina beyrichi, Sheldonia sp. n. F [ground], S. vitalis

<u>Restricted Endemics</u>
Beetles: Sciobius asper; Land Snails: Sheldonia pondoensis, S. puzeyi; + 12 other endemics given as restrcted to the Pondoland and Southern Transkei Cosatal Belt CONEs</td></tr>
<tr><td>Southern Transkei Coastal Belt (3)</td><td>Beetles: Dwesasilvasedis medinae; Land snails: Sheldonia lightfooti, S. sp. “Bashee”</td><td colspan="2">Not nested within a Centre of Endemism</td></tr>
</table>

Centres of Narrow Endemism [a]		Centres of Endemism [b]		Areas of Endemism [c]	
Centre & endemicity	**List of narrow endemics**	**Centre & endemicity**	**List of centre endemics ***	**Area & endemicity**	**List of area endemics ***
Knysna (13)	**Beetles:** *Anomalipus capensis, Meridioclita capensis, Outenikwanus tomentosus;* **Land Snails:** *Afrorhytida kraussi, Capitina schaerfiae, Nata* sp. "Van Stadens", *Sheldonia knysnaensis;* **Velvet worms:** *Peripatopsis clevigera, P. sedgwicki, P.* sp. "grootvadersbosch", *P.* sp. "knysna", *P.* sp. "tsitsikamma", *P.* sp. "wilderness"	Albany-Knysna (18)	Characteristic Endemics **Land Snails:** *Sheldonia hudsoniae* Restricted Endemics **Beetles:** *Anomalipus dentipes*, *Sciobius capeneri;* **Land Snails:** *Chlamydephorus parva, Sheldonia aloicola;* + 13 other endemics given as restrcted to the Knysna CONE	Extended Albany (21)	Characteristic Endemics **Beetles:** *Sciobius tottus;* **Land Snails:** *Sheldonia hudsoniae* Restricted Endemics **Beetles:** *Anomalipus dentipes, Sciobius capeneri, S. minusculus, S. nanua;* **Land Snails:** *Chlamydephorus parva, Sheldonia aloicola;* + 13 other endemics given as restrcted to the Knysna CONE

[a] Finest geographically contiguous clusters of the UPGMA dendrogram with at least 4 endemic species

[b] Assemblages identified through a phenon line form the UPGMA dendrogram with at least 7 endemic species

[c] Geographically contiguous clusters of OGUs in the PAE dendrogram with atleast two endemic species

* Characteristic Endemics: Endemic species, occupying more than two-thirds of ZUs (when there are more than 2) in the centre/area, and distributed over a half of its range. Narrow Endemics: Endemic species with a much narrower range within the centre/area. Species endemic to CONEs nested within a given centre/area are also included to its total endemicity

CHAPTER 5

Herpetofaunal zoogeography and endemism in eastern South Africa, Lesotho & Swaziland

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ABSTRACT

Aim Although several taxon-specific zoogeographical studies have been conducted, a regional-scale combined analysis of herpetofaunal distributions with a finer geographic resolution is lacking for south-eastern Africa, and none of the previous studies explore patterns of endemism. Here we use atlas data for Anura (frogs) and Squamata (lizards and snakes) aiming to (a) regionalise the area according to herpetogeographical patterns, (b) map their patterns of endemism and (c) analytically recognise areas and centres of endemism.

Location South Africa east of 23°E, southern Cape Floristic Region, Lesotho & Swaziland.

Methods Incidence data for 112 species of Anura and 333 species of Squamata in 361 half-degree-squares (18,258 presence records in total) were subjected to hierarchical cluster analyses (Jaccard's similarity index and the Unweighted Pair-Group Method using Arithmetic Averages; UPGMA) to establish zoogeographical regions. Various measures of endemism were also mapped. A Parsimony Analysis of Endemicity (PAE) was used to detect Areas of Endemism (AOEs).

Results Our herpetofaunal regionalisation presents two distinct provinces within the area, the greater Maputaland-Pondoland-Albany (GMPA) and the Highveld, together harbouring 22 different assemblages. These two provinces together form the south-east African dominion, as previously recognised. Although some complementarity exists in species richness peaks between Anura and Squamata, their patterns of endemism are largely congruent (if the areas of high endemism are more extensive in Squamata). The combined herpetofaunal dataset shows high congruence between the diversity and endemism centres. Maps of endemism patterns and AOEs suggest high endemicity along and below the Great Escarpment, supporting the GMPA region of endemism.

Main conclusions The use of atlas data and cluster analyses at the finest possible resolution provide opportunities to reveal patterns within regional-scale zoogeography. PAE involving larger databases accurately defines AOEs, from which centres of endemism of high conservation importance can be selected. The areas and centres of south-east African herpetofaunal endemism described here are novel, and provide information for conservation prioritisation.

Key Words

Anura, cluster analysis, conservation, endemism, herpetofauna, Maputaland-Pondoland-Albany, Parsimony Analysis of Endemicity, southern Africa, Squamata, zoogeography

INTRODUCTION

Eastern South Africa, together with Lesotho and Swaziland, harbours a rich assemblage of endemic biota. In this region, the patterns of plant endemism have long been established over a series of studies, starting with the proposal of a Tongaland-Pondoland Regional Mosaic along the south-eastern coastal belt and an Afromontane archipelago-like regional centre of endemism along the Great Escarpment (White, 1993). The south-eastern seaboard and the south-eastern Great Escarpment encompass several centres of floristic endemism: the Maputaland, Pondoland and Albany; and the Soutpansberg, Wolkberg, Sekhukhuneland, Barberton, and Drakensberg, respectively (van Wyk and Smith, 2001). In addition to the “Indian Ocean Coastal Belt”, a unique biome on its own, the area includes sections of the Forest, Albany (Sub-tropical) Thicket, Savanna and Grassland biomes, each represented by a diversity of bioregions (Mucina and Rutherford, 2006). Well established floristic knowledge of the area has led to the identification of the Maputaland-Pondoland-Albany (MPA) biodiversity hotspot (Mittermeier *et al.*, 2004), encompassing van Wyk and Smith’s (2001) Maputaland-Pondoland region and the Albany centre of floristic endemism.

From a zoogeographical perspective, south-eastern Africa has recently been recognised as a dominion (south-east African dominion; SEAD; Perera *et al.*, 2013a,b) within the southern African subregion (given as a region in Linder *et al.*, 2012) of the Afrotropical region (Holt *et al.*, 2013; given as a subregion in Procheş & Ramdhani, 2012), according to the global biogeographical taxonomic hierarchy (Ebach *et al.*, 2008). The area along the coast and the adjacent Escarpment of south-eastern Africa show exciting patterns of endemism for vertebrates, leading to the description of the Greater Maputaland-Pondoland-Albany (GMPA) region of endemism (Perera *et al.*, 2011), that was later confirmed as a valid zoogeographical province within the SEAD upon a numerical analysis (Perera *et al.*, 2013a,b). The herpetofauna of the SEAD exhibits high diversity and endemism levels (Branch, 1998; du Preez & Carruthers, 2009). The broad patterns of vertebrate endemism delineating the GMPA region are in fact dominated by the herpetofauna, reptiles having a higher number of endemic species (88) within the region, than all other vertebrate groups combined (78). Frogs, with 32 endemics have the second highest endemicity (Perera *et al.*, 2013b). These include many ancient lineages, some of possible Gondwanan ancestry, and some of which underwent recent speciation (Plio-Pleistocene speciation within the last five million years; deMenocal, 2004) resulting in narrow-range endemism (e.g. *Bradypodion*, *Heleophryne*, *Xenopus*; see Poynton & Broadley, 1978; Tolley *et al.*, 2008; Whitton *et al.*, 2012). The GMPA region encompasses six centres of endemism for vertebrates *viz.* Maputaland, Natal-Pondoland, Albany and Knysna along the sea-board, and the Mpumalanga Escarpment and Drakensberg along the Escarpment, which were further dissected into ten centres of narrow endemism (Perera *et al.*, 2013b). The MPA biodiversity hotspot alone (incorporating only the Maputaland, Natal-Pondoland and the Albany centres) comprise reptile and frog faunas numbering 230 species with 33 endemics (14.3% endemicity) and 75 species with 16 endemics (21.3% endemicity), respectively (Perera *et al.*, 2011).

The zoogeography of frogs and reptiles in southern Africa has been analysed as separate groups or as a part of broader groups by several authors (as summarised in Table 1). Even though the particular interest on the zoo- (bio-) geography of south-eastern Africa dates back as far as Poynton (1960, 1961), none of the subsequent biogeographical studies have given a particular attention to the area until Perera *et al.* (2011, 2013b).

Amidst the zoogeographical studies summarised in Table 1, a regional-scale combined analysis of herpetofaunal distributions at a finer geographic resolution is lacking for south-eastern Africa, while none of the above works (except Perera *et al.*, 2011, 2013b) has explored the patterns of endemism. Such analyses can provide important insights for the theoretical, historical as well as the conservation biogeography of the area. An opportunity for such a numerical analysis of the herpetogeography and endemism at a finer scale of geographic resolution is provided by the atlas projects for South Africa, Lesotho and Swaziland (see Robertson *et al.*, 2010), data being available at the quarter-degree square (QDS) scale; despite the collection biases, especially in the frog atlas (see Botts *et al.*, 2011). Hence we attempt here to utilise those atlas databases (Minter *et al.*, 2004, mirrored by ADU, 2012a for frogs and ADU 2012b for reptiles) in order to: a) regionalise the area according to herpetogeography; b) map the patterns of endemism; and c) analytically recognise the areas and centres of endemism; for the eastern half of South Africa, Lesotho and Swaziland. While fine-scale taxon-specific zoogeographical regionalisations presented here are compared to previous studies, herpetofaunal areas and centres of endemism are presented for the first time.

Reference	Taxa	Aim	Methods	Study area	Geographic Resolution
Poynton (1960)	Frogs	Regionalisation	Intuitive	South-eastern Africa	N/A
Poynton (1961)	Frogs	Regionalisation	Intuitive	Southern Africa	N/A
Crowe (1990)	Frogs, lizards snakes, birds and large mammals	Regionalisation	Numerical: Multidimensional Scaling, Bray-Curtis similarity measure	Southern Africa	~Two-Degree Square
Poynton (1999)	Frogs	Regionalisation	Qualitative	Sub-Saharan Africa	N/A
Seymour *et al.* (2001)	Frogs	Regionalisation, Conservation prioritisation	Numerical: Centroid Clustering Algorithm, Bray-Curtis similarity measure.	Sub-equatorial Africa	One-Degree Square
Alexander *et al.* (2004)	Frogs	Regionalisation	Numerical: Clustering with Euclidean distance and Ward's minimum-variance method, Bray-Curtis similarity measure	South Africa, Lesotho and Swaziland	Half-Degree Square
Perera *et al.* (2011)	Endemic vertebrates	Regionalisation, Patterns of endemism	Qualitative: using "endemic vertebrate distributions"	South-eastern Africa	N/A
Linder *et al.* (2012)	Birds, Mam-mals, Frogs, snakes and Plants	Regionalisation	Numerical: UPGMA clustering, β (sim) similarity measure	Sub-Saharan Africa	One-Degree Square
Perera *et al.* (2013b)	Endemic vertebrates	Regionalisation, Patterns of endemism	Numerical: UPGMA clustering, Jaccard's similarity measure	South-eastern Africa	Zoogeoaphical Units of Perera *et al.* (2011)

Table 1. A summary of previous studies relevant to the zoogeography of the south-east African herpetofauna.

MATERIALS & METHODS

Study Area and Operational Geographic Units

Our study area comprised South Africa east of 23ºE, Lesotho and Swaziland, and the southern parts (south of 33ºS) of the Cape Floristic Region (CFR) to the west of 23ºE (Fig. 1; see Perera *et al*., 2013b for details). This area fully encompassed the GMPA region of endemism including its Knysna extension into the CFR, together with the Grassland biome in the Highveld region. At the same time, this selection of the study area excluded most of the Nama-karoo biome in arid north-western South Africa, hence excluding most of the under-sampled QDSs in the atlas range (see Alexander *et al*., 2004; Botts *et al*., 2011). One thousand four hundred and eighteen Quarter-Degree Squares (QDSs), 361 Half-Degree Squares (HDSs) and 97 Full-Degree Squares, that have more than 25% of land cover in each cell within the above latitude-longitude boundaries were used as Operational Geographic Units (OGUs) for the analyses.

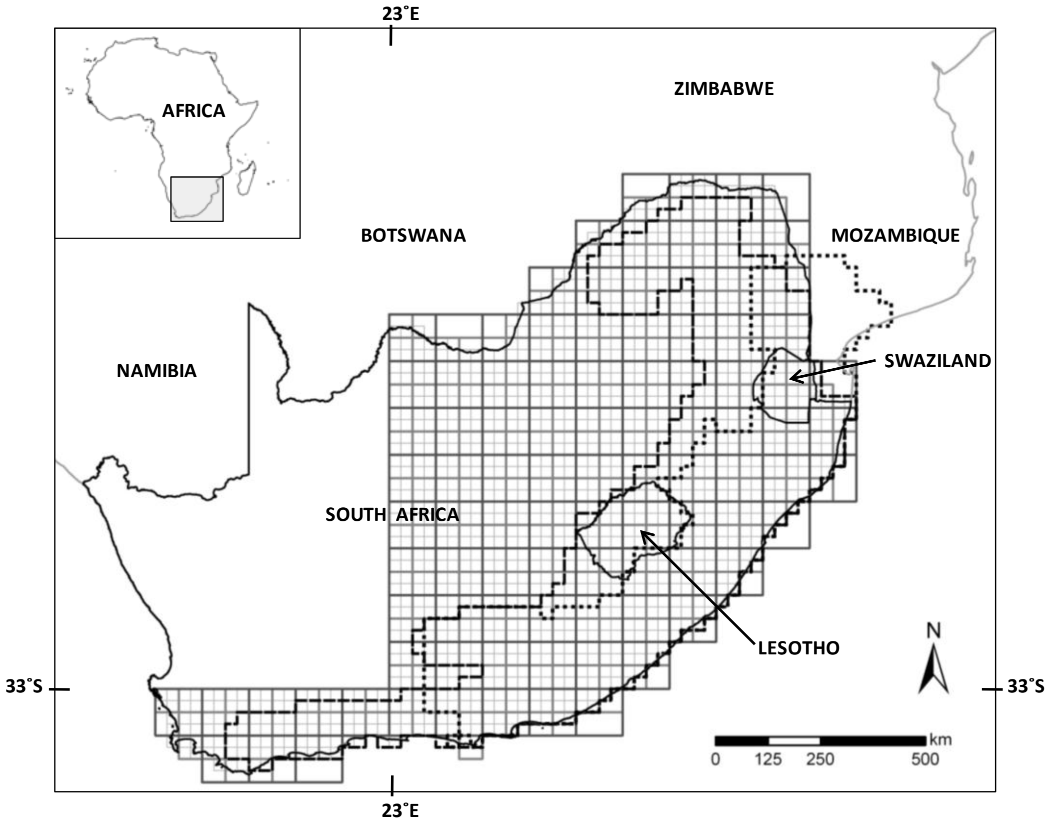


Figure 1. The study area including South Africa east of 23ºE, Lesotho and Swaziland, and the Cape Floristic Region south of 33ºS, including 1418 Quarter-Degree Squares, 361 Half-Degree Squares and 97 Full-Degree Squares, with more than 25% of land cover in each cell that were used as Operational Geographic Units for analyses. The boundaries of the Maputaland-Pondoland-Albany biodiversity hotspot (Mittermeier *et al.,* 2004) and the greater Maputaland-Pondoland-Albany region of vertebrate endemism (including extensions; Perera *et al.*, 2013b), both redrawn along the quarter-degree square borders, are indicated by dotted and dashed lines, respectively.

The database

A geographic database of incidence data (presence/absence) for all native, non-marine species of two monophyletic herpetofaunal taxa *viz.* Order Anura (Chordata: Amphibia) and Order Squamata (Chordata: Reptilia) found within the study area was compiled by extracting data for all the selected OGUs from, (a) the Atlas of the Frogs of South Africa, Lesotho and Swaziland (Minter *et al.,* 2004; mirrored by Animal Demography Unit, 2012a) and (b) the Reptile Atlas of Southern Africa (Animal Demography Unit, 2012b), both available online at the Virtual Museum of Animal Demography Unit, University of Cape Town. The anuran species list extracted from Minter *et al.* (2004) was updated adopting the latest taxonomy as of du Preez & Carruthers (2009) and also thereby adding four new species *viz.* two species of *Arthroleptella* described after the work by Minter *et al.* (2004), *A. subvoce* (Turner *et al.*, 2004), *A. rugosa* (Turner & Channing, 2008) and two undescribed species of *Cacosternum* (du Preez & Carruthers, 2009). Squamate taxonomy follows the Animal Demography Unit (2012b).

Data Analysis

Three different analyses – two types of numerical biogeographical analyses on OGUs *viz.* phenetic clustering for zoogeographical regionalisation and parsimony analyses of endemicity (PAE), and thirdly the calculation and mapping of several quantitative spatial measures of endemism were conducted separately for anurans and squamates, and then for a combined dataset, at all three scales of OGUs. For both the phenetic clustering and parsimony analyses, HDSs resulted in reasonably contiguous geographical clusters, without considerably distorting the natural boundaries of resulting zoogeographical entities. Hence the results of all the analyses are presented only at the HDS scale and mapped using ArcGIS 9.3 (ESRI, 2009).

Zoogeographical Regionalisation

The combined matrix of species incidence in OGUs, and its subsets (Anura and Squamata) were analysed using a phenetic clustering technique to identify hierarchical zoogeographical divisions (provinces, districts and assemblages) and to define relationships between such entities. OGUs in each species incidence matrix were compared pair-wise using the Jaccard index (Jaccard, 1901) as the measure of similarity/distance. The Jaccard index of similarity does not consider shared absences in its calculation (Jardine, 1972), hence artefacts introduced by possible false-absences in the dataset should be disregarded. The resultant similarity/distance matrices were clustered using UPGMA (Unweighthed Pair-Group Method using Arithmetic Averages), an agglomerative, hierarchical clustering algorithm as recommended by Kreft & Jetz (2010). As the cells with few species are reported to give biased results (Alexander *et al.*, 2004; Kreft & Jetz, 2010; Linder *et al.*, 2012), we manually removed such cells from each data matrix prior to the cluster analyses. HDSs with less than four species in the anuran matrix (as done by Alexander *et al.*, 2004) and those with less than seven species in both the squamate and combined matrices were removed in this study. These cut-off values were determined by identifying the point from which histograms of species richness in HDSs for each matrix approximate a normal distribution. The analyses were conducted using PAUP* 4.0b10 (Swofford, 2002), with the "p" distance (=Jaccard index of similarity; see Procheş & Ramdhani, 2012) and UPGMA options. The resulting dendrograms were visualised using the TreeView 1.6.6. (Page, 1996; available from http://taxonomy.zoology.gla.ac.uk/rod/treeview.html). In these dendrograms, OGUs with similar herpetofauna were clustered together, and hence used to define relationships between different herpetogeographical divisions. Which of the clusters identified by the UPGMA algorithm are actual biogeographical entities needs to be determined by setting an objective set of "stopping rules" (Alexander *et al.*, 2004; Kreft & Jetz, 2010; Procheş & Ramdhani, 2012; Linder *et al.*, 2012). Here we adopted the rules of Linder *et al.* (2012: p. 1192): a) "*the regions could not be nested within each other*"; b) "*a phenon line was employed to provide a rigorous definition of the groups*". Additionally, a guideline was set regarding the acceptable number of assemblages (twenty-five to fourty, cf. six to eight regions in Linder *et al.*, 2012), also following the principle of geographical contiguity (Procheş, 2005) in determining clusters as zoogeographical assemblages. An attempt was thus made to have assemblages that were congruent (cf. Procheş & Ramdhani, 2012) and as similar in number as possible (cf. Kreft & Jetz, 2010) for all three analyses, while still adhering to the first two rules. All the grid cells that were removed from analyses for statistical purposes and those not forming geographically-contiguous clusters were left unassigned when mapping zoogeographical entities. In addition to the zoogeographical regionalisation based on individual taxon matrices and the combined matrix (total evidence approach; Linder *et al*., 2012) for the herpeofauna, we also conducted a consensus regionalisation (adapted from Linder *et al*., 2012), where each grid cell was assigned to an assemblage only if the cell concerned was identified from more than one analysis as belonging to the particular assemblage. Hence, the cells assigned to different assemblages in single-taxon (Anura and Squamata) analyses were excluded in the first-order consensus regionalisation, while some of them were brought back into the assemblage if recovered in the combined analysis, resulting in a second-order consensus regionalisation. Both the combined and consensus regionalisations contributed to the final herpetofaunal regionalisation proposed for eastern South Africa, Lesotho and Swaziland.

Patterns of endemism

Geographic patterns were mapped for the species richness and four spatially-based quantitative measures of endemism calculated for each OGU: a) south-east African endemic species richness, b) narrow endemism (range-restricted species richness), c) the weighted endemism (WE; Crisp *et al.*, 2001) and d) the weighted endemism corrected for the species richness (WECSR = corrected weighted endemism *sensu* Crisp *et al.,* 2001). We defined south-eastern Africa based on the overall coverage of all zoogeographical assemblages that contribute to the GMPA and Highveld Provinces in any of the anuran, squamate and combined cluster analyses, hence coinciding with the border of the combination of above provinces in the final consensus regionalisation for herpetofauna. All the species strictly endemic within that boundary and species that are almost endemic with not more than three marginal HDSs just outside the boundary, not contributing more than 50% to their range size are considered here as south-east African endemics (e.g. *Acontias richardi* occupying only two HDSs along the northern boundary of the GMPA province, one HDS inside and the other just outside is considered as an endemic to SEA). The only exception to this is the inclusion of *Bitis inornata* a Sneeuberg endemic occupying two HDSs both marginally outside the southern boundary of the Highveld province, this being the only endemic to the Sneeuberg centre, and it not being collected from the incorporated portion of the centre could be attributed to faunal under-sampling in the area (Clark *et al*., 2011, 2012).

The measure of narrow endemism (range restricted species richness) was based on a cut-off approach to defining endemism (Crisp *et al.*, 2001), range-restricted species being defined here as species restricted to an area less than or equal to six conterminous HDSs (even with gaps of a single HDS in between). Two endemism measures without spatial cut-offs, (a) WE, and (b) WECSR were calculated for each HDS as, (a) the sum of the reciprocal of the total number of HDSs each species is found in (as in Dony & Denholm, 1985, Williams & Humphries, 1994; Williams *et al*., 1994), and (b) by simply dividing the WE by the species richness in the respective HDS (as in Crisp *et al.*, 2001), in order to detect deviations from the generally observed correlation between the species richness and endemism (Gaston *et al*., 1998). The inclusion of widespread species in a calculation of an endemism measure for a geographical extent smaller than its range can result in miscalculations (Slatyer *et al.*, 2007). Hence, WE and WECSR were calculated only using the species endemic to south-eastern Africa (also see Huang *et al.*, 2008), rather than using the entire species incidence database for the latitude-longitude boundary of our study area.

Each of the calculated measures of endemism and the species richness were mapped with a graduated grey scale of five classes. Classes were determined with natural breaks calculated using Jenk's optimisation, so that the patterns inherent in the data are best revealed.

Areas and centres of endemism

A Parsimony Analysis of Endemicity (PAE; Rosen 1988; Moronne, 1994; Morrone & Crisci, 1995) was conducted on the species incidence per HDS data for each group using PAUP* 4.0b10 (Swofford, 2002), where a full heuristic search was performed with tree bisection-reconnection (TBR) branch swapping and the maximum trees limit set at 1000, after the constant characters (species present or absent in all HDSs) and uninformative characters (autapomorphies; species found only in a single HDSs) were excluded. A strict consensus tree was constructed from all the most parsimonious trees for each analysis and used to delimit areas of endemism (AOEs), by mapping the resultant clades of HDSs. Geographically contiguous clades of HDSs on the strict consensus tree carrying at least two endemic species with congruent distribution are recognized as AOEs (to comply with Nelson and Platnick's, 1981 definition of AOEs). A species endemic to such a clade with a marginal HDS outside the clade was still considered a clade endemic, to account for biases caused in allocating artificial HDS for natural range edges. Clades on the strict consensus tree that showed geographical scattering when mapped, those forming contiguous geographical clusters only along the inland boundaries of our study area, and those characterised by less than two endemic species were disregarded. As the narrow endemic species were removed from the PAE during initial steps (i.e. autapomorphies), we manually detected single HDS areas of endemism (hereafter, areas of point endemism; AOPEs) by recognising individual HDSs with two or more endemic species exclusive to them (see Moreno Saiz *et al.*, 2012). AOEs that harbour four or more endemic species are recognised as centres of endemism (see Perera *et al.*, 2013b for a discussion on AOEs and centres of endemism).

RESULTS

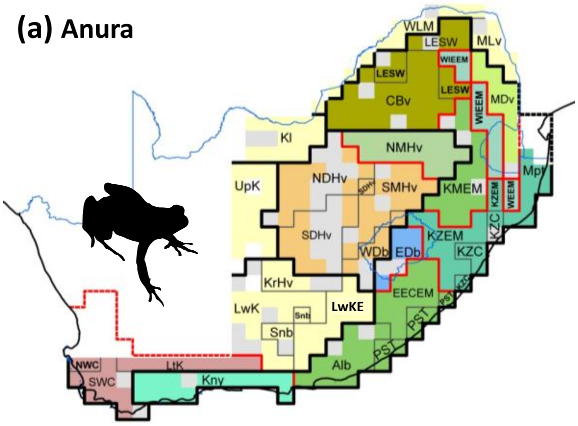
The database

Incidence data for 112 species of Anura and 333 species of Squamata (445 species in total) in 361 HDSs of eastern South Africa, Lesotho and Swaziland (18,258 presence records in total) were analysed in an effort to understand their overall zoogeography and the patterns of endemism. The number of herpetofaunal species (except Crocodilia and Chelonia) per HDS in the study area ranges from a minimum of two species in the arid north-west (one species for Anura and zero for Squamata) to a maximum of 140 species in the tropical and mesic north-east, particularly Maputaland and the Eastern Escarpment (53 species for Anura and 103 species for Squamata), with an average of 51 species per HDS (15 species for Anura and 35 species for Squamata). Twenty-four narrow endemic species (six anurans and 18 squamates) within the limits of our study area were found exclusive to single HDSs, distributed along the Eastern Escarpment, Natal, Knysna and the South-western Cape.

Herpetofaunal Regionalisation

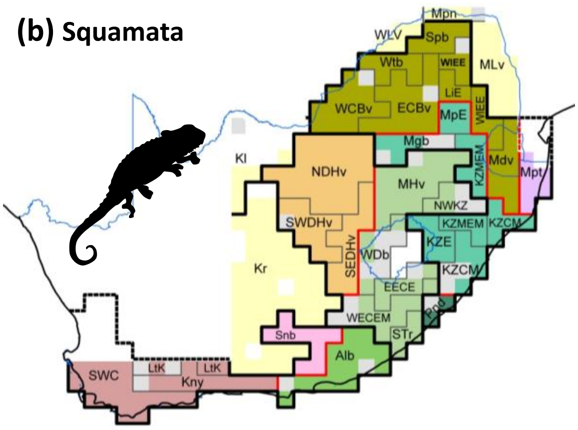
Hierarchies of zoogeograohical provinces, districts and assemblages were first established individually for the anuran, squamate, and combined analyses (Fig. 2), as defined by phenon lines on the relevant UPGMA dendrograms (Appendix S1). Spatial congruence between the assemblages recovered from the above analyses provided consensus on at least 22 herpetofaunal assemblages that are found completely within the study area. The congruence of assemblages from different analyses and their contribution to consensus assemblages are summarised in Appendix S2. The consensus regionalisation for the herpetofauna is given in Fig. 3. The final herpetofaunal regionalisation for eastern South Africa, Lesotho and Swaziland (Fig. 4) was completed primarily based on the hierarchy established in the combined regionalisation, while incorporating only those 22 assemblages recovered by the second order consensus. A few manual amendments were also incorporated at higher levels in the hierarchy, in consensus with individual regionalisations presented here and the combined endemic vertebrate regionalisation of Perera *et al.*, 2013b, in order to overcome caveats in possible under-sampling in some areas and the unnatural limits of the study area and HDSs (see discussion). The final regionalisation presents two distinct hereptofaunal provinces in the area, the GMPA and the Highveld, that harbour 22 different assemblages. These two provinces together form the SEAD, as previously proposed for endemic vertebrates (Perera *et al*., 2013b) and selected groups of invertebrates (Perera *et al*., 2013a).

(a) Anura



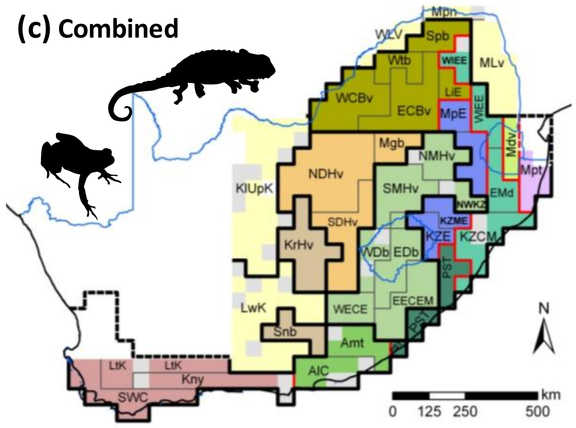
Provinces	Dictricts	Assemblages
Greater Maputaland-Pondoland-Albany	Bushveld	CBv & LESW
	Wolkberg-Eastern Escarpment	WIEEM
	Middleveld	Mdv
	Maputaland-Natal	KZC, KZEM & Mpt
	Drakensberg	EDb
	South-eastern Escarpment	Alb, EECEM, KZMEM & PST
	Knysna	Kny
Highveld	Northern Mesic Highveld	NMHv
	Southern Highveld	NDHv, SDHv, SMHv & WDb
Cape-Lower Karoo	Cape	LtK, NWC & SWC
	Lower Karoo	LwK, KrHv, Snb & LwKE
Upper Karoo*	Upper Karoo	UpK
Kalahari*	Kalahari	Kl
Lowveld*	Lowveld	MLv & WLVM

(b) Squamata



Provinces	Dictricts	Assemblages
Greater Maputaland-Pondoland-Albany-Cape	Bushveld	ECBv, LiE, Mdv, Spb, Wtb, WCBv & WIEE
	Maputaland	Mpt
	Greater Natal	KZCM, KZE, KZMEM, Mgb & MpE
	Pondoland	Pnd
	Albany	Alb
	Sneeuberg	Snb
	Cape	Kny, LtK & SWC
Highveld	Dry Highveld	NDHv, SEDHv & SWDHv
	Mesic Highevld-Transkei Coast	EECE, MHv, NWKZ, STr, WDb & WECEM
Karoo*	Karoo	Kr
Kalahari*	Kalahari	Kl
Lowveld*	Lowveld	Mpn, MLv & WLV

(c) Combined



Provinces	Dictricts	Assemblages
Greater Maputaland-Pondoland-Albany-Cape	Bushveld	ECBv, LiE, Spb, Wtb & WCBv
	Middleveld	Mdv
	KZN-Mpu Escarpment	KZE, KZME & MpE
	Maputaland	Mpt
	Natal-E Escarpment	Emd, KZCM & WIEE
	Pondoland-S Transkei	PST
	Albany	Amt & Cal
	Cape	Kny, LtK & SWC
Mesic Highveld	Mesic Highveld	EECEM, Edb, NMHv, NWKZ, SMHv, WECE & WDb
Dry Highveld	Dry Highveld	Mgb, NDHv & SDHv
Karoo-Highveld Transition		KrHv, Snb
Lower Karoo*	Lower Karoo	LwK
Kalahari-Upper Karoo*	Kalahari & Upper Karoo	KlUpK
Lowveld*	Lowveld	Mpn, MLv & WLV

Figure 2. Zoogeographical regionalisation of eastern South Africa, Lesotho and Swaziland based on the distribution of (a) Anura, (b) Squamata and (c) combined herpetofauna. Herpetofaunal assemblages (bordered by thin grey lines) are labelled with acronyms on each map and given in accompanying tables, with their hierarchical allocation to districts (named in tables and boundaries denoted by thick red lines on maps) and to provinces (named in tables and boundaries denoted by thick black lines on maps). Province marked with * extends extralimital to the study area hence their assignment to the "Province" rank is not confirmed. Acronyms for assemblage names are: Alb –

Albany; AlC – Albany Coast; Amt – Amatolas; CBv – Central Bushveld; ECBv – East of Central Bushveld; ECEM – Eastern Cape Escarpment-Midlands; EDb – Eastern Drakensberg; EECE – East of Eastern Cape Escarpment; EECEM – East of Eastern Cape Escarpment- Eastern Cape Midlands; Emd – Eastern Midlands; Kl – Kalahari; KlUpK – Kalahari-Upper Karoo; Kny – Knysna; Kr – Karoo; KrHv – Karoo–Highveld Transition; KZC – KwaZulu-Natal Coast; KZCM – KwaZulu-Natal Coast–Midlands; KZE – KwaZulu-Natal Escarpment; KZEM – KwaZulu-Natal Escarpment–Midlands; KZME – KwaZulu-Natal-Mpumalanga Escarpment; KZMEM – KwaZulu-Natal-Mpumalanga Escarpment-Midlands; LESW – Limpopo Escarpment-Soutpansberg-Waterberg; LiE – Limpopo Escarpment; LtK – Little Karoo; LwK – Lower Karoo; LwKE – Lower Karoo-Escarpment; Mdv – Middleveld; Mgb – Magaliesberg; MHv – Mesic Highveld; MLv – Mozambique Lowveld; MpE – Mpumalanga Escarpment; Mpn – Mopane; Mpt – Maputaland; NDHv – Northern Dry Highveld; NMHv – Northern Mesic Highveld; NWC – North-western Cape; NWKZ – North-western KwaZulu-Natal; Pnd – Pondoland; PST – Pondoland-Southern Transkei; SDHv – Southern Dry Highveld; SMHv – Southern Mesic Highveld; SEDHv – South-eastern Dry Highveld; Snb – Sneeuberg; Spb – Soutpansberg; STr – Southern Transkei; SWC – South-western Cape; SWDHv – South-western Dry Highveld; UpK – Upper Karoo; WCBv – West of Central Bushveld; WDb – Western Drakensberg; WECE – West of Eastern Cape Escarpment; WECEM – West of Eastern Cape Escarpment-Midlands; WlEE – Wolkberg-Eastern Escarpment; WlEEM – Wolkberg -Eastern Escarpment-Midlands; WLV – Western Limpopo Valley; WLVM – Western Limpopo Valley-Mopane; Wtb – Waterberg.

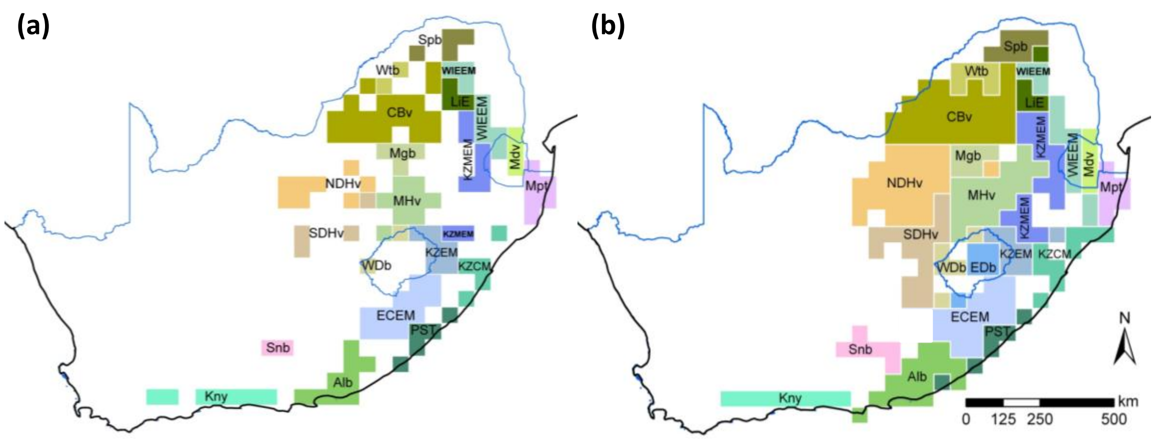


Figure 3. The first and second order consensus regionalisations for herpetofauna in eastern South Africa, Lesotho and Swaziland, based on the consensus between single taxon analyses (for Anura and Squamata) and the combined herpetofauna: (a) first order consensus - HDSs assigned to similar assemblages in single-taxon (Anura and Squamata) analyses and (b) second order consensus - if recovered from the combined analysis as well. See the caption of Fig. 2 for assemblage names denoted by acronyms.

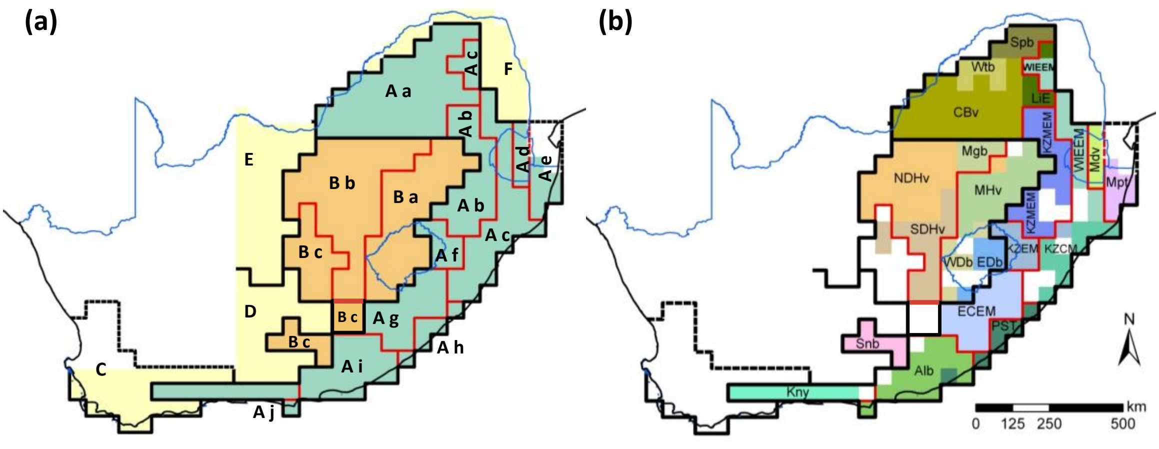


Figure 4. Herpetofaunal regionalisation of eastern South Africa, Lesotho and Swaziland. (a) Herpetogeographical provinces (bordered by thick black lines and denoted by upper case letters) and districts (bordered by red lines and denoted by lower case letters) of the south-east African dominion: A - Greater Maputaland-Pondoland-Albany (a – Bushveld, b - KwaZulu-Natal-Mpumalanga Escarpment-Midlands, c - Natal-Eastern Escarpment, d – Middleveld, e – Maputaland, f - KwaZulu-Natal Escarpment, g - Eastern Cape Escarpment-Midlands, h - Pondoland-S Transkei, i- Albany, and j – Knysna); B – Highveld (a - Mesic Highveld, b - Dry Highveld, and c - Karoo-Highveld Transition); C – Cape; D – Lower Karoo; E – Kalahari- Upper Karoo; F - Lowveld. Provinces C-F extend outside the study area and their extralimital boundaries are not known (the boundary of the Cape Province is suggested based on that of the Cape Floristic Region). No attempt was made to establish districts and assemblages of these Provinces. (b) Herpetogeographical assemblages within each district, denoted by different colours and acronyms (see the caption of Fig. 2 for assemblage names denoted by acronyms)

Patterns of herpetofaunal richness and endemism

The species richness patterns (Fig. 5a) show partially complementary peaks in single-taxon patterns for Anura and Squamata, but a consistent high diversity of herpetofauna (combined pattern) in the south-eastern Africa, especially along the Escarpment and the coastal belt. An eastwards gradient of species richness from middle to eastern longitudes of South Africa (roughly along a transect from Kimberley to the coast of Maputaland) is clear on the maps. A comparatively high diversity area in the west can be seen along the southern coast and especially in south-western Cape, but not in the western interior (not included in our study area; see Poynton & Broadley, 1978; Crowe, 1990). A Maputaland-Natal anuran centre of diversity is evident, while squamate diversity peaks along the Eastern Escarpment, and the Albany-Knysna is a centre of combined herpetofaunal diversity. The Bushveld region also shows a comparatively high diversity for squamates, but not for anurans.

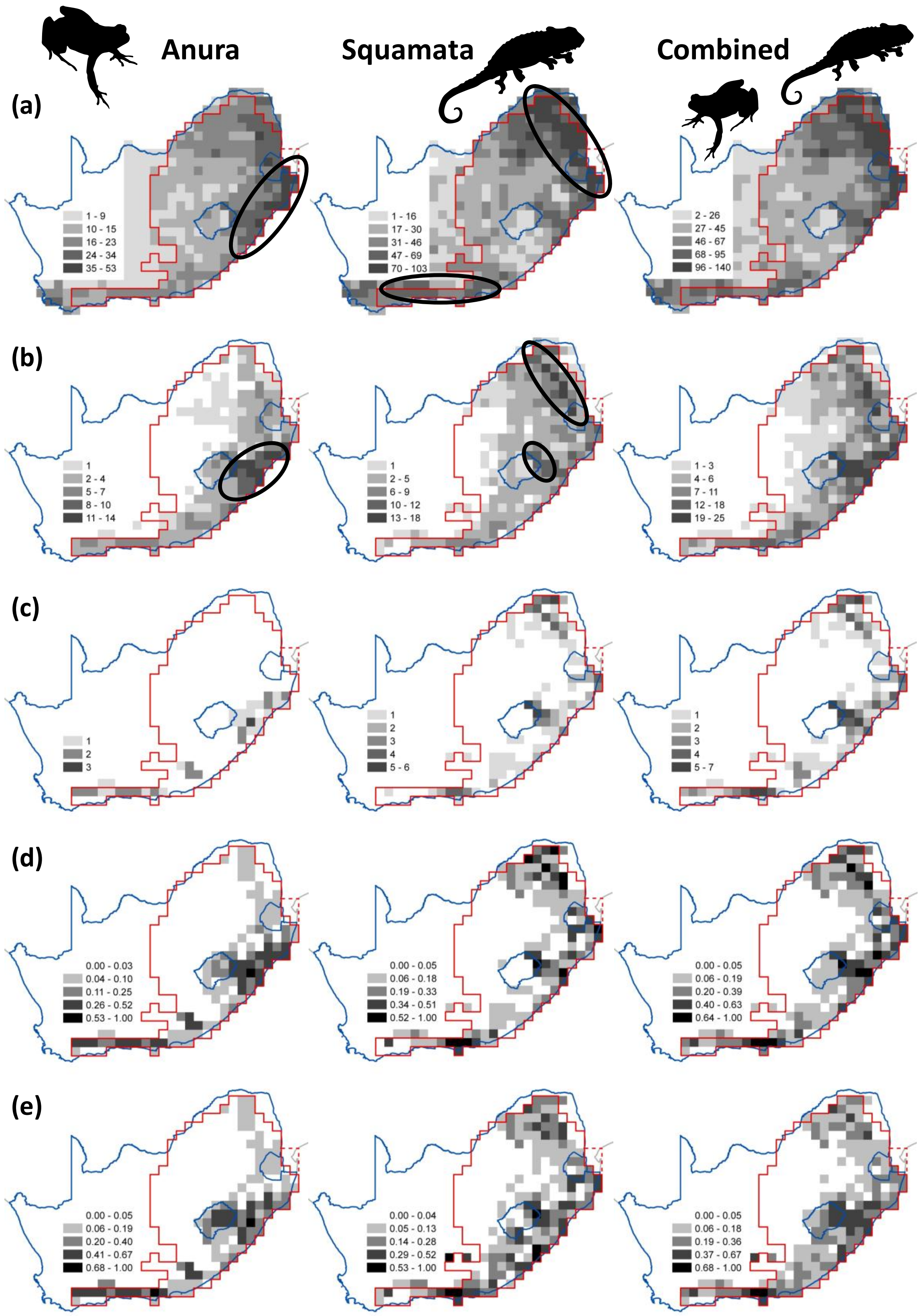


Figure 5. Spatial pattern of species richness and quantitative measures of endemism for Anura, Squamata and the herpetofauna combined (columns indicated by relevant symbols), in south-eastern Africa, given along rows; (a) species richness, (b) south-east African endemic species richness, (c) narrow endemism (range-restricted species richness), (d) weighted endemism, and (e) weighted

endemism corrected for the species richness. Peaks of species richness and endemism within south-eastern Africa are indicated by circles in rows (a) and (b). Zoogeographical margin for South-eastern Africa, derived for herpetofauna based on quantitative analysis (see Fig. 3; text for details) is denoted by the red line.

Spatial patterns mapped for four measures of herpetofaunal endemism (Fig. 5b-e) indicate high values along and below the Escarpment. Anuran endemism is more concentrated around the coastal and mid-altitude KwaZulu-Natal, while squamate endemism extends towards the Eastern Escarpment from the south-eastern coast, and even further inland to the eastern Bushveld. High herpetofaunal endemism is also evident in the Knysna assemblage, which is transitional between the GMPA region of endemism and the CFR. Between the Anura and Squamata, the patterns of endemism are largely congruent (if high endemism areas are more extensive in Squamata), as opposed to the partial complementarity in species richness pattern.

The results also show a high overall level of congruence between the diversity and endemism centres for herpetofauna in south-eastern Africa (though this relationship differs among study taxa). Our combined herpetofaunal dataset shows a comparatively good correlation (r^2 = 0.44) between the number of endemic species and the species richness in HDSs of south-eastern Africa (all HDSs belong to the GMPA and Highveld provinces in any of the single taxon or combined regionalisations), while the narrow endemism is less correlated with species richness (r^2 = 0.24). The correlation between the species endemism and richness is higher in Squmata (r^2 = 0.52) than in Anura (r^2 = 0.44).

Areas and centres of herpetofaunal endemism

The PAE defines a set of eleven AOEs for squamates, while anuran endemics only form four AOEs, largely congruent with some of those recognised in squamates (Fig. 6). An incongruence of anuran and squamate AOEs can be seen in the Maputaland-Natal-Pondoland area, where anuran endemics define a Natal-Pondoland AOE, without including Maputaland, while squamate endemics define a separate Maputaland-Natal AOE, giving Pondoland the status of an AOE on its own. The South-western Cape AOE, although it rests completely within our study area (south of 33ºS) for Anura, it extends north along the west coast of South Africa for squamates. AOEs with high species endemicity (≥4 endemic species) for the relevant taxa are recognised here as COEs; the South-western Cape for Anura (Fig. 6a) and the Wolkberg-Eastern Escarpment, Maputaland-Natal, Albany-Amatola and Knysna for Squamata (Fig. 6b). Only five herpetofaunal AOPEs are detected within the study area while they are all nested within COEs; two for Anura (HDSs 3318C and 3419A, both nested within the South-western Cape COE; Fig. 6a) and three for Squamata (HDSs 2430D, 2930D and 3324C, nested within Wolkberg-Eastern Escarpment, Natal-Pondoland and Knysna COEs, respectively; Fig. 6b).

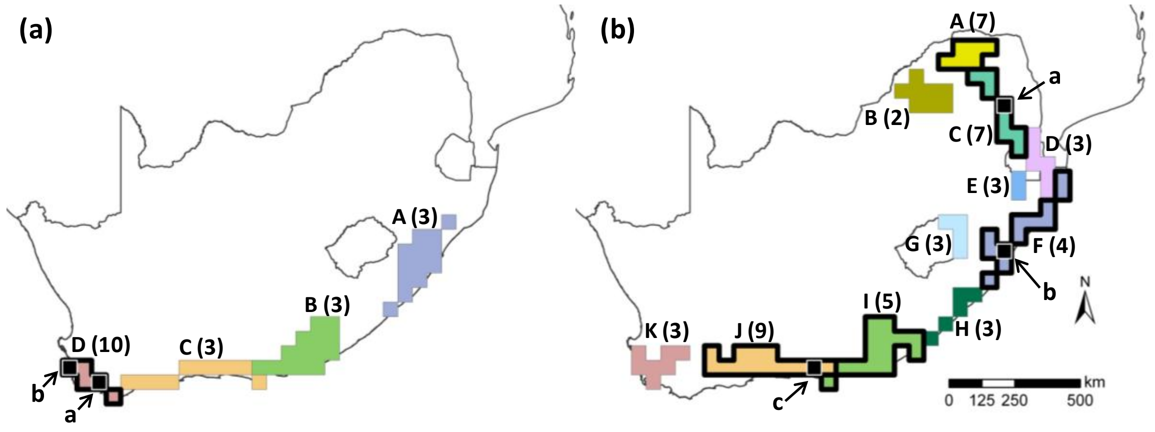


Figure 6. Areas of endemism (AOEs) and areas of point endemism (AOPEs) for Anura and Squamata in south-eastern Africa, identified from Parsimony Analysis of Endemicity on the incidence of species in half-degree-squares: (a) Anura: AOEs – A- Natal-Pondoland, B- Albany-Amatola, C- Knysna and D-South-western Cape; AOPEs (Half-degree-square; HDS) – a-3419A and b-3318C; (b) Squamata: AOEs – A- Soutpansberg, B- Waterberg, C- Wolkberg-Eastern Escarpment, D-Lebombo, E-Pongola, F- Maputaland-Natal, G- KwaZulu-Natal Escarpment, H- Pondoland, I- Albany-Amatola, J-Knysna and K-South-western Cape; AOPEs (HDSs) – a-2430D, b-2930D and c-3324C (HDS labels follow Larsen *et al*., 2009). AOEs with thick borders are regarded as centres of endemism (with more than or equal to four congruent endemics in either study taxa). Number of species endemic to each AOE is given in parenthesis. See Table 2 for species endemic within each AOE and text for details.

Species endemic within each AOE are listed in Table 2. A few genera that show high levels of radiation within some of the AOEs are noteworthy: for Anura - *Cacosternum* in Natal, *Heleophryne* in Albany-Knysna area and a remarkable radiation of *Arthroleptella* in the south-western Cape; and for Squamata - *Afroedura* in AOEs along the Eastern Escarpment, *Scelotes* in and around Maputaland, *Bradypodion* in the Maputaland-Natal-Pondoland areas, and especially in the Knysna area. Each AOPE harbours two endemic species exclusive to them: for Anura - *Arthroleptella lightfooti* and *Heleophryne rosei* in 3318C and *Arthroleptella drewesii* and *A. rugosa* in 3419A; and for Squamata - *Afroedura* sp. "Mariepi" and *A.* sp. "Rondavelica" in 2430D, *Aparallactus guentheri* and *Scelotes guentheri* in 2930D and *Bradypodion* sp. "Baviaans" and *B.* sp. "Jagersbos" in 3324C.

Areas of Endemism for		Endemic Species
Anura	**Squamata**	
	Soutpansberg (7)	**Squamata:** *Acontias richardi, Afroedura* sp. "Pienaari", *Af.* sp. "Soutpansbergensis", *Australolacerta rupicola, Homopholis mulleri, Platysaurus monotropis* & *P. relictus*
	Waterberg (2)	**Squamata:** *Afroedura* sp. "Waterbergensis" & *Lygodactylus waterbergensis*
	Wolkberg-Eastern Escarpment (7)	**Squamata:** *Acontias rieppeli, Afroedura major, Af.* sp. "Mariepi", *Af.* sp. "rondavelica", *Af.* sp. "Rupestris", *Lygodactylus methueni* & *Tetradactylus eastwoodae*
	Lebombo (3)	**Squamata:** *Leptotyphlops telloi, Platysaurus lebomboensis* & *Scelotes arenicolus*
	Pongola (3)	**Squamata:** *Afroedura* sp. "Lebomboensis", *Af.* sp. "Pongolae" & B*radypodion ngomeense*
	Maputaland-Natal (4)	**Squamata:** *Bradypodion caeruleogula, B. nemorale, Scelotes guentheri* & *S. inornatus*
Natal-Pondoland (3)		**Anura:** *Anhydrophryne ngongoniensis, Cacosternum poyntoni* & *C.* sp. "A"
	KwaZulu-Natal Escarpment (3)	**Squamata:** *Bradypodion sp.* "Emerald", *Montaspis gilvomaculata,* & *Pseudocordylus langi*
	Pondoland (3)	**Squamata:** *Acontias poecilus, Bradypodion caffer* & B. kentanicum
Albany-Amatola (3)	**Albany-Amatola** (5)	**Anura:** *Anhydrophryne rattrayi, Heleophryne hewitti* & *Vandijkophrynus amatolicus*
		Squamata: *Afroedura amatolica, Bitis albanica, Cryptactites peringueyi, Nucras taeniolata* & *Scelotes anguineus*
Knysna (3)	**Knysna** (9)	**Anura:** *Afrixalus knysnae, Heleophryne orientalis* & *H. regis*
		Squamata: *Afroedura* sp. "Kouga", *Bradypodion* sp. "Barbatulum", *B.* sp. "Baviaans", *B.* damaranum, *B.* sp. "Groendal", *B.* sp. "Grootvadersbosch", *B.* sp. "Jagersbos", *B. taeniabronchum* & *Cordylus aridus*
South-western Cape (10)	South-western Cape (3)	**Anura:** *Amietophrynus pantherinus, Arthroleptella drewesii, Ar. landdrosia, Ar. lightfooti, Ar. rugosa, Ar. villiersi, Heleophryne rosei, Microbatrachella capensis, Poyntonia paludicola* & *Xenopus gilli*
		Squamata: *Afroedura hawequensis, Cordylus niger* & *Hemicordylus nebulosus*

Table 2. Areas of endemism for Anura and Squamata in south-eastern Africa, identified from Parsimony Analysis of Endemicity on the incidence of species in half-degree-squares (dendrograms not provided). Areas given in bold letters are treated here as centres of endemism (with more than or equal to four congruent endemic species for either of study taxa. See Fig. 6 for the map.

DISCUSSION

Methods Revisited

Regionalisation

We attempted to achieve a robust regionalisation using numerical methods, starting with a set of rules, and then seeking consensus between single taxon and combined regionalisations. Nevertheless, the final regionalisation for herpetofauna involved a few manual amendments incorporating the knowledge from previous regionalisations to interpret the output of our numerical analyses.

(a) The results for individual taxon analyses diverged at the western limit of the GMPA province. Only the Knysna assemblage is included in the GMPA province in the anuran dendrogram, whereas the entire CFR is included in the squamate dendrogram. A similar incongruence was evident between the single taxon analyses for reptiles and amphibians, between the sub-region boundaries within the Southern Africa Region of Linder *et al.* (2012), as well as in the biogeographical zones defined by Crowe (1990). Linder *et al.* (2012) recognised (a) a South-western Cape as a separate sub-region different from the South Africa sub-region, in their amphibian regionalisation and (b) a reptile pattern different from all other vertebrate groups in southern Africa, where the Cape clusters with a broader eastern South Africa. Poynton (1960) also identified the amphibian fauna of the South-western Cape as a southern temperate fauna different from that of the east. Consulting previous zoogeographical analyses for amphibians (Crowe 1990; Alexander *et al.*, 2004; Linder *et al.* (2012), and for endemic vertebrates (Perera *et al.*, 2013b), we have included the Knysna assemblage into the GMPA province (as a transitional extension; Perera *et al.*, 2011, 2013a), leaving the South-western Cape as a separate province.

(b) The Sneeuberg assemblage was a part of the GMPA-Cape province for squamates, but not for anurans, where it clustered with the Lower Karoo. However, in the combined analysis, the Sneeuberg diverged early in the tree, giving it a province rank on its own, while this analysis also identified a similarly early-diverging province transitional between the Karoo and the Highveld. The early divergence, and hence the assignment of province rank for these clusters is believed to be an artefact resulting from the exclusion of western South Africa in the analysis. Hence, we included both of them into the closest province in the tree, the dry Highveld, as representing a district of the Karoo-Highveld transition. In doing so, the western part of the Eastern Cape escarpment (clustered in the wet Highveld) was also joined to the Karoo-Highveld transition, as is the case for Anura. The inclusion of the Sneeuberg into the GMPA province, as a transitional extension in the regionalisation for endemic vertebrates (Perera *et al.*, 2013b) is disputed here due to its distant placement in the dendrogram, and needs further investigation.

(c) Assemblages spatially located within the Lowveld bioregion (Mucina & Rutherford, 2006) were found geographically scattered in all three (anuran, squamate and combined) dendrograms. This may also an artefact of the incomplete inclusion of the entire Lowveld bioregion in our study area, constrained by the data unavailability beyond the political boundary of South Africa, and hence corrected manually (see Appendix S1)

(d) In the UPGMA cluster dendrogram for Anura (Appendix S1 a), the geographically widely separated assemblages of the South-western Cape and the Maputaland cluster together. This can only be caused by the shared presences of widespread species, as none of the characteristic endemics in these assemblages are shared. The species these assemblages share with the areas extralimital to the study area are not counted in the analysis, giving precedence to the shared and widespread species found in both assemblages when calculating the similarity. Therefore, we manually placed the South-western Cape assemblage within the Cape district (see Appendix S1c).

(e) The combined and squamate analyses did not cluster the Eastern Cape Escarpment-Midlands and the North-western KwaZulu-Natal assemblages with the GMPA province, as was the case in anuran analysis. This is caused by these assemblages representing gaps for endemism (see Perera *et al*., 2011, 2013b) not sharing many of the GMPA-wide endemics, possibly due to unique historical causes. So that, the few GMPA endemic elements in them are overshadowed by the shared widespread species occupying both the Highveld and the GMPA provinces, causing them to cluster with the Highveld province. Hence, these two assemblages are manually allocated to the GMPA province in the final regionalisation, in conformity with previous regionalisations.

Only the phenetic approach of biogeographic regionalisation (UPGMA clustering) was used here in regionalisation, as it had greater power in establishing hierarchical relationships between geographic units (Perera *et al.*, 2013a). The parsimony approach (PAE) regionalised units giving a higher weight to shared endemic species, rather than the entire species assemblage as is the case in phenetics (Perera *et al.*, 2013a). Even though UPGMA clustering has been proven to provide rigorous results at 1° scale for global (Kreft & Jetz, 2010) and African (Linder *et al*., 2012) regionalisations, that did not attempt to resolve the lower levels of biogeographical hierarchy (such as assemblages), our results suggest that biogeographically-informed adjustments are required for local scale regionalisations specifically targeting finer levels of the hierarchy. This is particularly correct in a context where the study area is not bordered by well-defined biogeographical barriers to cause vicariant speciation within its limits. In such cases the “edge effects” of the numerical classification needs to be manually dealt with, incorporating the existing biogeographical knowledge of the area.

Patterns of endemism

Among the measures of endemism we mapped, not much of a difference was observed between the WE and the WECSR (compare Fig. 5d and 5e; correlation r^2 = 0.78 between the two measures for the combined herpetofauna). This is because our dataset shows a high correlation between species richness and endemism (r^2 = 0.44). Furthermore, the lower correlation between the WE and species richness in our dataset (r^2 = 0.39) indicates that there is little residue from species richness to be reduced in the WE values for HDSs. Slatyer *et al*. (2007) argue against the WECSR, stating that this measure (a) is less sensitive to the presence of narrow endemic species, and (b) produces high endemism values for poorly sampled areas where widespread species are under-sampled, as compared to the WE. Our correlation between the WE and species richness is comparable to that (r^2 = 0.30) of Slatyer *et al*. (2007), and is much lower compared to that (r^2 = 0.76) of Crisp *et al*. (2001) that was used to justify the use of WECSR over the WE. Therefore, we agree with Slatyer *et al*. (2007) preferring the WE over CWE, and recommend the use of CWE only if the WE is highly correlated with species richness.

Areas of endemism

The PAE detected better resolved AOEs when a higher number of characters (species in our data) are involved (i.e. a well-structured dendrogram for the 333 species of squamates, but a more pronounced basal polytomy with fever clusters for the 112 species of anurans; dendrograms not presented). In order to account for this problem with the anuran database, and to provide more biogeographically meaningful AOEs, three of the clades that were scattered in the basal polytomy (representing the Natal Midlands, the Albany coastal belt and the Little Karoo) and carrying only single endemic species, but geographically adjoining AOEs defined by two or more endemic species (the Natal-Pondoland, the Albany-Amatola and the Knysna, respectively) were merged to those AOEs. Furthermore, *Anhydrophryne rattrayi*, largely endemic to the Hogsback forest [however, with a single positively identified record representing a considerable range extension, that has not been confirmed ever since its initial collection in 1961; Minter *et al.*, (2004)] is considered here as a Hogsback endemic. The recovery of 2930D as an AOPE for squamates is noteworthy, as both the species responsible for this identification (*Aparallactus guentheri* and *Scelotes guentheri*) are, based on collections to date, point endemics occupying a single coastal QDS (2931CC), which does not contribute to an HDS with >25% cover of land. Hence, this QDS was removed from the analysis, but the species were allocated to the closest HDS, which is 2930D.

A PAE involving a simultaneous analysis of a multi-taxon combined dataset is reported to maximise cladistic parsimony (Nixon and Carpenter, 1996), better identifying AOEs, than is the case for subsets of the database. Our results for the PAE conducted for the combined database of herpetofauna (445 species) is consistent with this observation, resulting in a better structured dendrogram (not presented here), than for any of the single taxon analyses. But, following Morrone *et al.* (1999), we have presented only those AOEs detected individually for Anura and Squamata, in order to see if they are congruent. Furthermore, this approach provides more taxon-relevant information important for conservation.

Comparison of our findings with previous herpetofaunal regionalisations

Amphibian regionalisation studies in the area date back to Poynton (1960), who identified a broad transition zone of amphibian zoogeography in south-eastern Africa, between the Afrotropical fauna of East Africa and the southern temperate fauna of the Cape. According to him, this transition zone harbours four localised centres of endemism, out of which the two eastern transitional centres when combined are congruent with the SEAD, an eastern tropical transitional (a zone of southward subtraction of the tropical fauna along the south-eastern coast), and an eastern temperate transitional (a zone of northward subtraction of the temperate fauna along the South-eastern Escarpment and the Highveld). Poynton (1961) further emphasised the transitional nature of the area's biota adding plants, vertebrates as well as invertebrate taxa into his analysis. The SEAD has recently been proposed as a zoogeographical dominion in congruence for both vertebrates (Perera *et al*., 2013b) and invertebrates (Perera *et al*., 2013a), based on numerical analyses using qualitatively defined OUGs (zoogeographical units for south-eastern Africa; Perera *et al*., 2011), harbouring two provinces; the GMPA and the Highveld. This demarcation is consistent with Crowe's (1990) "9-shaped configuration" in south-eastern Africa for vertebrates, of which the northern border is demarcated by the Limpopo river valley, while the "tail" of the 9 is made up by the southern or south-western Cape. Herpetogeographical entities of similar geographical extent proposed by subsequent studies on the area are summarised in the Table 3, in comparison to the results of the present study. Here we compare our GMPA province without the Bushveld and Knysna districts, while those districts are included in the comparison as separate entities, as their inclusion varies across studies.

<table>
<tr><th colspan="2">Current study - frogs & Squamate reptiles combined</th><th>Poynton (1960) - frogs</th><th>Crowe (1990) - frogs</th><th>Crowe (1990) - Lizards</th><th>Crowe (1990) - snakes</th><th>Poynton (1999) - frogs</th><th colspan="2">Seymour (2001) - frogs</th><th colspan="2">Alexander et al. (2004) - frogs</th><th>Linder et al. (2012) - frogs</th><th>Linder et al. (2012) - reptiles</th><th colspan="2">Linder et al. (2012) - vertebrates & plants combined</th></tr>
<tr><th>Dominions</th><th>Provinces & Districts</th><th>localised centres of endemism</th><th>Zones</th><th>Zones</th><th>Zones</th><th>convenient areas for distributional discussion</th><th>Sub-regions</th><th>Provinces</th><th>Sub-regions</th><th>Districts & Assemblages</th><th>Regions & Sub-regions</th><th>Regions & Sub-regions</th><th>Regions</th><th>Sub-regions</th></tr>
<tr><td rowspan="4">South-east African (SEA)</td><td>Bushveld District</td><td rowspan="4">Eastern tropical transitional
Eastern temperate transitional</td><td rowspan="4">East-south (the 9-shaped configuration)</td><td rowspan="3">East-North-south + East-South-north (the 9-shaped configuration)</td><td>East-North-south</td><td>Mid Southern (extends north)</td><td colspan="2">Zambezia — Tropical South
(extends north)</td><td rowspan="4">Eastern</td><td>Bushveld D (extends north)</td><td rowspan="4">Southern African Region (extends north)</td><td rowspan="5">South African Sub-region (almost exact match except in the Bushveld)</td><td rowspan="5">Southern African Region (extends north)</td><td rowspan="2">Kalahari (extends north)</td></tr>
<tr><td>Highveld Province</td><td rowspan="4">East-South (the 9-shaped configuration)</td><td>South Central</td><td rowspan="4">South/south-east</td><td rowspan="2">Highveld/Escarpment</td><td>Central D</td></tr>
<tr><td>GMPA Province (except Bushveld & Knysna)</td><td rowspan="3">South-east Lowland
Southern Temperate</td><td rowspan="2">Eastern Escarpment/Coastal District</td><td>Natal</td></tr>
<tr><td>Knysna District</td><td rowspan="2">East-South-south</td><td rowspan="2">Cape Fold Mountain</td><td rowspan="2">Cape</td></tr>
<tr><td>Extension of SEA? or Cape</td><td>South-western Cape District</td><td>Southern Temperate</td><td>West-South (extends north)</td><td>Western</td><td>South-western Cape A</td><td>Cape Sub-region</td></tr>
</table>

Table 3. Herpetogeographical entities of previous studies in comparison to the south-east African dominion and the Highvel and Greater Maputland-Pondoland-Albany districts proposed by the current study.

The current analyses (both for squamates and the combined datasets) support a monophyletic geographical cluster joining the SEAD with the Cape Region (as is the case for reptiles in both Crowe, 1990 and Linder *et al*., 2012). This may be a pattern inherent in reptile distributions, while the Cape separates out clarifying the western limits of the SEAD when different biogeographical elements are brought into analyses involving multiple taxa (as in Perera *et al*., 2013b). The Cape region is clearly separated, even including the Knysna assemblage in Linder *et al*.'s (2012) combined regionalisation, possibly due to the inclusion of plants in his study. The biogeographical validity of including the Cape Region in the SEAD needs to be further tested at a fine grain of analysis involving equal-area OGUs (a grid of QDS / HDS) for the entire southern African sub-continent.

However, the current analyses clearly confirm two distinct zoogeographical provinces – the GMPA and the Highveld, which combined are congruent with the SEAD as previously published. But, contrary to the demarcation of GMPA in previous studies, the present analysis includes Bushveld region into it. This inclusion may represent a genuine pattern inherent in herpetofaunal biogeography, as reptiles show high species richness at least in the eastern section of the Bushveld (more so than all other vertebrate groups). But the results of previous studies (summarised in Table 3) suggest it could also be an artefact of the methods used in the present study, as the savanna regions north of the Limpopo River are not included, as constrained by the availability of data. Some of the Africa-wide analyses given in Table 3 have excluded the Bushveld from GMPA-similar biogeographical entities. The transitional nature of the Knysna assemblage is also visible in the Table 3, given its inconsistency in being recovered as a part of GMPA-similar entities. Consequently, we included both Knysna and the Bushveld into the SEAD here, but are considered transitional extensions of the GMPA.

The only previous study on herpetofaunal regionalisation in the area to present assemblage-level entities is the one on amphibians by Alexander *et al*. (2004). Most of their assemblages are comparable to the districts in our hierarchy. None of the previous regionalisations based on the reptile fauna of the area have approached as low a level as assemblages. Hence, the present study provides the finest available regionalisation for the herpetofauna in south-eastern Africa. At the same time, the zoogeographical assemblages derived here for each numerical analysis (Fig. 2) are highly congruent to the qualitatively defined zoogeographical units of Perera *et al*. (2011), confirming their legitimacy.

Species richness and endemism gradients

The gradient of species richness increasing from west to east along the middle latitudes of South Africa is consistent with patterns recorded previously for both amphibians (Poynton & Broadley, 1978; and du Preez & Carruthers, 2009), and reptiles (Crowe 1990), but with a second peak towards the west coast only for reptiles, that is not captured within our study area. Although the herpetofaunal species richness show a smooth eastwards gradient, endemism shows an abrupt increase once at the Great Escarpment. Spatial patterns mapped for several measures of endemism at HDS scale are comparatively similar to those Perera *et al*. (2013b) mapped for all vertebrates at the scale of zoogeographic units (Perera *et al*., 2011), as vertebrate endemism in south-eastern Africa is dominated by the herpetofauna. Although herpetofaunal richness peaks are partially complementary, the areas of endemism are largely congruent. It is believed that the former are driven predominantly by the ecological plasiticity in taxa that differ considerably, while the latter are driven by habitat heterogeneity in the area predominantly due to historical causes and affecting both taxa equally. The partial complementarity of diversity peaks between anurans and squamates can be explained by the water dependency and the lower ability to thrive in cool winters in amphibians (Poynton, 1964), as opposed to the lower ability of tolerating excessive wetness and the ability to exploit seasonally abundant resources in reptiles (Crowe, 1990). The high diversity and endemism (especially narrow endemism) of the herpetofauna along and especially below the Great Escarpment (its eastern slopes and the eastern coastal belt) can be credited to the habitat heterogeneity created by the rapid topographic variation and the parallel river valley systems flowing eastwards from the Escarpment intersecting the Midlands and the coastal plain. This has historically created refugia during the Pleistocene climatic cycles, and is also responsible for contemporary fire-free refugia in an otherwise fire-prone grassland/savanna matrix (see Perera *et al.*, 2013a,b and references therein). This unique pattern exhibited by all endemism measures mapped for the herpetofauna supports the delimitation of the GMPA region of animal endemism (Perera *et al.*, 2011, 2013a,b).

Endemism and conservation implications

While the AOEs are largely congruent between Anura and Squamata, the partial complementarity of their species richness conveys important considerations for conservation planning. This supports a multi-taxon approach in biodiversity assessments, rather than relying on a single surrogate/indicator taxon, while emphasising the need to incorporate both measures of species diversity and endemism in conservation prioritisation. Excitingly, all the AOPEs detected here are nested within one of the COEs, suggesting that these areas have undergone rapid rates of allopatric speciation within narrow ranges. This can be attributed to the refugial role these areas played for the herpetofauna during Pleistocene climate cycles, providing multiple sites for allopatric speciation within a small area. This makes these COEs carry not only a high species endemicity, but a great genetic heterogeneity, and possibly rapid rates of concurrent evolution and extinction too, making them high priority sites for conservation planning. Our results are consistent with Poynton & Broadley (1978) and Crowe (1990) in suggesting refugia that were environmentally complex, but remained comparatively stable during Plio-Pleistocene climate changes, and hence acted as centres of allopatric speciation resulting in contemporary centres of narrow endemism for frogs in south-western Cape, and for reptiles along the Eastern Escarpment. In addition to the above areas, the Maputaland-Natal-Pondoland and the Albany-Knysna areas, carrying COEs, are of high conservation importance.

CONCLUSIONS

This paper provides a first numerical regionalisation for the combined herpetofauna of the area, and one reaching deeper levels of zoogeographical hierarchy than any previous partial approaches. At the same time, a considerable degree of consensus is achieved for two monophyletic groups with different life histories, one essentially depending on the availability of water, and the other one not. Nevertheless, the study groups have physiological and ecological similarities such as poikilothermy and low dispersal abilities, causing similar evolutionary and geographical histories, and hence defining congruent areas of endemism.

The study highlights the different roles that different types of analyses can play. The use of atlas data and UPGMA hierarchical cluster analyses at the finest possible resolution provide opportunities to reveal otherwise unknown details in regional-scale zoogeography. PAE analyses involving larger databases, on the other hand, accurately define AOEs, from which centres of endemism of high conservation importance can be selected. Areas and centres of south-east African herpetofaunal endemism are reported here for the first time and provide information for conservation prioritisation in south-eastern Africa.

The pattern of endemism presented here is assumed to be overwhelmingly a product of the Plio-Pleistocene climate change and corresponding expansions and contractions of forest refugia (see Perera *et al.*, 2013a,b and references therein). In this context, the incorporation of phylogenetic data into the regionalisation (cf. Holt *et al*., 2013), as well as data on the phylogenetic relatedness of AOE endemics (especially narrow endemics) should inform any further progress in studying the herpetogeography of the area.

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BIOSKETCHES

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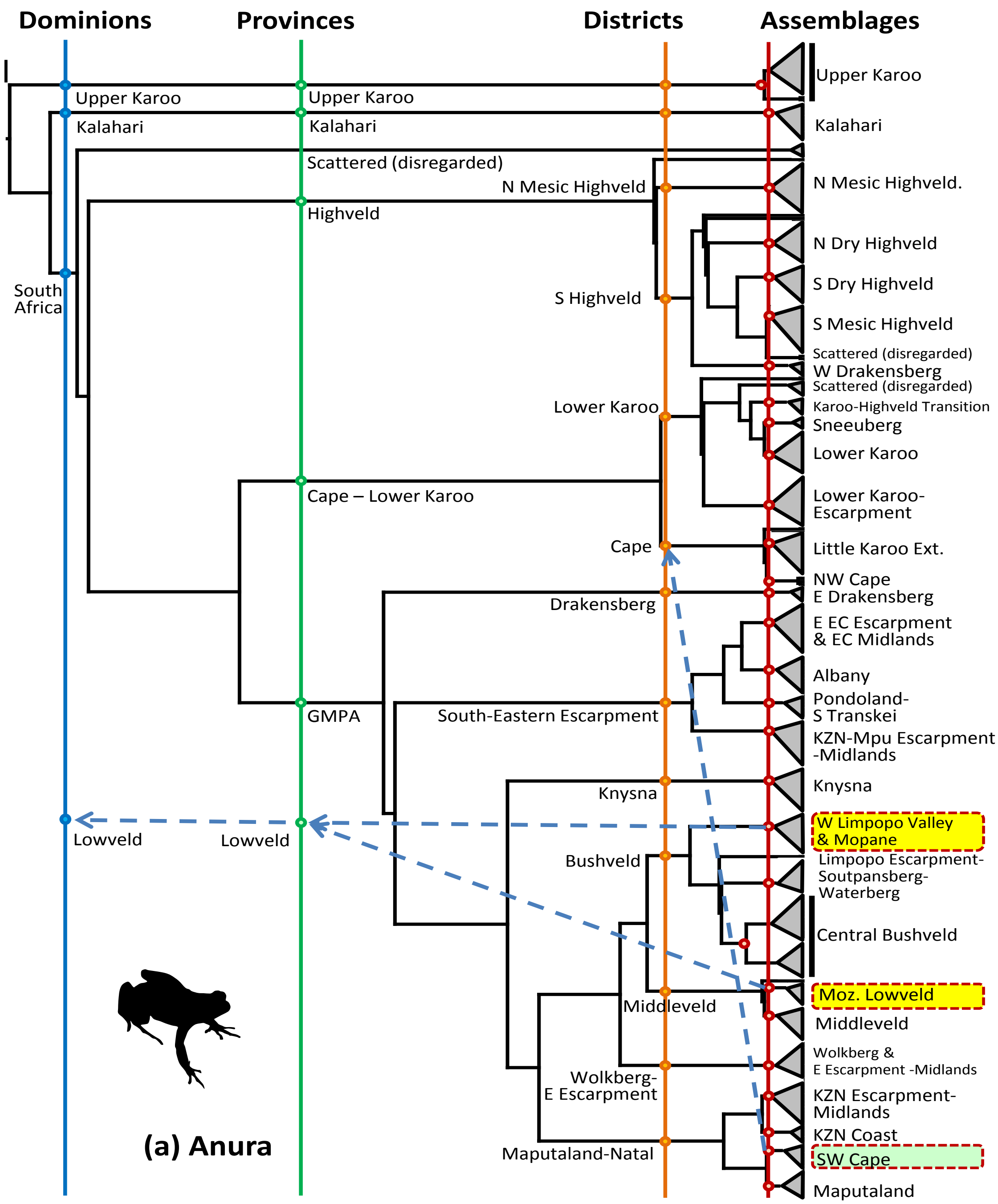
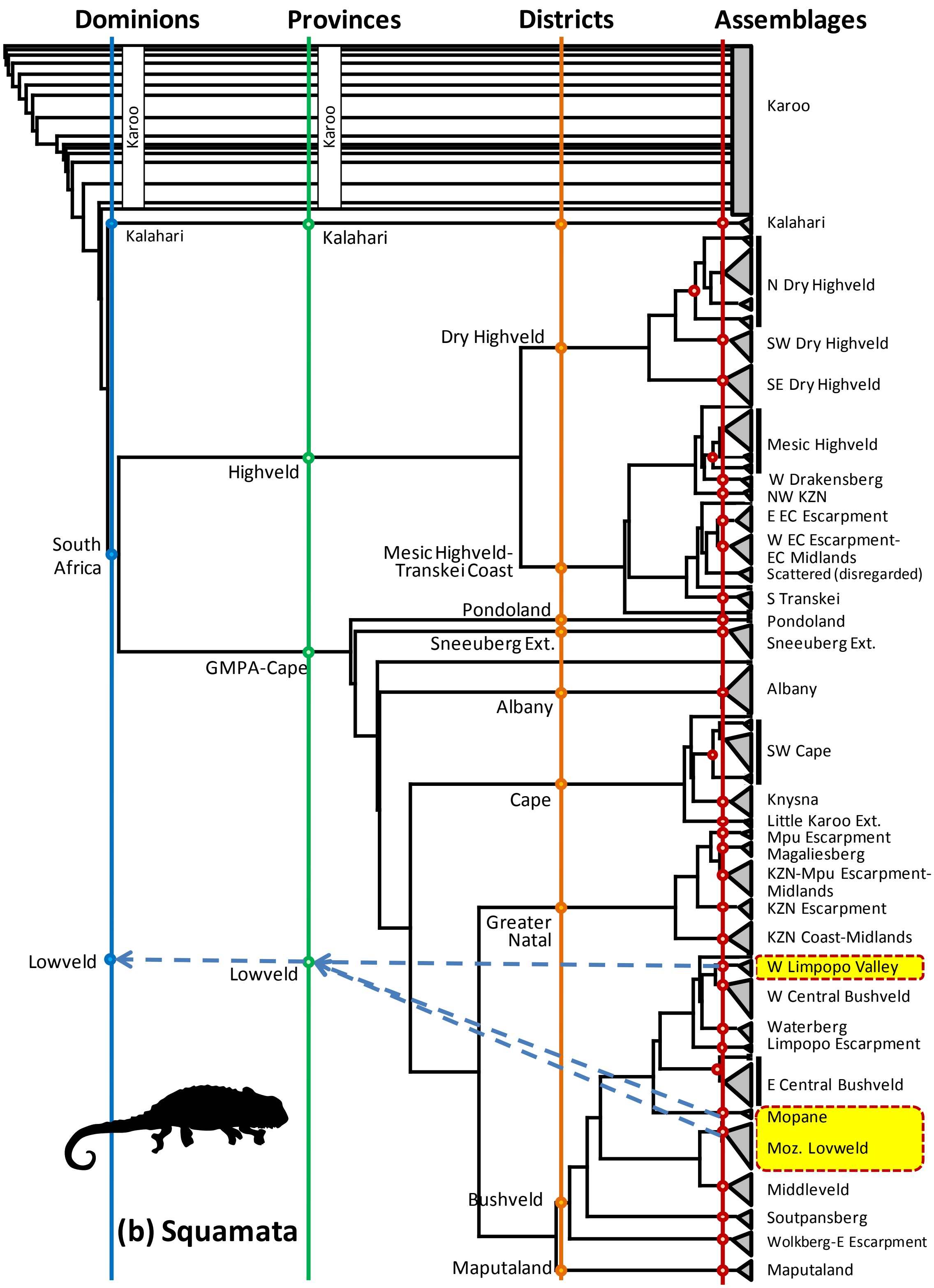
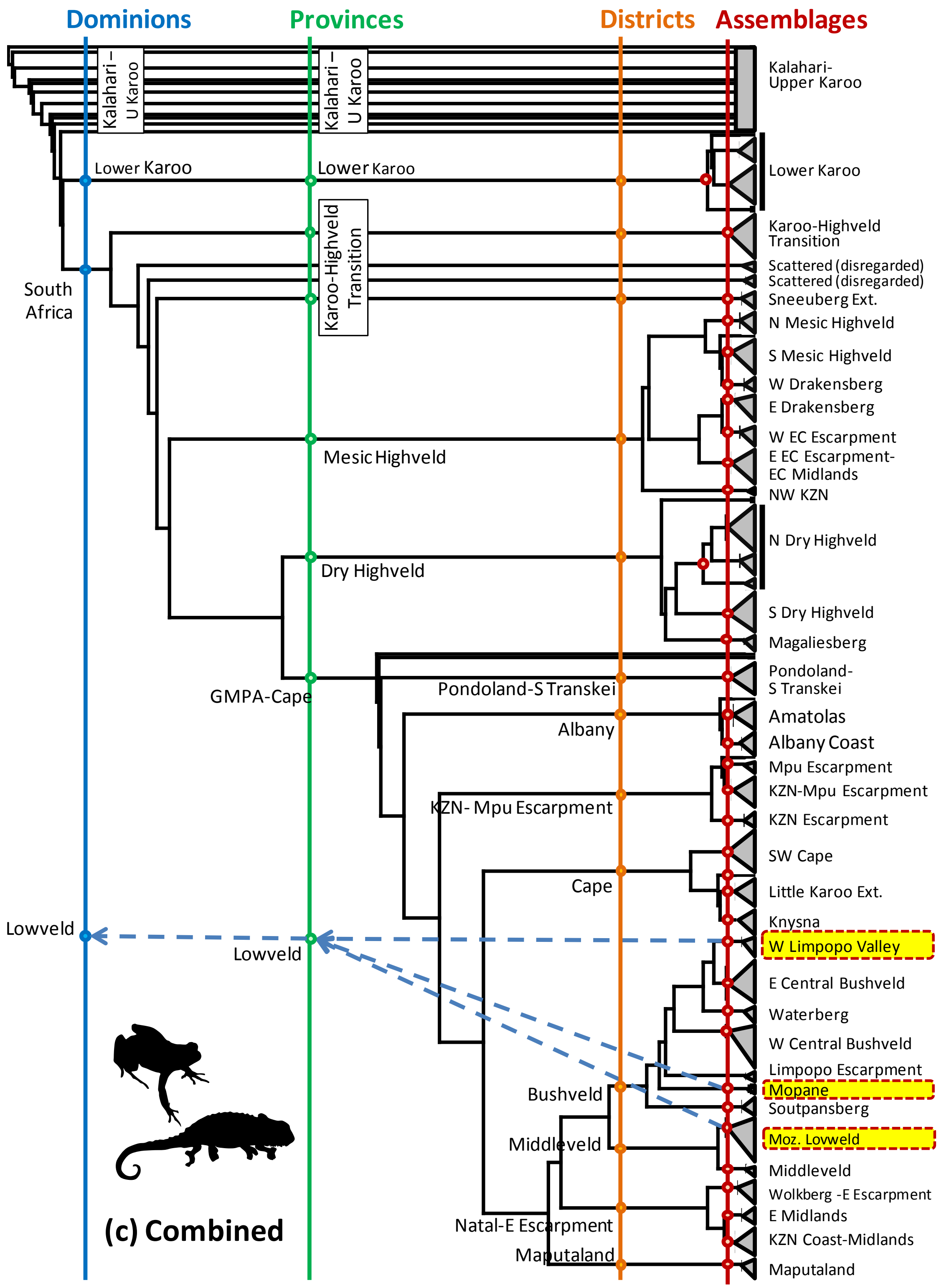
Appendix S1. Dendrograms of the UPGMA cluster analyses and their interpretation by phenon lines for individual taxon groups (a) Anura and (b) Squamata, and (c) for the combined dataset. Acronyms: EC – Eastern Cape; KZN – KwaZulu-Natal; Mpu – Mpumalanga; N – Northern; S – Southern; E – Eastern; W – Western; SW – South-western; SE – South Eastern; and NW – North Western.



Apprndix S1. Continued…



Appendix S1. Continued…



Appendix S2. The spatial congruence of assemblages recovered from UPGMA cluster dendrograms for the analysis of individual taxon incidence datasets for Anura and Squamata, for the combined dataset of herpetofauna and their contribution to achieve consensus on assemblages (n=22) for final herpetofaunal regionalisation.

<table>
<tr><th>Herpetofaunal (combined) assemblages</th><th>Anuran Assemblages</th><th>Squamate Assemblages</th><th>Herpetofaunal (consensus) assemblages</th><th>No.</th></tr>
<tr><td>Amatolas</td><td rowspan="2">Albany</td><td rowspan="2">Albany</td><td rowspan="2">Albany</td><td rowspan="2">1</td></tr>
<tr><td>Albany Coast</td></tr>
<tr><td rowspan="2">South-western Cape</td><td>South-western Cape</td><td rowspan="2">South-western Cape</td><td rowspan="2">South-western Cape</td><td rowspan="2">2</td></tr>
<tr><td>North-western Cape</td></tr>
<tr><td>East of Central Bushveld</td><td rowspan="2">Central Bushveld</td><td>East of Central Bushveld</td><td rowspan="2">Central Bushveld</td><td rowspan="2">3</td></tr>
<tr><td>West of Central Bushveld</td><td>West of Central Bushveld</td></tr>
<tr><td>Limpopo Escarpment</td><td rowspan="3">Limpopo Escarpment-Soutpansberg-Waterberg
(a disjunct cluster)</td><td>Limpopo Escarpment</td><td>Limpopo Escarpment</td><td>4</td></tr>
<tr><td>Soutpansberg</td><td>Soutpansberg</td><td>Soutpansberg</td><td>5</td></tr>
<tr><td>Waterberg</td><td>Waterberg</td><td>Waterberg</td><td>6</td></tr>
<tr><td>Eastern Drakensberg</td><td>Eastern Drakensberg</td><td>n.r.s.c.</td><td>Eastern Drakensberg</td><td>7</td></tr>
<tr><td>Western Drakensberg</td><td>Western Drakensberg</td><td>Western Drakensberg</td><td>Western Drakensberg</td><td>8</td></tr>
<tr><td>Northern Dry Highveld</td><td>Northern Dry Highveld</td><td>Northern Dry Highveld</td><td>Northern Dry Highveld</td><td>9</td></tr>
<tr><td rowspan="2">Southern Dry Highveld</td><td rowspan="2">Southern Dry Highveld</td><td>South-eastern Dry Highveld</td><td rowspan="2">Southern Dry Highveld</td><td rowspan="2">10</td></tr>
<tr><td>South-western Dry Highveld</td></tr>
<tr><td>East of EC Escarpment-EC Midlands</td><td>East of EC Escarpment-EC Midlands</td><td>n.r.s.c.</td><td rowspan="2">EC Escarpment-EC Midlands</td><td rowspan="2">11</td></tr>
<tr><td>n.r.s.c.</td><td>n.r.s.c.</td><td>East of EC Escarpment</td></tr>
<tr><td>West of EC Escarpment</td><td>n.r.s.c.</td><td>n.r.s.c.</td><td rowspan="4">NA (Not recovered in consensus)
Karoo-Highveld Transition ?</td><td rowspan="4"></td></tr>
<tr><td>n.r.s.c.</td><td>n.r.s.c.</td><td>West of EC Escarpment-EC Midlands</td></tr>
<tr><td>Karoo-Highveld Transition</td><td>Karoo-Highveld Transition</td><td>n.r.s.c.</td></tr>
<tr><td>n.r.s.c.</td><td>Lower Karoo-Escarpment</td><td>n.r.s.c.</td></tr>
<tr><td rowspan="2">Kalahari-Upper Karoo</td><td>Kalahari</td><td>Kalahari</td><td rowspan="3">NA (extends extralimital)</td><td rowspan="3"></td></tr>
<tr><td>Upper Karoo</td><td rowspan="2">Karoo</td></tr>
<tr><td>Lower Karoo</td><td>Lower Karoo</td></tr>
<tr><td>Knysna</td><td>Knysna</td><td>Knysna</td><td>Knysna</td><td>12</td></tr>
<tr><td>KZN Coast-Midlands</td><td>n.r.s.c.</td><td>KZN Coast-Midlands</td><td rowspan="2">KZN Coast-Midlands</td><td rowspan="2">13</td></tr>
<tr><td>n.r.s.c.</td><td>KZN Coast</td><td>n.r.s.c.</td></tr>
<tr><td>KZN Escarpment</td><td>n.r.s.c.</td><td>KZN Escarpment</td><td rowspan="2">KZN Escarpment - Midlands</td><td rowspan="2">14</td></tr>
<tr><td>n.r.s.c.</td><td>KZN Escarpment-Midlands</td><td>n.r.s.c.</td></tr>
<tr><td>North-western KZN</td><td>n.r.s.c.</td><td>North-western KZN</td><td>NA (Not recovered in consensus)</td><td></td></tr>
</table>

KZN-Mpu Escarpment	n.r.s.c.	n.r.s.c.	KZN-Mpu Escarpment-Midlands	15
n.r.s.c.	KZN-Mpu Escarpment-Midlands	KZN-Mpu Escarpment-Midlands		
Mpu Escarpment	n.r.s.c.	Mpu Escarpment		
Little Karoo (extended)	Little Karoo (extended)	Little Karoo (extended)	NA (extends extralimital)	
Magaliesberg	Magaliesberg (extended)	Magaliesberg	Magaliesberg	16
Maputaland	Maputaland	Maputaland	Maputaland	17
Middleveld	Middleveld	Middleveld	Middleveld	18
Northern Mesic Highveld	n.r.s.c.	n.r.s.c.	Mesic Highveld	19
Southern Mesic Highveld	n.r.s.c.	n.r.s.c.		
n.r.s.c.	Mesic Highveld	Mesic Highveld		
Mozambique Lowveld	Mozambique Lowveld	Mozambique Lowveld	NA (extends extralimital)	
Mopane	n.r.s.c.	Mopane		
Western Limpopo Valley	Western Limpopo Valley-Mopane	Western Limpopo Valley		
Pondoland-Southern Transkei	Pondoland-Southern Transkei	n.r.s.c.	Pondoland-Southern Transkei	20
n.r.s.c.	n.r.s.c.	Pondoland		
n.r.s.c.	n.r.s.c.	Southern Transkei		
Sneeuberg (extended)	Sneeuberg	Sneeuberg (extended)	Sneeuberg	21
Wolkberg-Eastern Escarpment	n.r.s.c.	Wolkberg-Eastern Escarpment	Wolkberg-Eastern Escarpment-Eastern Midlands	22
Eastern Midlands	Wolkberg-Eastern Escarpment-Eastern Midlands	n.r.s.c.		

* n.r.s.c. = not recognised as a separate/single cluster
NA (extends extralimital) = Not allocated to a consensus assmeblage as the unit(s) extends the limits of study area and the extralimita boundary of the unit(s) is/are unknown.
Three of the administrative Provinces of South Africa are abbreviated as EC = Eastern Cape, KZN = KwaZulu-Natal and Mpu = Mpumalanga

CHAPTER 6

General discussion and conclusions

The importance of understanding zoogeographical patters in south-eastern Africa was first emphasized by Poynton (1960, 1961), who identified the transitional nature of the region's biota between tropical East Africa and the southern temperate Cape region, while harbouring its own endemism with high species turnover. Unfortunately, the region's zoogeography has long been unattended since, despite some faunal studies on the whole of sub-Saharan Africa or southern Africa. Comparatively, the knowledge of the region's flora is more advanced. Intuitively defined centres of floristic endemism (van Wyk and Smith, 2001) in the area have led to the delimitation of the Maputaland-Pondoland-Albany (MPA) biodiversity hotspot (Mittermeier *et al*., 2004; Fig 1a). Indeed, all global biodiversity hotspots are intuitively delimited based on high floristic endemism. Their boundaries have seldom been tested based on endemism patterns observed in animals. The MPA hotspot is no exception, and that is the knowledge gap this thesis intended to fill. While studying the zoogeography of south-eastern Africa as a whole, biogeographical regionalization principles were applied here to refine the MPA hotspot's delimitation, based on animal endemism. The study involved both vertebrate and invertebrate taxa for the first time, and employed a range of methods from an initial qualitative approach to multiple numerical biogeographical analyses.

Chapter 2 initially presented an updated account of vertebrate endemism in the MPA hotspot, with 62 endemic species and 60 near-endemics. Nevertheless, many more vertebrate taxa were recorded as endemic to south-eastern Africa as a whole, and classifiable into 23 endemic vertebrate distributions (EVDs). Among these, the narrow-range EVDs with high congruence of endemics were used to qualitatively demarcate a greater MPA (GMPA) region of vertebrate endemism, with 146 endemic species (Fig. 1b). Based on the EVDs, this chapter also demarcated a set of zoogeographical units (ZUs) for south-eastern Africa. Numerical analyses using these ZUs as operational geographic units (OGUs) confirmed the GMPA region of endemism for vertebrates (Chapter 3) as well as invertebrates (Chapter 4). Fourteen of these ZUs were identified as areas of endemism (AOEs), further confirming the validity of the GMPA region, which included 13 of them (Fig. 1b; see Chapter 2 for details).

The GMPA region of endemism was numerically confirmed in Chapter 3 for vertebrates, with 166 endemic species (Fig. 1c). The zoogeographical regionalisation based on the vertebrate fauna also confirmed the GMPA as a legitimate zoogeographical province within the south-east African dominion (SEAD), and six centres of endemism (COEs) and ten centres of narrow endemism (CONEs; Fig. 1c) were detected within it. The analysis revealed a considerable numerical consensus among the patterns of distribution for different vertebrate groups (amphibians, reptiles, birds and mammals), while freshwater fishes had the most distinctive zoogeography. The herpetofauna was the main determinant of the overall pattern of vertebrate endemism in the region. The south-east African zoogeographical dominion was formally proposed for the first time in this chapter, comprising two provinces, and vertebrate endemism being markedly lower in the Highveld province, compared to the GMPA province.

Similarly, in Chapter 4, invertebrates also indicated a GMPA region of endemism (with 134 endemic species from the selected groups), but narrower than that for the vertebrates (Fig. 1d). Although it was not recognised as a zoogeographical province as such (in contrast to vertebrates), two zoogeographical provinces covered most of the GMPA region of invertebrate endemism. The region included three COEs and nine CONEs (Fig. 1d). The incorporation of invertebrates in the overall zoogeographic regionalisation is of great importance, as invertebrates form an incomparably larger share of the fauna than vertebrates (Wilson, 1987), but they have long been underrepresented in taxonomic and biogeographical studies (see both the Linnean shortfall and Wallacean shortfall; Brown & Lomolino, 1998; Lomolino, 2004; Whittaker *et al.*, 2005). The analysis revealed comparable results to those on vertebrates, although invertebrates tend to partition areas finer than vertebrates at a given level in the biogeographical hierarchy. Cluster analyses that recovered the GMPA region of invertebrate endemism most similar to its original delimitation were the parsimony analysis of endemicity for all selected invertebrates, and a phenetic clustering analysis for a group of predominantly forest-dwelling invertebrates with low vagility. This suggests an important refugial role played by forests in shaping the invertebrate endemism of the area (see Chapters 4, 5, and references therein).

The robustness of the analyses was further increased in Chapter 5 using finer-scale, equal-area OGUs (half-degree-squares; HDSs), to study endemism patterns for the herpetofauna (the vertebrate group driving endemism patterns in the area; see Chapters 2, 3). The analyses used reasonably complete distribution databases available for the South African herpetofauna in the form of atlases (Minter *at al.*, 2004, mirrored by ADU, 2012a for frogs and ADU 2012b for reptiles). This chapter utilised phenetic clustering to establish a herpetogeographic regionalisation, defining a GMPA province including the bushveld region for the first time. At the same time, parsimony analyses of endemicity established three areas of endemism (AOEs) for Anura and ten such for Squamata, that are indicative of a GMPA region of herpetofaunal endemism similar to the one proposed in Chapter 3 (Fig. 1e). A considerable degree of consensus is achieved for these two monophyletic groups with different life histories. The species richness patterns show partially complementary peaks for the two groups (presumably due to ecological factors impacting differently on their different life histories), while the areas of endemism are largely congruent (if more extensive in Squamata), presumably due to historical factors causing natural fragmentation of refugial habitats, which affected both taxa similarly.

Figure 1 summarises the findings of chapters 2-5, confirming the GMPA region of animal endemism as a zoogeographically-delimited broader region of conservation concern with high cross-taxon congruence, and incorporating a multitude of centres of endemism. From all the above analyses, a consensus is achieved here for a core GMPA region with 17 ZUs, and possible extensions towards (from north to south) the Waterberg, the Drakensberg and its Eastern Cape escarpment, the Sneeuberg and Knysna (Fig. 2; thick red line). The Inhambane/Mopane extension towards the north-east, recognised only in the qualitative demarcation, is not being confirmed by any numerical analysis. Patterns of weighted endemism (Crisp *et al*., 2001) mapped separately for south-east African vertebrates and invertebrates at the scale of zoogeographic units (Chapters 3 & 4, respectively) and for the herpetofauna at HDS scale (Chapter 5) also indicate high levels of endemicity within the GMPA region of endemism (Fig. 2a-c). Two gaps are evident between the three intuitively-defined plant COEs mapped in Fig. 1a (shaded areas), representing respectively the Natal and Transkei. The analytical AOEs and CONEs mapped for animals in Fig. 1b-f (shaded areas) indicate only one such gap. The 'Transkei gap' (Vernon, 1999) is evident from analyses in all the chapters of the thesis, and presumed to be a real biogeographical depression in both species richness and endemism. It is unlikely to be a result of undersampling alone, although the Eastern Cape in general needs more sampling efforts in documenting biodiversity than other provinces. But the Natal floral gap of endemism (Fig. 1a) is possibly a result of overlooking the endemics in the area, as suggested by the rich endemic fauna mapped in this study (Fig. 1b-f and Fig. 2).

This contribution certainly refines the original delimitation of the MPA hotspot (based on intuitively-defined centres of floristic endemism; Fig. 1a) as a global conservation priority, by clarifying its boundaries, incorporating hitherto undescribed patterns of faunal endemism, and hence providing local conservation priorities within it ('hottest spots'; Fig. 2d). The patterns of animal endemism presented here are presumed to be influenced by a variety of ecological factors related to habitat heterogeneity along the Indian Ocean coastal belt and the south-eastern Great Escarpment, but even more prominently a product of historical factors such as Plio-Pleistocene climate change, and corresponding expansions and contractions of forest refugia (see Chapters 3-5 and references therein).

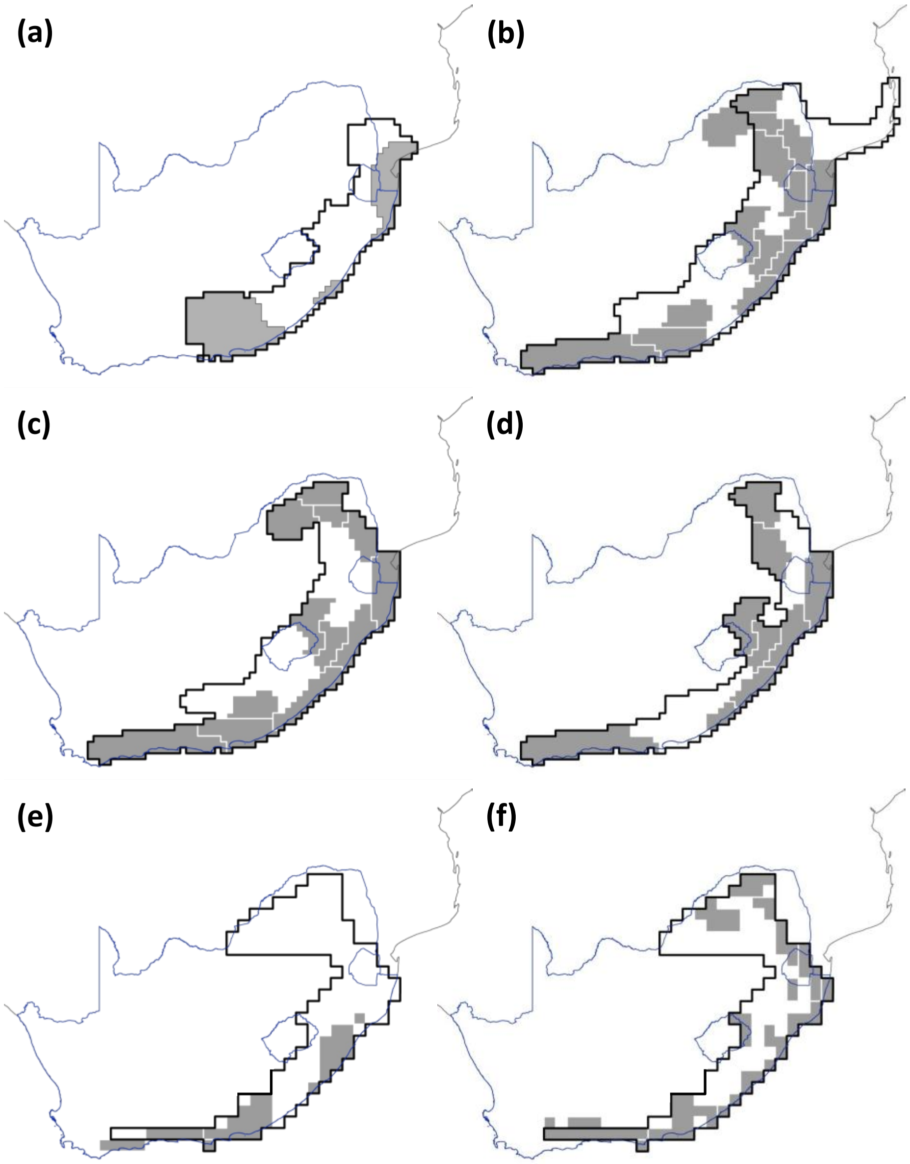


Figure 1 Zoogeographical refinements to the boundary of the Maputaland-Pondoland-Albany (MPA) biodiversity hotspot (thick line) and its centres of endemism (shaded): (a) the MPA hotspot as defined by Mittermeier *et al*. (2004) and the centres of floristic endemism (van Wyk & Smith, 2001) after which the hotspot is named; (b) qualitative delimitation of the greater MPA (GMPA) region of vertebrate endemism, and its areas of endemism for vertebrates (Chapter 2); (c) numerical recovery of the GMPA region of endemism for endemic vertebrates and their centres of narrow endemism (Chapter 3); (d) numerical recovery of the GMPA region of endemism for selected genera of invertebrates and their centres of narrow endemism (Chapter 4); (e-f) half-degree-square-based numerical delimitation of the herptogeographical GMPA province as based on phenetic clustering, and areas of endemism based on parsimony analysis of endemicity for Anura (e) and Squamata (f). See the respective chapters for details on the shaded areas.

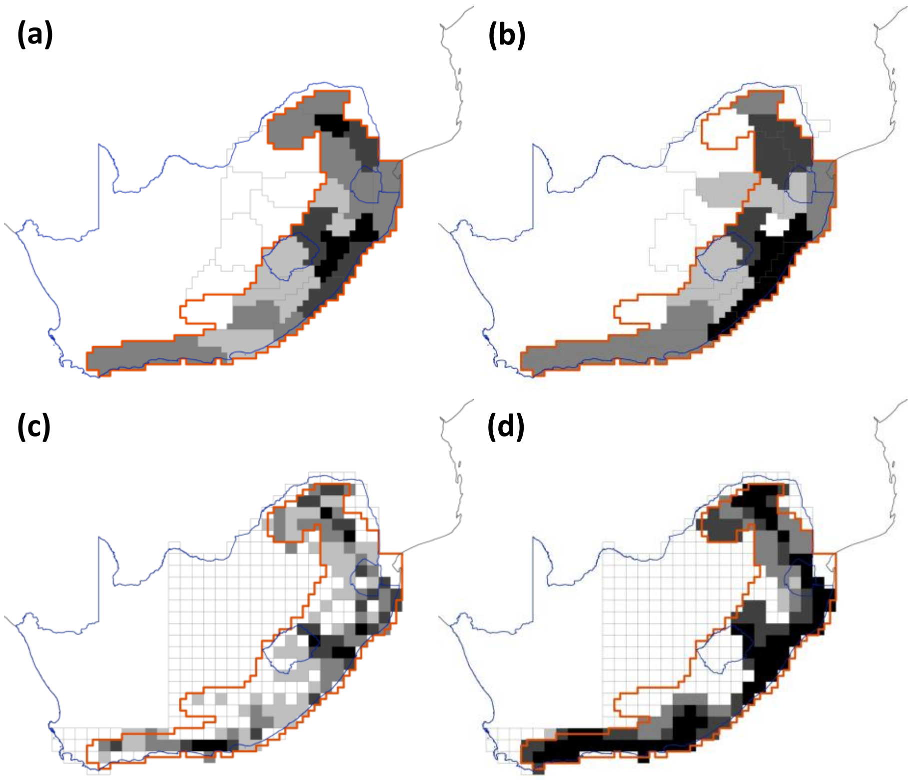


Figure 2 Patterns of endemism mapped for the south-east African fauna indicating the greater Maputaland-Pondoland-Albany region of endemism (the red line, in consensus from all delimitations in Fig 1b-f): (a) weighted endemism (WE) corrected for area for vertebrates in zoogeographical units (ZGs) (Chapter 3); (b) WE corrected for area for selected invertebrates in ZGs (Chapter 4); (c) WE for the herpetofauna in half-degree-squares (HDSs) (Chapter 5); (d) grey-scale illustration of the overlap patterns in the areas of endemism and centres of narrow endemism at HDS scale (based on Fig. 1b-f), hence identifying the "hottest spots" (black) in and around the Maputaland-Pondoland-Albany biodiversity hotspot. See the respective chapters for details.

All numerical regionalisation analyses presented in the thesis (despite being based on different animal groups/datasets) provide consensus for the SEAD, placed in the global zoogeographical hierarchy as given in Table 1 [following the international code of area nomenclature (Ebach *et al*., 2008), and based on global regionalisations (Procheş & Ramdhani, 2012; Holt *et al*., 2013) and the continental regionalisation for Africa (Linder *et al*., 2012)]. A high congruence can be noted across analyses at province level, entities becoming increasingly inconsistent from district to assemblage level. Nevertheless, the south-western limits of the SEAD are not well resolved, in some cases including the entire Cape Floristic Region, in some only the Knysna extension, and in some neither (see Chapters 4, 5; Table 1). Precision in this respect is to some extent constrained by the limits of the study area, as the focus of the present study was on the MPA hotspot.

Table 1. Placing the south-east Africa dominion (and its provinces derived from the analyses given in Chapters 3-5) in the global zoogeographical hierarchy

Realm [a]	Region [b]	Sub-region [c]	Dominion [d]	Province [d]		
				Herpetofauna	Vertebrates	Invertebrates
Afrotropical	Afro-tropical	Southern African	South-east African	Greater Maputaland-Pondoland-Albany	Greater Maputaland-Pondoland-Albany	Greater Maputaland-Pondoland-Albany
					Extended Highveld	Bushveld
				Highveld		Highveld
			Greater Cape			
			Kalahari			
			Karoo			
		Zambezian	East African			
		Sudanian				
		Ethiopean				
		Somalian				
	Congolian	Congolian				

[a] Holt *et al*. (2013), = A region in Procheş & Ramdhani (2012); [b] Holt *et al*. (2013), = sub-regions in Procheş & Ramdhani (2012); [c] Regions in Linder *et al*. (2012) named here as sub-regions; and [d] Chapters 3-5 in this thesis (areas not applicable to the present study are remained blank)

The SEAD is also supported by previous studies, similar entities being proposed under different names: a south-east district for Afrotropical birds (Crowe, & Crowe, 1982); various units under various names for frogs, large mammals and birds, but not for reptiles in southern Africa (Crowe, 1990); a Highveld/Escarpment province for frogs of sub-equatorial Africa (Seymour *et al.*, 2001); an eastern sub-region for frogs of South Africa, Lesotho and Swaziland (Alexander *et al.*, 2004); and a southern African region in the consensus regionalisation for all terrestrial vertebrates and plants in sub-Saharan Africa (Linder *et al.*, 2012). The combined regionalisation for terrestrial vertebrates and plants at 1° square scale for the entire African continent (Linder *et al.*,2012), recovers a Natal sub-region, narrower than the SEAD as given here, but establishing the link between the south-eastern seaboard, escarpment and the mesic Highveld. Another continental regionalisation involving only endemic birds (de Klerk *et al*., 2002), separates a unit similar to the GMPA from the Highveld at a higher level in the hierarchy, thus not forming a single dominion. Nevertheless, the results indicate that a common biogeographical regionalisation is feasible involving vertebrates, selected groups of invertebrates, and higher plants. This opens up an avenue for future studies, despite differences in the availability of distributional data across taxa.

Some observations made during the present study on the biogeographical methods used are summarised below:

- The initial qualitative evaluation of zoogeography of an area based on EVDs is recommended as a qualitative approach to identify biogeographic units where distributional data are scarce, and hence do not facilitate numerical biogeographical analyses (Chapter 2). Such delimitations based on intuitive perception need further confirmation by rigorous numerical analyses (White, 1993; van Wyk and Smith, 2001) when better data become available.
- The approach taken in Chapters 3 and 4 (establishing OGUs as narrowly as possible, through qualitative analysis of EVDs as in Chapter 2, and the use of such OGUs in a numerical analysis to establish their biogeographical relationships and to detect areas/centres of endemism) provides well-resolved and more natural boundaries for the resulting biogeographical entities, until more complete distributional databases at fine geographic scales (at least quarter-degree-square) are available, with minimal geographical bias. This is important, as the incompleteness of species distribution databases and collection biases (Reddy & Dávalos, 2003; Botts *et al.*, 2011) hinder such rigorous analyses using fine OGUs, while an analysis at coarse scale (1° square or above) would not detect patterns of narrow endemism, and can distort the margins of geographical entities.
- The phenetic approach (Unweighted Pair-Group Method Using Arithmetic Means – UPGMA clustering; as endorsed by Kreft & Jetz, 2010) is preferred for regionalisation studies due to its strength in detecting hierarchical patterns, as compared to the parsimony approach (Parsimony Analysis of Endemicity – PAE; Rosen, 1988). The PAE, on the other hand, is better at detecting patterns driven by endemism, and especially areas of endemism (see Morrone & Crisci, 1995)
- The results of UPGMA clustering on endemic species only are similar to the results of PAE analyses for entire faunas (see Chapter 5, Chapter 3 for a discussion).
- Comparative results obtained from the phenetic and parsimony approaches in Chapter 4 for the same dataset suggests that PAE provides a better (species endemism-based) hierarchy at deeper levels, i.e. areas of narrow endemism, areas of endemism, and regions of endemism, but does not perform that well higher up in the hierarchy. In contrast, UPGMA recovers ‘biogeographical provinces’ mostly congruent with the ‘regions of endemism’ from PAE, and then clusters them into dominions, sub-regions, etc., in geographically contiguous and faunistically more meaningful clusters than in the case of PAE.

Chapters 3-5 provide evidence that a common zoo- or even bio- geographical regionalisation for the area is feasible. One important next step would be to incorporate plants in to such an analysis (cf. Linder *et al*., 2012 for sub-Saharan Africa). Such a study will presumably establish floristic support for a GMPA region of endemism. Although botanical/floristic studies of the area have suggested that plant patterns likely match the GMPA region of endemism (e.g. Cowling and Hilton-Taylor, 1997; Küper *et al.*, 2004; Cowling *et al.*, 2005, van Rooy & van Wyk, 2011), arbitrary patterns are still used in describing endemism within the region, as was the case with the MPA originally. Most importantly, traditional centres of plant endemism have overlooked a Natal centre, for which there appears to be good floristic support (Chapter 2, 3; David Styles, *pers. comm.*). Hence, it is of high importance to thoroughly document the plant component of the Natal centre of endemism.

Another important next step would be to incorporate the phylogenetic relationships between species into the current similarity matrices based only on species incidence data (cf. Holt *et al.*, 2013 for global regionalization). This way, the resulting regionalisation can illustrate the evolutionary relationships of taxa. Also, linking AOEs to the phylogenetic relatedness of the congruent, range-restricted taxa occupying them will provide clues to the origin and evolution of faunal endemism in south-eastern Africa. While the documented patterns of endemism are only weighted by range size, a parameter of endemism weighted by evolutionary age would provide important insights for conservation of evolutionary processes.

The GMPA region's weight in global conservation biogeography can only be described as notable, as it harbours a multitude of broad to narrow centres of endemism. The setting of local conservation priorities within this globally identified region of high conservation concern is critical, for which the present study provides vital information. An assessment of the protected area network in comparison to the areas/centres of endemism detected here is out of the scope of this thesis. Nevertheless, the results of the study suggest the need of such a systematic conservation planning assessment ensuring the representativeness of the protected area network within the GMPA (Margules & Pressey, 2000; Margules *et al.*, 2002).

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APPENDIX 1

Abstract of the paper presented at the Faculty of Science and Agriculture Postgraduate Research Day, University of KwaZulu-Natal, 23 September 2010.

A preliminary assessment on areas of vertebrate endemism in south-east Africa

Sandun J. Perera

Distribution ranges of endemic vertebrate taxa in south-east Africa were reviewed in an exercise to delimit areas of vertebrate endemism. Distributional data for different groups differ widely in availability, accuracy and scale, which often results in the exclusion of certain groups from quantitative biogeographical analyses. Here we present a qualitative analysis involving all vertebrate taxa endemic to south-east Africa, defined here as the area south of 22S° and east of 24E°, bordered by the Indian Ocean to the south-east. Four hundred and ninety-six vertebrate taxa endemic to south-east Africa (260 species and 236 disjunct infra-specific taxa) were assessed using a chorological approach to identify Endemic Vertebrate Distributions (EVDs). The identification of EVDs was primarily based on visual perception and intuitive discernment, through an extensive review, visual sorting, and matching of published distribution maps. Each taxon selected for the study was assigned to the narrowest of the EVDs encompassing all its accepted breeding records. Areas of narrow-endemism were then delimited by overlaying distribution ranges of taxa assigned to each EVD, and demarcating the areas of overlap.

Among the 23 EVDs identified for south-east Africa, seven are narrow and show little overlap, *viz.*, in the decreasing order of endemic species numbers, Eastern escarpment, Natal, Drakensberg, Maputaland, Amatola-Winterberg-Sneeuberg, Coastal Albany, Coastal Transkei. The first four narrow-range EVDs, respectively with 26, 20, 15 and 12 endemic species, encompass a series of non-overlapping areas of narrow-endemism, hence presented as provisional centres of vertebrate endemism. Reptiles (56 species) show the highest degree of endemism within the seven narrow-range EVDs, followed by amphibians (15), freshwater fishes (13), mammals (4) and birds (2).

All in all, 15 areas of narrow-endemism (> 4 endemic taxa) are identified in south-east Africa, that are critical for efficient fine-scale conservation planning and implementation. They are as follows (in the order of their conservation significance, with the number of endemic species + endemic infra-specific taxa): Drakensberg-KwaZulu-Natal Escarpment (8+6); Southern Maputaland (7+17); Northern Middleveld (7+3); Coastal Albany (6+8); Natal Midlands (6+0); Amatola-Winterberg (5+2); Waterberg (5+2); Wolkberg (4+3); Southern Middleveld (4+2); Natal Coastal Belt (3+4); Ngoye (3+2); Soutpansberg (2+5); Pondoland (2+3); Northern Mpumalanga Escarpment (2+2); and Northern Maputaland (1+6).

These areas of vertebrate endemism justify the floristically identified Maputaland-Pondoland-Albany biodiversity hotspot; however, they suggest an extension of its boundaries to incorporate the south-eastern components of the Great Escarpment, to make it a significant region of conservation relevance.

APPENDIX 2

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Conference Abstracts

South African Association of Botanists – Annual Meeting 2011

Abstracts of papers and posters presented at the 37th Annual Congress of the South African Association of Botanists held at Rhodes University, Grahamstown, 17–19 January 2011

The presenter of multi-authored papers is underlined

of interspecific relationships, was able to formulate a

a water use efficiency (the ratio of the increment in annual biomass to total evapotranspiration) value for this veld type. Using seasonal biomass measurements from March 2000 and March 2007, we developed a model for predicting increment in annual biomass using the relationship between measured aboveground biomass (kg DM) and fraction of photosynthetically active radiation obtained from MODIS product (f_{PAR}). This

A greater Maputaland–Pondoland–Albany region of vertebrate endemism

S.J. Perera, D. Ratnayake-Perera, Ş. Procheş

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The Maputaland–Pondoland–Albany (MPA) biodiversity hotspot was primarily recognised based on its high plant endemism. Here, we present a first ever biogeographical study of the entire endemic vertebrate fauna of south-east Africa, in an exercise that (a) refines the delimitation of the MPA, (b) illustrates within-hotspot areas of endemism and (c) defines non-overlapping biogeographical units. The study reviews the distribution patterns of 496 vertebrate taxa endemic to south-east Africa, listing 62 vertebrates endemic and 60 near-endemic to the MPA hotspot. Twenty-three Endemic Vertebrate Distributions (EVDs) are recognised, among which the Eastern Escarpment, Natal, Drakensberg, and Maputaland distributions are the most common. The geographical patterns illustrated by EVDs suggest an expansion of the hotspot to incorporate sections of the Great Escarpment from the Amatola-Sneeuberg Mountains through the Drakensberg to the Soutpansberg. This redefinition gives rise to a Greater Maputaland–Pondoland–Albany (GMPA) region including 137% more endemics with only 88% surface area added to the MPA hotspot. The GMPA has a more natural boundary in terms of EVDs and vegetation units, and we argue that previous studies on plant endemism support it too. The study also highlights 14 areas of endemism (13 within the GMPA), potentially important to conservation planning within the region. Besides conservation, the accurate delimitation of this hotspot would benefit theoretical biogeography, and in this context we use EVDs to delimit zoogeographical units for south-east Africa.

(4.8%), birds (3.8%), settling moths (3.6%), sphingid moths (3.1%), butterflies (2.0%) and beetles (1.0). Orchids considered to be broad generalists, being pollinated by two or more or these groups of animals, account for 3.3% of species. Of the 734 species for which data on rewards are available, 58.4% are rewarding while 41.6% are deceptive. Rewards include fragrance compounds, oils, wax and other exudates as well as nectar. This analysis of rates of deception is comparable with, but higher than, the earlier estimates for the Orchidaceae.

The prickly problem of *Berkheya* Ehrh. (Asteraceae)

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Berkheya Ehrh. is a genus of daisies in the tribe Arctotideae, subtribe Gorteriinae. With over 80 species, most of which occur in Southern Africa, this genus has centres of diversity associated with the montane regions of South Africa, including the Drakensberg Alpine Centre and Mpumalanga escarpment regions. Previous molecular and morphological studies indicate that *Berkheya* is paraphyletic. We present preliminary phylogenies based on nrDNA (ITS; Internal Transcribed Spacer) as well as some cpDNA (psbA-trn-H) data. These phylogenies are used to assess generic limits and to investigate the biogeographic patterns and life history traits of *Berkheya* and its allies. Preliminary molecular dating shows that the divergence of *Berkheya* clades occurred at the Miocene–Pliocene boundary.

APPENDIX 3

Abstract of the poster presented at the Student Conference on Conservation Science, University of Cambridge, 19-21 March 2013.

"Hottest spots" in a hotspot: patterns of animal endemism in and around the Maputaland-Pondoland-Albany biodiversity hotspot

Sandun J. Perera

Biodiversity hotspots are delimited intuitively based on floristic endemism and are seldom tested for animal patterns. The present study explores the zoogeography of the Maputaland-Pondoland-Albany hotspot, while analytically refining its delimitation and identifying centres of endemism (COEs; local conservation priorities) within and around it. Endemic vertebrate distributions in south-eastern Africa are used to set eco-geographic units for numerical analyses (hierarchical clustering, mapping endemism measures) on the distributions of endemic vertebrate and selected invertebrate taxa. The results indicate a greater Maputaland-Pondoland-Albany region of animal endemism, encompassing a multitude of COEs in Maputaland, Natal, Pondoland, Albany, and the Drakensberg and Mpumalanga escarpments, emphasizing high levels of narrow endemism in the herpetofauna, land-snails, beetles and velvet-worms.

APPENDIX 4

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A rapid multi-disciplinary biodiversity assessment of the Kamdebooberge (Sneeuberg, Eastern Cape, South Africa): implications for conservation

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Abstract

Botanical work since 2008 on the Sleeping Giant section of the Kamdebooberge (Sneeuberg mountain complex, Eastern Cape, South Africa) has indicated that these mountains may be of significant conservation value. Accordingly, a precursory, rapid multi-disciplinary biodiversity assessment was undertaken in January 2011, focusing on plants, tetrapod vertebrates and leafhoppers. The botanical results confirm the Kamdebooberge as being of high botanical conservation value, hosting three strict endemics, healthy populations of five other Sneeuberg endemics, and fynbos communities comprising species not found elsewhere in the Sneeuberg. The Kamdebooberge are important for herpetofauna (excluding serpentoids) and mammals, hosting several range-restricted and regional endemics. The expedition uncovered three new leafhopper species, together with several species previously only known from the Cape Floristic Region. Further detailed faunal work may provide further interesting results from these mountains, which show a high conservation value unique to the southern Escarpment.

Keywords: Endemics, Great escarpment, Kamdebooberge, Plants, Invertebrates, Sneeuberg centre of floristic endemism, Vertebrates

Introduction

The Sleeping Giant section of the Kamdebooberge forms the south-western end of the arc-shaped Sneeuberg mountain complex, in the Eastern Cape Province of South Africa (Figure 1). The Sneeuberg forms part of the overall poorly explored southern African Great Escarpment, and was recently recognised as a new centre of floristic endemism (Clark et al. 2009, 2011; Figure 1), and as a distinct zoogeographical unit within the Greater Maputaland–Pondoland–Albany region of vertebrate endemism (Perera et al. 2011). The Kamdebooberge themselves have become increasingly interesting following the discovery in 2008 of two new, very localised plant taxa, two of which belong to genera previously unknown from these drier southern Great Escarpment mountains (e.g. Williams 1982; Rebelo 2001). Apart from two narrow-endemic butterfly species (*Cassionympha camdeboo* and *Thestor camdeboo*; Woodhall 2005) and a few bird records, not much is known about the fauna of the Kamdebooberge.

Due to absence of any previous faunal research on the Kamdebooberge, and the potential for further important botanical findings, a multi-disciplinary team of ten biodiversity scientists visited the Kamdebooberge from 22–25 January 2011. The purpose was a precursory, rapid biodiversity survey of the southern section of the Kamdebooberge, focusing on the disciplinary skills of each scientist, and to obtain an indication of the conservation value and natural heritage of these mountains. Results indicated high levels of endemism in animals, with some links to adjoining biomes. For the flora, more records of endemics were established in a poorly explored region. This multidisciplinary approach serves as an example for future research in the poorly explored Great Escarpment.

The study area

A detailed overview of the Sneeuberg Centre of Floristic Endemism and the Great Escarpment is provided by

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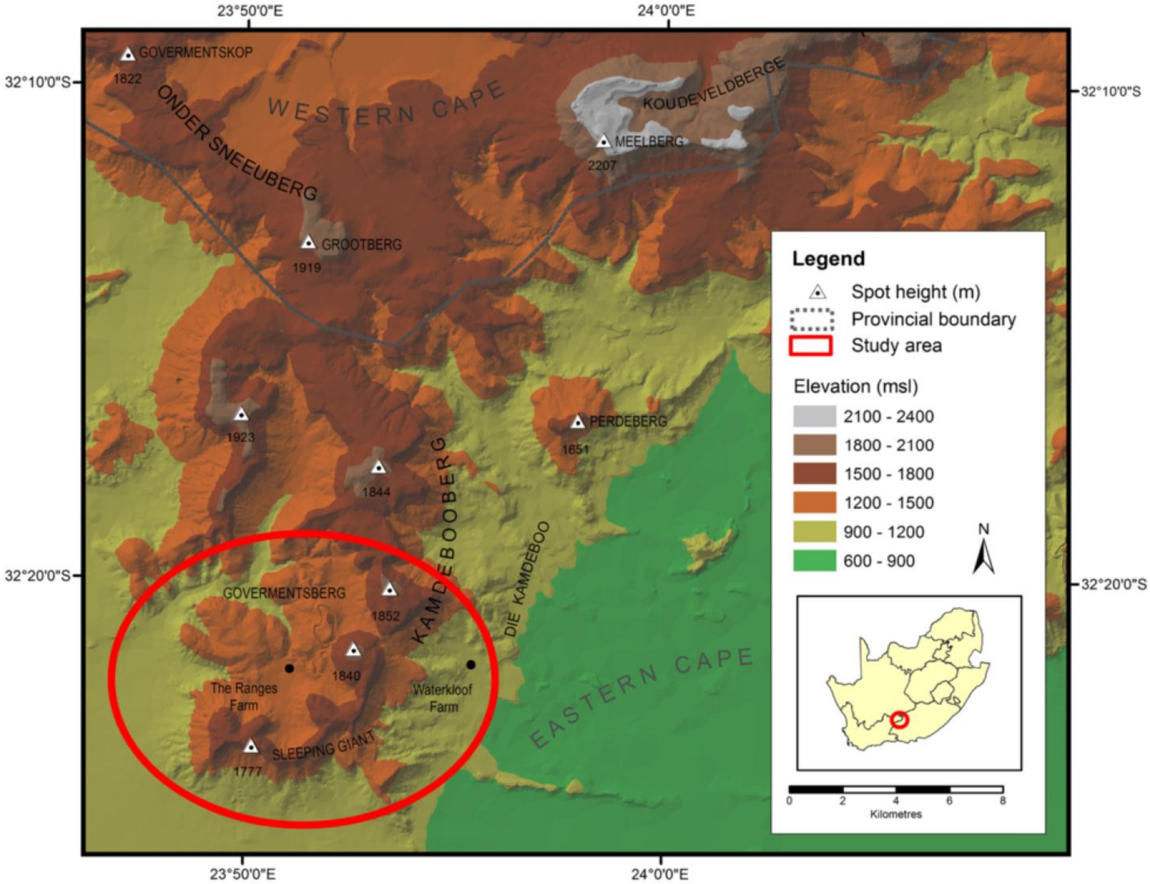

Figure 1 The location of the Kamdebooberge (Sleeping Giant section), Sneeuberg mountain complex, indicating the field survey area.

Clark et al. (2009, 2011 respectively) and provides the broader context for this study.

The Kamdebooberge itself covers some 170 km^2 and comprises a dissected plateau-spur off the higher (2,100–2,300 m) Meelberg–Koudveldberge–Toorberg plateau to the north (Figures 1, 2). It is characterised by isolated, gently sloping plateaus (altitude 1,600–1,900 m) connected by cols and often bounded by vertical cliffs. The geology is comprised of shales and sandstones of the Beaufort Group, heavily intruded by dolerites. The more resistant dolerite sills and dykes have given the mountain range a characteristic shape, and when viewed from the east looks like a 'Sleeping Giant', as named accordingly (Chief Director of Surveys and Mapping 1987). The Farms visited were Plaas 96, 97, 98 and 99, and parts of The Ranges 69 and Oaklands 104 (the area between 32°20′S to 32°24′S, and 23°50′E to 23°53′E).

Mean annual rainfall at the base of the Kamdebooberge (Farm Waterkloof) is ca. 400 mm, and on the south-east-facing slopes of the mountain is predicted to be at least 700–800 mm due to orographic effect as evidenced by the incipient forest and afromontane grassland and fynbos. Rainfall on the mountain is augmented by regular mist, and snowfalls occur most winters. Exceptional rains had fallen in the Kamdeboo Karoo since the middle of December 2010, breaking a severe two-year drought, and the weather during the expedition was a combination of heavy morning mist, heavy evening showers, and sunshine.

From four previous botanical trips to the area by VRC, several vegetation types can be defined as occurring on the Kamdebooberge, providing a variety of habitats for fauna and flora:

- Drier thicket/closed woodland occupies the north-facing slopes and lower southern/south-eastern slopes. Typical species are *Acacia karroo* Hayne, *Aloe ferox* Mill., *Buddleja glomerata* H.L.Wendl., *Carissa haematocarpa* (Eckl.) A.DC., *Diospyros lycioides* Desf., *Dodonaea viscosa* var. *angustifolia* (L.f.) Benth, *Ehretia rigida* (Thunb.) Druce subsp. *rigida*, *Euclea crispa* (Thunb.) Gürke subsp. *crispa*,

Figure 2 The Kamdebooberge: a fynbos communities; b summit grassland; c & d the southern scarp; e panoramic view looking north-west over 'The Ranges' towards the Meelberg (far distance); f the Team, from left to right: Sandun & Dayani Perera, Peter Weston, Charlie Stirton, Mike Stiller (front), Gareth Coombs, Pavel Stoev, Dale Morris, Ralph Clark. Goewermentsberg in the background. Photo credits: Ralph Clark.

Gymnosporia buxifolia (L.) Szyszyl., *Olea europaea* subsp. *africana* (Mill.) P.S.Green, *Searsia lancea* (L.f.) F.A.Barkley and *S. pallens* (Eckl. & Zeyh.) Moffett.

- Mesic thicket and closed woodland occur on the moister mid-altitude slopes. Typical species are *Celtis africana* Burm.f., *Cussonia spicata* Thunb., *Kiggelaria africana* L., *Leucosidea sericea* Eckl. & Zeyh., *Searsia longispina* (Eckl. & Zeyh.) Moffett and *S. pyroides* (Burch.) Moffett.
- Very localised 'pre'-afromontane forest occurs on the SE-facing slope of Goewermentsberg. Typical species are *Buddleja salviifolia* (L.) Lam., *Diospyros scabrida* var. *cordata* (E.Mey. ex A.DC.) De Winter, *Grewia occidentalis* L. var. *occidentalis*, *Heteromorpha arborescens* (Spreng.) Cham. & Schltdl. var. *arborescens* (interior form), *Kiggelaria africana* L., *Maytenus acuminata* (L.f.) Loes. var. *acuminata*, *M. undata* (Thunb.) Blakelock, *Olinia emarginata* Burtt Davy, *Pittosporum viridiflorum* Sims, *Searsia dentata* (Thunb.) F.A.Barkley and *S. rehmanniana* var. *glabrata* (Sond.) Moffett.
- Closed shrubland dominates the drier mid-slopes, and is characterised by species such as *Elytropappus rhinocerotis* L.f., *Euryops annae* E.Phillips and *Otholobium macradenium* (Harv.) C.H.Stirt.
- A very species-rich afromontane grassland-shrubland mosaic occurs on the moister mid- to upper altitude slopes and summit plateau, and is mixed with numerous fynbos elements (see below). The dominant grasses are *Themeda triandra* Forssk. and *Merxmuellera disticha* (Nees) Conert. Several

Sneeuberg endemics are common to abundant, such as *Euryops dentatus* B.Nord., *Gazania caespitosa* Bolus and *Psoralea margaretiflora* C.H. Stirt. & V.R.Clark.

- Pure stands of fynbos occur in fire-refugia, and are typically dominated by species such as *Acmadenia* sp. nov., *Agathosma* sp., *A. venusta* (Eckl. & Zeyh.) Pillans, *Cliffortia montana* Weim., *Clutia alaternoides* L., *Erica leucopelta* Tausch, *E. passerinoides* (Bolus) E.G.H.Oliv., *Ficinia nigrescens* (Schrad.) J.Raynal, *Ischyrolepis* sp. aff. *constipata* H.P.Linder, *Phylica paniculata* Willd., *Rhodocoma capensis* Steud., *R. fruticosa* (Thunb.) H.P.Linder, *Tetraria cuspidata* (Rottb.) C.B.Clarke and *T. fourcadei* Turrill & Schönland. These fynbos elements are particularly interesting in that some of these species are disjunctions from the Cape Floristic Region (hereafter CFR).
- Localised habitats (micro-habitats) occur, the mostly typical being summit wetlands and cliff-lines. Wetlands are characterised by *Kniphofia caulescens* Baker and *Merxmuellera macowanii* (Stapf) Conert), and cliff-lines by a variety of lithophytic ferns such as *Asplenium adiantum-nigrum* L. var. *adiantum-nigrum*, *A. trichomanes* subsp. *quadrivalens* D.E. Mey., *Cystopteris fragilis* (L.) Bernh., and succulents such as *Crassula perforata* Thunb., *Haworthia marumiana* var. *batesiana* (Uitewaal) M.B.Bayer, *Othonna patula* Schltr. and *Senecio articulatus* (L.f.) Sch.Bip.

Methods

Plants

As the Kamdebooberge falls into one Quarter Degree Grid Square (3223BD), the intention was not to collect every species encountered, but to rather complement previous comprehensive work done on the adjacent Goewermentsberg since 2008. Thus species not previously collected in the Kamdebooberge were prioritised over other species. The vegetation was in excellent condition following the exceptional recent rainfalls, a previous burn on some of the plateau, and the absence of livestock grazing.

Plants on the mostly uniform summit plateau were sampled by traversing the plateau on foot, as an approximation of the line transect method (Buckland et al. 2007). Micro-habitats (rock outcrops, seeps, cliff-lines, dolerite boulder-fields) were more intensively sampled on an *ad hoc* basis by careful visual examination. Plants were pressed as per standard practice and later identified in the Selmar Schonland Herbarium (GRA), Albany Museum, Grahamstown, with some specimens sent to taxonomists for expert identification (see Acknowledgements). Apart from these latter specimens, all specimens are now lodged in GRA, with duplicates having been sent to the Bolus Herbarium (University of Cape Town, BOL), the National Herbarium of New South Wales (Australia, NSW), the Royal Botanical Gardens, Kew (K), Missouri Botanical Gardens (MO), the University of Stellenbosch Herbarium (STEU), and the Swedish Museum of Natural History (S).

General fauna

A preliminary rapid survey on the Kamdebooberge fauna was conducted while traversing the summit plateau on foot. The rapid assessment methods included opportunistic observations on amphibians, birds and mammals; active searches (Garden et al. 2007) for reptiles; and random collection and photography of common invertebrates. Particular emphasis was given to looking for the bird *Chaetops aurantius* (Drakensberg Rockjumper) for the purposes of obtaining DNA samples of this Eastern Cape Escarpment and Drakensberg/Maluti endemic (Hockey et al. 2005).

Rodent trapping was attempted using 30 Sherman traps, but logistical difficulties and the preliminary nature of the expedition frustrated trapping on the summit plateau itself. Instead, traps were laid in three transects of ten traps each (ten metres apart) at 1,320 m on the mid-altitude plateau some 500 m east of the farmhouse 'The Ranges', in disturbed, closed shrubland and seasonal marshland, for one night ($\sum$*c.* 300 trapping hours), using peanut butter with chopped vegetables as the bait.

Leafhoppers and planthoppers

Leafhoppers (Hemiptera: Cicadomorpha: Cicadellidae) and planthoppers (Hemiptera: Fulgoromorpha) were the only invertebrate groups sampled systematically. The method used to collect leafhoppers was the traditional sweep net. Mechanised methods such as vacuum sampling could not be used due to the inaccessibility of the terrain. Two tree species were sampled by fogging with a pyrethroid pesticide in the foothills. Identification of leafhoppers was undertaken by MS at the National Collection of Insects, Biosystematics Division of the Agricultural Research Council, using dissections, published descriptions, and comparing with available described species and undescribed specimens housed in this institution.

Results and discussion

Plants

Ninety-seven plant specimens were collected, representing 92 species (Additional file 1: Appendix 1). Five of the species collected – *Albuca tortuosa* Baker, *Cyperus tabularis* Schrad., *Disa porrecta* Sw., *Microchloa kunthii* Desv. and *Syringodea concolor* (Baker) M.P.de Vos – are additions to Clark et al.'s (2009) flora of the Sneeuberg.

An updated version of the Sneeuberg flora is available on the Great Escarpment Biodiversity Programme website: http://thegreatescarpment.110mb.com.

A new population of the Kamdebooberge endemic Rutaceae species (*Acmadenia* sp. nov.) was discovered on the south-east-facing, upper scarp slope on the Farm Ossehoek 99. Fruiting material was collected for the first time and has been sent to BOL for description and publication of the species.

Psoralea margaretiflora C.H.Stirt. & V.R.Clark (Stirton et al. 2011) – first collected in 2005 in the eastern Sneeuberg – was verified in the field by CHS as being a new species, and a manuscript was prepared on site from the Kamdebooberge specimens. The plant is locally abundant in the eastern and western sections of the Sneeuberg. *Erica passerinoides*, originally only known from the Toorberg (20 km to the north; Clark et al. 2009), was collected again on the Kamdebooberge (a second, large population was discovered on Goewermentsberg in 2010). The Kamdebooberge may thus actually represent the core distribution of this poorly-known western Sneeuberg endemic.

New records on species until recently considered exclusively CFR species were obtained. New populations of *Rhodocoma capensis* and *Tetraria fourcadei* were encountered on the Farm Ossehoek 99, the former being the dominant species in Kamdooberge mountain fynbos. Both species are known from Goewermentsberg, where they are abundant and were the first records of these species outside of the CFR.

A massive population (i.e. several hundred thousand individuals) of the shrub *Otholobium macradenium* was encountered on the north-east facing slopes below the summit plateau on Farms Plaas 96 and The Ranges 69 (1,300–1,700 m). This was the first time this species has been collected in flower in the Sneeuberg since the discovery of the initial Sneeuberg population in December 2005. The species is rare in the CFR (where it has only been sporadically collected) but is abundant in certain areas of the Sneeuberg, notably the Kamdebooberge and from the Nardousberg eastwards to Buffelshoek-se-Pas behind Pearston. The majority of the total population thus seems to be in the Sneeuberg.

Cliffortia montana was recorded as abundant and forming almost pure stands on the Farm Ossehoek 98. This species has a patchy distribution, occurring on the Swartberg (in the CFR), the western Sneeuberg (Kamdebooberge to the Toorberg) and then on the Nardousberg massif.

General Fauna

A total of 24 tetrapod vertebrate species were recorded (Additional file 2: Appendix 2, Figure 3), in addition to several other invertebrates recorded incidentally (except the leafhoppers, addressed separately).

The vertebrates included three species of amphibians recorded on the summit; *Amietophrynus rangeri* (Raucous Toad), *Cacosternum boettgeri* (Dainty Frog) and *Strongylopus grayii* (Clicking Stream Frog). Both *Strongylopus grayii* and *Cacosternum boettgeri* were recorded from a streamlet on the summit plateau, also indicating the watershed value of the Kamdebooberge. Though not recorded from the summit (hence not included in the list) *Tomopterna tandyi* (Tandy's Sand Frog) was found from the foothills of the Kamdebooberge, on Farm Oaklands 104.

Five species of reptiles were recorded from the summit, among which *Cordylus cordylus* (Cape Girdled Lizard), *Trachylepis homalocephala* (Red-sided Skink) and *Afroedura karroica* (Karoo Flat Gecko) were the most common. *Pachydactylus maculatus* (Spotted/ Thick-toed Gecko) was observed only in the lower reaches and excluded in the list. Serpentoid reptiles were conspicuous in their absence from the summit plateau.

Avifauna on the mountain was sparse, with only twelve species recorded during the survey. Apart from raptors and two southern African endemics, these were mostly inconspicuous birds. Three of the raptors – *Buteo vulpinus* (Steppe Buzzard), *Falco amurensis* (Amur Falcon) and *Milvus migrans* (Yellow-billed Kite) – are non-breeding migrants and not confined to mountain regions (Hockey et al. 2005). No evidence (visual or audio) of *Chaetops aurantius* (Drakensberg Rockjumper) was noted, although the habitat is favourable. As the bird was recorded visually on the higher Koudeveldberge massif (20 km to north) in December 2011 by VRC, there is a chance that it may occur sporadically on these lower Kamdebooberg mountains. The greatest number of bird species were noted from the surrounding Karoo plains (not included in the Additional file 2: Appendix 2), most spectacularly an influx of *Neotis ludwigii* (Lüdwig's Bustard) feeding on the emergent insects during and after the heavy rains.

Four mammals species were recorded, namely *Hystrix africaeaustralis* (Cape Porcupine), *Oreotragus oreotragus* (Klipspringer), *Pelea capreolus* (Grey Rhebok) and *Procavia capensis* (Rock Hyrax/ Dassie). Rodent trapping was unsuccessful, possibly due to inclement weather, the trapping period being too short, and the absence of pre-baiting.

An interesting array of invertebrates was noted on the summit plateau. A rich butterfly fauna is evident, with *Aeropetes tulbaghia* (Mountain Pride) being one of the most conspicuous species seen. Several specimens were collected for Garreth Keevey's systematics research on this CFR–eastern Great Escarpment endemic (Woodhall 2005). Other interesting species recorded were *Tarucus*

Figure 3 **Selection of photographs of fauna encountered during the survey: a *Strongylopus grayii* (Clicking Stream Frog), b *Cacosternum boettgeri* (Common Caco), c *Trachylepis homalocephala* (Red-sided Skink), d *Pseudocordylus microlepidotus* (Cape Crag Lizard), e *Cordylus cordylus* (Cape Girdled Lizard), f *Afroedura karroica* (Karoo Flat Gecko), g *Cisticola lais* (Wailing Cisticola), h *Oreotragus oreotragus* (Klipspringer), i *Aeropetets tulbaghia* (Mountain Pride), j *Hadogenes* sp., k *Orthoporoides* sp., l *Neita durbani* (D'Urban's Brown), m *Dictyophorus spumans*, n *Decapotoma lunata*, o *Heterochelus* sp..** Photo credits: a–c, e, g–j, l–o Sandun Perera; d, f & k Pavel Stoev.

thespis (Fynbos Blue; found in CFR, Sneeuberg and Great Winterberg–Amatolas) and *Neita durbani* (D'Urban's Brown; an Eastern Cape endemic; Woodhall 2005). Among the other invertebrates recorded were four myriapods two species of the genus *Orthoporoides* (Spirostreptida) and one of Polydesmida (Diplopoda), and *Rhysida afra* (Chilopoda: Scolopendromorpha); a *Hadogenes* species (scorpion); grasshoppers such as *Dictyophorus spumans* and *Scintharista* cf. *saucia*; the blister beetle *Decapotoma lunata*, the dung beetle *Macroderes bias*, and a monkey beetle of the genus *Heterochelus*.

Leafhoppers

Recent work on grass-feeding endemic leafhoppers in the Fynbos and Grassland Biomes in South Africa (Durr 1988; Stiller 2002, 2009a, 2009b, 2010a, 2010b, 2011) has produced three new genera and 61 new species. Many forb, shrub and tree-associated leafhoppers are still awaiting description. The total number of leafhoppers in southern Africa is estimated conservatively at 600 species, up considerably from the estimated 350 of Scholtz and Holm (1985).

Thirty-nine species were recorded on the Kamdebooberge (Additional file 3: Appendix 3, Figure 4), with at least three well documented Grassland Biome endemics. Records of widespread species include pests or potential pests that could transmit plant viruses. These widespread species include *Accacidia improvisa* (first described from Egypt and Sudan on *Acacia*), *Austroagallia*, *Chlorita*, *Circulifer*, *Coloborrhis*, *Empoasca*, *Exitianus*, *Naudeus*, *Paradorydium*, *Recilia*, *Tetartostylus* and *Vilargus*. The species of *Chlorita* are difficult to distinguish, with *C. exilis*, described by Theron (1977, 1986, 1988) from specimens only found in the CFR on *Elytropappus rhinocerotis* and *Seriphium plumosum* L. (both Asteraceae). *Chlorita cylindrica* was redescribed (Theron 1988) from many records in the Western Cape, Eastern Cape and Free State, with *Chrysocoma ciliata* L. (Asteraceae) as host from some of these records. *Iseza* is characterised by distinct marking on the head, but species are difficult to distinguish. *Naudeus bivittatus* is known to feed on the grass *Imperata cylindrica* (L.) Raeuschel in South Africa (this grass was not recorded on this expedition but is known from the Sneeuberg region; Clark et al. 2009). *Tzitzikamaia* sp. cannot be identified further as only

Figure 4 Leafhoppers and planthoppers collected on the Kamdebooberge (average length of specimens 5 mm): a *Afralycisca umbrina*, b n.gen & sp.1, Athysanini, c *Austroagallia* sp1, d *Austroagallia* sp2, e *Balclutha* sp., f *Cephalelus attenuatus*, g *Chlorita cylindrica*, h *Circulifer struthiola*, i *Drakensbergena gigascutica*, j *Exitianus taeniaticeps*, k *Hangklippia signata*, l *Iseza* sp., m *Molopopterus* sp., n *Paradorydium* sp., o *Tetartostylus* sp., p *Teinopterus mikrophallus*, q *Tetramelasma litopyx*, r *Tzitzikamaia* sp., s Cixiidae, t *Menenches atropos*, u *M. decuma*.

nymphs and females were collected; three species of this genus are known from South Africa. *Molopopterus damus* was described from Swellendam, Western Cape, and the Kamdebooberge specimen may represent a disjunction onto the southern Great Escarpment from the CFR. *Molopopterus obliquus* Theron was described in 1978 from a long series of specimens from Jonkershoek, near Stellenbosch (Western Cape Province) on *Otholobium obliquum* (E. Mey.) C.H.Stirt. The survey specimens were swept from *Otholobium macradenium* and *Passerina montana*, and may also represent a disjunction from the CFR onto the southern Great Escarpment. Uncertainty within *Molopopterus* species can be seen in Dworakowska (1973, 1974, 1981) with 22 new species from Central Africa, on grasses. Einyu and Ahmed (1983) described one species and Ahmed (1979) two species from Uganda. Theron (1978) described 27 species from South Africa, on shrubs, based on records from the CFR.

Rare or endemic species feeding on Monocotyledons includes the following: *Cephalelus attenuatus* is one of 18 species from the CFR, and this genus is always associated with one or more species of Restionaceae (of which at least four species occur in the Kamdebooberge). Records of *C. attenuatus* suggest a wide distribution in the western and southern parts of South Africa. *Drakensbergena gigascutica*, *Teinopterus mikrophallus* and *Tetramelasma litopyx* are endemic to Karoo Escarpment Grassland (Vegetation Unit GH1 of Mucina and Rutherford 2006), which occurs patchily along the southern Great Escarpment from the eastern Nuweveldberge to the Great Winterberg–Amatolas and Stormberg (Mucina and Rutherford 2006).

Dicotyledon-associations include the following: *Afralycisca umbrina* is known from few specimens and localities in South Africa. It is probably associated with forbs and appears to be more common on mountain tops in the Grassland Biome. *Hangklippia signata* is rare, based on the dearth of specimens. The new species of *Modderena* (sp. nov. near *M. albicosta* Theron in Additional file 3: Appendix 3) belongs to a genus that feed on shrubs and forbs that are relatively common in South Africa, but this species is not known from outside the Kamdebooberge. The three new genera and species in Athysanini show some similarities with species described from the CFR as well as a number of undescribed species from the Drakensberg, Soutpansberg, and mountains further north (e.g. some examined specimens from Kilimanjaro). Species 1 (#1 in Additional file 3: Appendix 3) bears some resemblance to a number of species described from the CFR. This leafhopper has well developed hind-wings, suggesting an ability to migrate, and close similarity is found in undescribed species of specimens from Storms River, Port Elizabeth, Kareedouw, Graaff-Reinet, Cradock and Fouriesburg, suggesting a wider range of this species than the Kamdebooberge. Species 2 has a reduced hind-wing that is about ⅓ as long as the forewing, suggesting a poor ability to fly, and no specimens with similar features have been found in any South African insect collection. Species 3 is known only from Farm Oaklands 104, at the base of the Kamdebooberge in mixed woodland/thicket.

In planthoppers, the dictyopharids and nogodinids probably feed on forbs and are difficult to collect by sweeping, and are probably South African endemics. Poor flying ability or lack thereof appears to be a feature of these endemics. Some planthoppers collected include short-winged species such as *Turneriola* sp., *Telmessodes proconsul* (known from the Eastern Cape), and *Menenches decuma* and *M. morta* (both described from the Drakensberg in KwaZulu-Natal).

Remarks on conservation value

The results confirm the botanical importance of the Kamdebooberge, with its two strict endemics (*Acmadenia* sp. nov., *Faurea* sp. nov.), healthy populations of five other Sneeuberg endemics (*Erica passerinoides*, *Euryops dentatus*, *Gazania caespitosa*, *Haworthia marumiana* var. *batesiana*, *Psoralea margaretiflora*), and the unique composition of the fynbos communities found on the upper SE-facing slopes. Further botanical exploration in these mountains may well yield more undescribed species, additional populations of local endemics, and additions to the Sneeuberg flora.

Although only the list for herpetofauna (except for serpentoid reptiles) could be considered fairly complete, the results indicate that the Kamdebooberge has a rich and varied faunal diversity. Among amphibians, *Amietophrynus rangeri* (Raucous Toad) and *Strongylopus grayii* (Clicking Stream Frog) are southern African endemics (Minter et al. 2004). Out of the five species of reptiles recorded, two are of high conservation importance. The *Afroedura karroica* (Karoo Flat Gecko) is endemic to the Sneeuberg range and its immediate surroundings, while *Cordylus cordylus* (Cape Girdled Lizard) is an Eastern Cape and Western Cape endemic. *Pseudocordylus microlepidotus* (Cape Crag Lizard) and *Trachylepis homalocephala* (Red-sided Skink are southern African endemics (Branch 1998). Among the birds recorded, *Macronyx capensis* (Orange-throated Longclaw) and *Serinus canicollis* (Cape Canary) are southern African endemics (Hockey *et al.* 2005). The importance of the Kamdebooberge for raptors-especially as a possible nesting site is evident, particularly for rugged terrain species such as *Aquila verreauxii* (Verreaux's/Black Eagle), and from previous sightings of *Aquila pennata* (Booted Eagle) and *Polemaetus bellicosus* (Martial Eagle). From a conservation perspective the most important among recorded mammals is the South African endemic *Pelea capreolus*

(Grey Rhebok), given its patchy montane distribution and its population stronghold in the Sneeuberg (Skinner and Chimimba 2005).

The total number of leafhopper species recorded is comparatively low, probably as a limited number of plants were sampled, the weather was not optimal for collecting, and the expedition took place early in the season. Furthermore, the apparent absence of fire might have an influence on leafhopper diversity, in contrast to the regularity of fire in the Grassland and Fynbos Biomes. The majority of species however are widespread throughout Africa or southern Africa, feeding on a wide range of plants, with some related to species that are sporadic or common pests in agriculture. The three undescribed species have so far only been recorded from the Kamdebooberge, and may have some affiliations with species from the CFR.

The faunal studies are still largely incomplete and demand intensive observations in future – including extensive trapping, nocturnal sampling and recording indirect evidence. Although preliminary, these results have however already sparked interest among zoologists (e.g. Myriapodes), who may pursue their own field surveys in the Kamdebooberge.

Additional files

Additional file 1: Appendix 1. Plant taxa collected in the Kamdebooberge (22–25 January 2011).

Additional file 2: Appendix 2. Tetrapod vertebrates recorded from the Kamdebooberge (22–25 January 2011).

Additional file 3: Appendix 3. Leafhoppers (Cicadellidae), planthoppers (Dictyopharidae, Nogodinidae, Tropiduchidae) and treehoppers (Membracidae) collected on the Kambebooberge (22–25 January 2011).

Supplementary online data available

Web-album: https://picasaweb.google.com/116442385816096754015/BiodiversityScientistsExploreThePoorlyKnownKamdeboobergeInTheGreatKaroo
Web-article: The Great Escarpment Biodiversity Research Programme http://thegreatescarpment.110mb.com/.

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