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REVIEW PAPER

The Great Escarpment of southern Africa: a new frontier for biodiversity exploration

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Abstract The biodiversity of the 5,000 km-long Great Escarpment of southern Africa is currently poorly known, despite hosting half of the subcontinent's centres of plant endemism and to have a rich endemic vertebrate fauna, particularly in the north-west and east. A country-based overview of endemism, data deficiencies and conservation challenges is provided, with Angola being the country in most need of Escarpment research and conservation. Given that the Escarpment provides most of the subcontinent's fresh water, protection and restoration of Escarpment habitat providing such ecological services is urgently required. Key research needs are exhaustive biodiversity surveys, systematic studies to test refugia and migration hypotheses, and the effects of modern climate change. Such research results can then be consolidated into effective conservation planning and co-ordinated international efforts to protect the rich biodiversity of the Escarpment and the ecological services it provides.

Keywords Great Escarpment · Biodiversity · Conservation priorities · Endemism · Research needs · Southern Africa · Unexplored

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The Great Escarpment in southern Africa

The southern African Great Escarpment is a 5,000 km-long, semi-continuous mountain range system comprised of most of southern Africa's principal geological suites, in varying climatic conditions (White 1983; Moore and Blenkinsop 2006), but with consistent geomorphology as a plateau margin (Van Zinderen Bakker 1983). The formation of the Escarpment has been a matter of debate for several decades (Birkenhauer 1991 provides a very detailed overview of Escarpment geomorphological theory and literature), but it is agreed that the Escarpment forms a (often dramatic) rim to the African plateau that dominates the interior of southern Africa (Van Zinderen Bakker 1983; White 1983; Birkenhauer 1991; Burke et al. 1998; Moore et al. 2009; McCarthy and Rubidge 2005; Burke and Gunnell 2008).

The total extent of the 'Great Escarpment' varies substantially between authors (Birkenhauer 1991). Here we define the Escarpment as the obvious scarp on the edge of the African Plateau from north-western Angola south through Namibia into South Africa and east and north-east through South Africa, Lesotho and Swaziland into eastern Zimbabwe and adjacent Mozambique (Figs. 1, 2). Following future research it may be reasonable to include the Muchinga Escarpment in Zambia, but further north than this the mountains are associated with the Rift Valley System and not with a passive continental margin. Several mountain ranges adjoin the Escarpment and are biogeographically related to it, but are excluded from this overview given their different orogenies (Schönhofer 2008; Moore et al. 2009; McCarthy and Rubidge 2005). These are the Soutpansberg, Witwatersrand, Magaliesberg, Waterberg, KwaZulu-Natal (KZN) Midlands (South Africa), Otavi-Waterberge (Namibia) and the Mashonaland plateau (Zimbabwe). The Karasberge (Namibia) have also been excluded, being isolated from the Escarpment although they were probably linked prior to incision by the (Namibian) Fish River.

The Escarpment is generally believed to have developed following the break-up of Gondwanaland in the late Jurassic/early Cretaceous (Partridge and Maud 1987; Gilchrist et al. 1994; Kooi and Beaumont 1994; McCarthy and Rubidge 2005; Moore et al. 2009). Most authors support an old Escarpment being a stable feature of the subcontinent, with its current position dating to the end of the Cretaceous (Gilchrist et al. 1994; Matmon et al. 2002; McCarthy and Rubidge 2005). Burke and Gunnell (2008), in contrast, provide evidence for a younger Escarpment. Generally, the Escarpment is considered to represent a passive, erosional remnant of the continental margin that has receded from the original zones of rifting by means of parallel retreat (Artyushkov and Hofmann 1998; Matmon et al. 2002; Moore and Blenkinsop 2006), and explains the current primarily parallel orientation of the Escarpment relative to the coast 50–200 km distant (Gilchrist et al. 1994; Kooi and Beaumont 1994). Actual rates of Escarpment retreat is a current debate, and recent research has questioned some traditional views (Burke and Gunnell 2008).

Biodiversity

The Escarpment of southern Africa harbours a rich assemblage of biodiversity that is poorly known and vastly under-represented in the holdings of museums and herbaria.

Steenkamp et al. (2005) indicate that most of the subcontinent's floristic diversity is centred on the Escarpment and adjacent coastal plains, while the interior plateau is relatively impoverished. The combinations of biodiversity assemblages along the Escarpment form nodes of high local endemism that have contributed towards the concept of 'centres

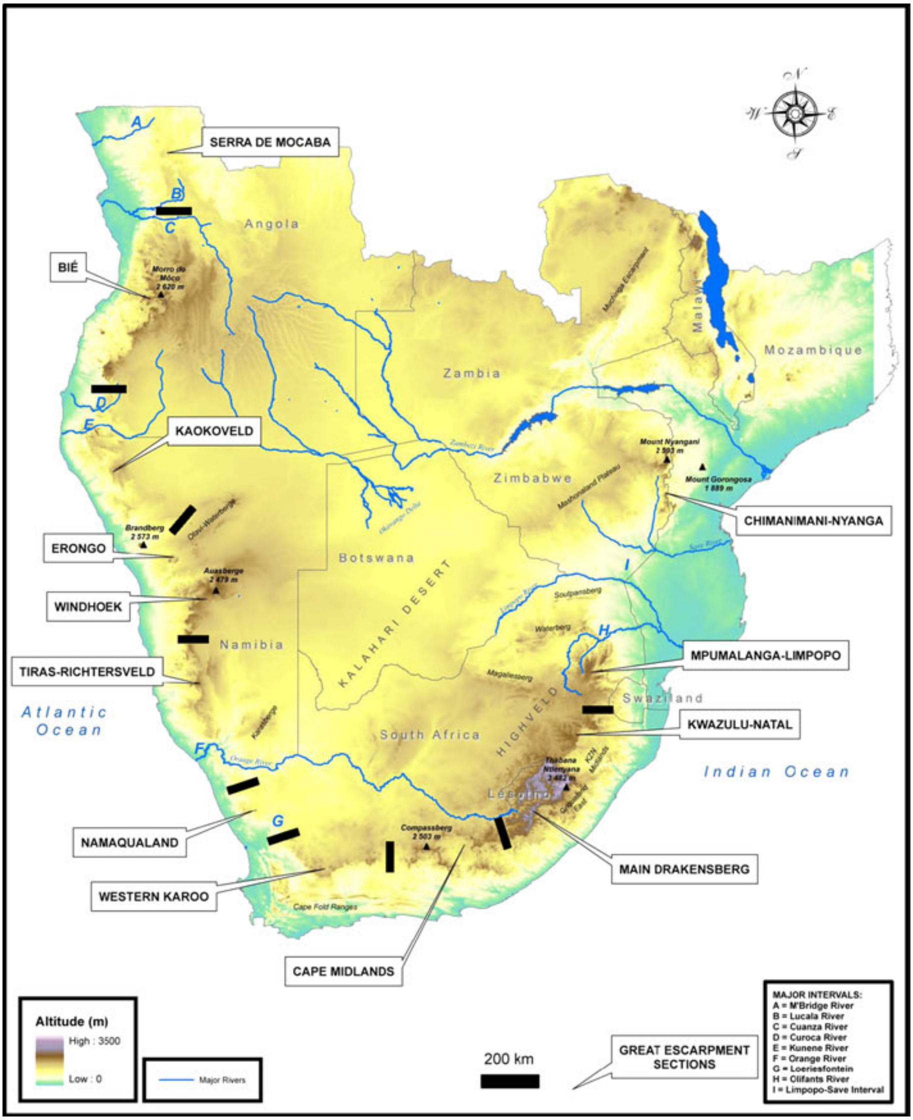

Fig. 1 The Great Escarpment in southern Africa. *Black bars* are separators between Escarpment sections where divisions are not obvious. *GIS data sources*: GeoNetwork 2000; Atlas of Namibia Project 2002; Geo Community 2009. Base relief map generated by G. Keevey (Department of Botany, Rhodes University)

of endemism' in southern Africa (Morrone 2004; Maggs et al. 1998; Van Wyk and Smith 2001). The concept of a 'centre of endemism' as used here follows the definition by Van Wyk and Smith (2001, p. 11) and reads: '*a convenient neutral term to designate a focal point of high endemism*', as opposed to a floristically hierarchical definition or the term 'hotspot'. Of the 18 plant centres described by Van Wyk and Smith (2001), nine are associated with the Escarpment. Adding the recently described Sneeuberg Centre (Clark et al. 2009) this means that more than half of southern Africa's centres of floral endemism

Fig. 2 A selection of photographs from the Great Escarpment in southern Africa, from north-west to northeast (Fig. 1 refers). ANGOLA: **a** the southern part of the Bié Escarpment near Lubango. NAMIBIA: **b** the Kaokoveld Escarpment near Warmquella; **c** a section of the Khomas Hochland, part of the Windhoek Escarpment. SOUTH AFRICA/NAMIBIA: **d** the Richtersveld, Tiras–Richtersveld Escarpment, with the Orange River in the foreground. SOUTH AFRICA: **e** The Kamiesberg, Namaqualand Escarpment; **f** the Ouberg Pass on the Roggeveldberge, Western Karoo Escarpment; **g** the eastern Nuweveldberge, Western Karoo Escarpment; **h** the Nardousberg (Sneeuberg), Cape Midlands Escarpment; **i** the Great Winterberg (Great Winterberg–Amatolas), Cape Midlands Escarpment; **j** the Stormberg at Penhoek Pass, Cape Midlands Escarpment; **k** part of the Main Drakensberg Escarpment near Barkley East. SOUTH AFRICA/LESOTHO: **l** Bannerman Face, Central Drakensberg, Main Drakensberg Escarpment; **m** the Buttress, Central Drakensberg, Main Drakensberg Escarpment. SOUTH AFRICA: **n** Sterkfontein Dam, on the KwaZulu–Natal Drakensberg. SOUTH AFRICA/SWAZILAND: **o** part of the Mpumalanga–Limpopo Escarpment. SOUTH AFRICA: **p** the Blyde River Canyon, Mpumalanga–Limpopo Escarpment. ZIMBABWE/MOZAMBIQUE: **q** the Chimanimanis, Chimanimani–Nyanga Escarpment; **r** Nyanga, Chimanimani–Nyanga Escarpment. Photos credits: **a**, **f–i**, **l**, **m**, **q**, **r** V.R. Clark; **b** Carl Huchzermeyer; **c** Colleen Mannheimer; **d** Gareth Hempson; **e** Syd Ramdhani; **j–k**, **n–p** Mario Martínez-Azorín

are Escarpment-centred. Several of these centres have been studied in some detail, while others are still poorly known (Van Wyk and Smith 2001). The Escarpment has an estimated floral endemism of 17% (1,460 species out of a projected flora of 8,574 species), representing 7% of southern Africa's flora.

Known vertebrate (birds, reptiles, mammals and fish) endemism on the Escarpment is also significant, with a total of 126 endemic species occurring on the Escarpment (Fig. 3a). Local endemism (i.e. confined to one section of Escarpment) is highest in the east and north-west, with the Chimanimani–Nyanga and Kaokoveld Escarpments having the highest number of local endemics and the section of Western Escarpment from Erongo south to Namaqualand the lowest (Fig. 3a). Local endemism mirrors mean annual rainfall, being highest overall in the east and north-west and lowest in the central- and south-west. Shared endemism between two or more sections of Escarpment is highest along the Western Escarpment—nearly half (eight) of these being Angolan endemics—followed by the Eastern Escarpment, and with only two species shared along the (shorter) Southern Escarpment. In terms of endemics restricted per country, South Africa has the highest number of endemics followed by Angola, while Lesotho, Zimbabwe and Mozambique have no endemics restricted within their borders (Fig. 3b). South Africa and Lesotho share the highest number of cross-border endemics, followed by Angola and Namibia, and Zimbabwe and Mozambique (Fig. 3c). With further research the total number of vertebrate endemics will certainly increase, such as indications of numerous undescribed fish species in the Mpumalanga–Limpopo and Angolan Escarpment river systems (Darwall et al. 2009).

Indications are that invertebrate endemism on the Escarpment is also high (such as Prendini 2005 for scorpions; Woodhall 2005 and Krüger 2007 for Lepidoptera; Kirk-Spriggs and McGregor 2009 for Diptera; Herbert 2006 for molluscs; and Darwall et al. 2009 for odonates and molluscs), but much field-collecting and updated taxonomic work is required in this regard for much of the Escarpment.

Country-based assessments of diversity, endemism, research needs and conservation priorities

Although there is continuity across international boundaries, we now consider the Escarpment on a county by country basis given that past biodiversity exploration and thus data availability and conservation challenges are best considered in this context.

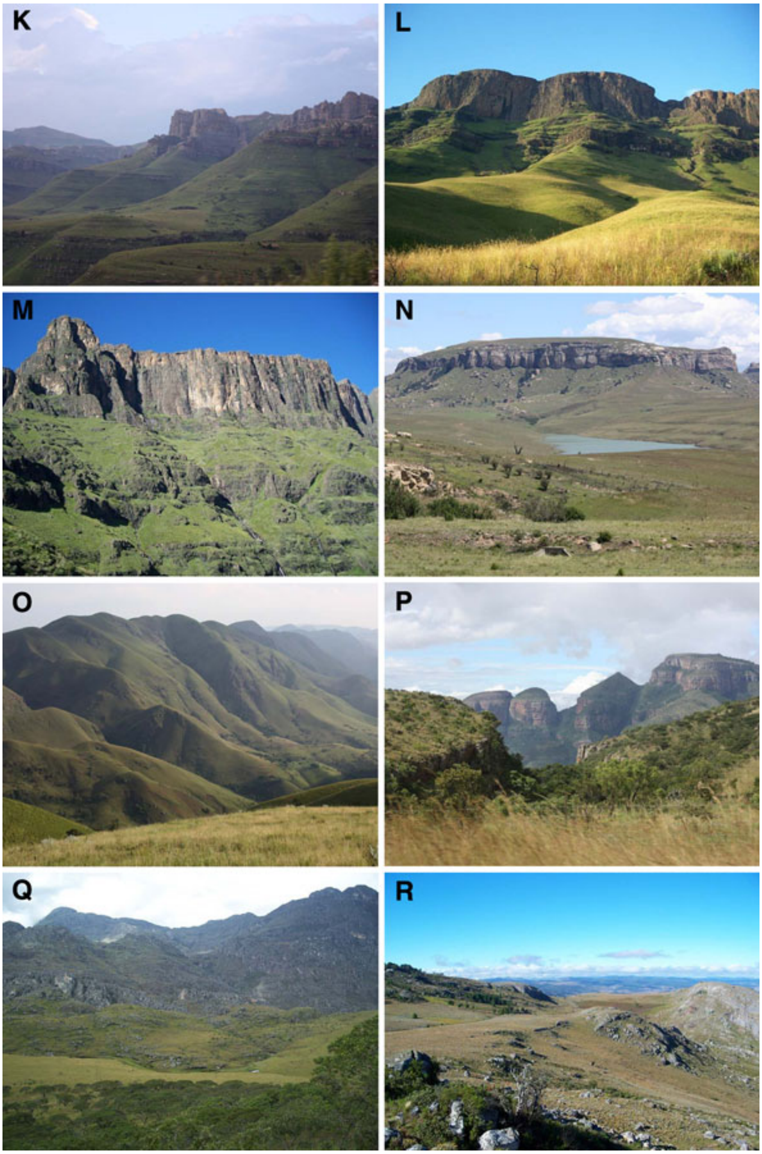

Fig. 2 continued

Angola

The Escarpment in Angola is approximately 1,000 km long, and is the least known section in terms of biodiversity (Huntley and Matos 1994; Dombo et al. 2002; Figueiredo 2010). Indications are that plant endemism is high (IUCN 1990; Figueiredo 2010), and it supports the highest number of vertebrate endemics after South Africa (Fig. 3b). Vegetation types range from tropical evergreen and semi-deciduous rainforest in the north, through

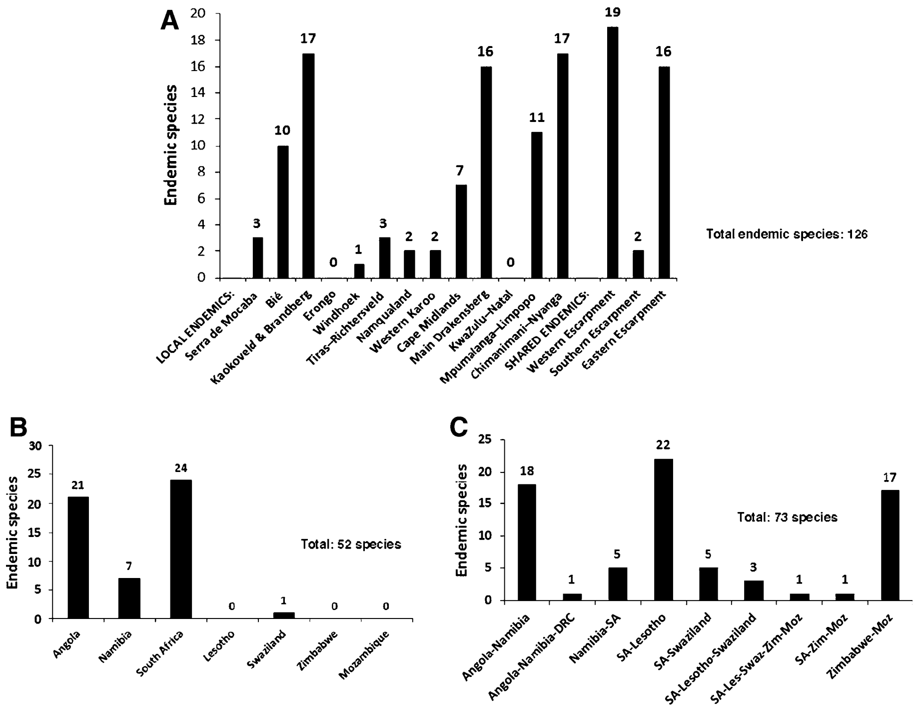

Fig. 3 Vertebrate endemism on the southern African Great Escarpment: **a** Local and shared endemics (Western Escarpment: Serra de Mocaba to Namaqualand; Southern Escarpment: Western Karoo & Cape Midlands; Eastern Escarpment: Cape Midlands to Chimanimani–Nyanga. See Fig. 1 for localities); **b** endemics restricted to each country; **c** endemics shared between countries (*DRC* Democratic Republic of Congo, *SA* South Africa, *Moz* Mozambique). *Data sources*: Birds: Sinclair and Ryan (2003), Hockey et al. (2005) and BirdLife International (2010). Reptiles: Barboza du Bocage (1895), Marx (1956), Mertens (1958), Branch (1998), Burgess et al. (2004) and Herpetologia Angola (sine anno). Mammals: Minter et al. (2004) and Skinner and Chimimba (2005). Amphibians: Channing (2001), Burgess et al. (2004) and Du Preez and Carruthers (2009). Fish: Skelton (2001)

Afromontane forest–grassland mosaics and miombo woodland in the centre, to Kalahari-Highveld shrublands and Nama-Karoo semi-desert in the south (Huntley and Matos 1994; Dean 2001; Dombo et al. 2002; World Wildlife Fund and McGinley 2008a, b).

While the Serra da Mocaba Escarpment (Fig. 1) is a series of steps, the sheer, moist Bié Escarpment is an abrupt change from the fairly flat, arid coastlands (Pickford et al. 1992; Klopper et al. 2009; Mills 2010), resulting in steep moisture gradients. The Bié Escarpment is a biogeographic buffer-zone between the lowlands and the plateau and hosts unique vegetation types (Hall 1960; Dean 2001; Sekercioglu and Riley 2005). Critically endangered and among the most biodiversity-rich areas on earth is the narrow band of what Airy Shaw (1947) calls 'cloud forest' and Olson and Dinerstein (1998) 'Angolan Escarpment Woodlands', confined to the Angolan Escarpment between 350 and 1,000 m above sea level, and the associated 'montane brushwood'. The Bié Escarpment summit and adjacent highlands is one of the most isolated sections of the Afromontane archipelago in Africa (Van Zinderen Bakker 1962; White 1983; Meadows and Linder 1993; Dupont and Behling 2003), and still requires detailed botanical investigation (Huntley and Matos 1994; Dean 2001; Dombo et al. 2002; World Wildlife Fund and McGinley 2008a). Localised stands of

Podocarpus milanjianus Rendle forest occur in the higher areas around Morro do Môco and southwards through Lubango (Airy Shaw 1947; Huntley and Matos 1994; Shi et al. 1998). Palaeo-connections between this section of the Afromontane Region and analogous areas in the East African mountains and West Africa have been a matter of consideration by *inter alia* White (1978, 1983), Dupont et al. (1996), De Busk (1998) and Grimshaw (1998).

The Angolan Escarpment, with 14 endemic bird species, forms the core of the Western Angola Endemic Bird Area (Hall 1960; Huntley and Matos 1994; Dean 2001; Burgess et al. 2004; Cohen et al. 2004; Sekercioglu and Riley 2005; Figueiredo and Smith 2008; World Wildlife Fund and McGinley 2008a, b; BirdLife International 2010). The Gabela region is particularly rich, with most of the Angolan Escarpment bird endemics found in this area (Cohen et al. 2004; Sekercioglu and Riley 2005—although this may simply be sampling bias; Mills 2010). Sub-specific endemism is also very high (Hall 1960). Avi-faunally there is a strong relationship between the Bié Escarpment and other distant Afromontane areas (Hall 1960), particularly the Cameroon Highlands (Njabo and Sorenson 2009). Examples are Monteiro's Bush-shrike *Malaconotus monteiri* (shared with the Cameroon Highlands) and Ludwig's Double-collared Sunbird *Cinnyris ludovicensis* (shared with the Nyika Plateau in Malawi) (Hall 1960; Sinclair and Ryan 2003). Frog and reptile endemism is also pronounced and detailed exploration will shed light on the poorly known endemics and almost certainly add new species.

The Angolan Escarpment is being proposed as a biodiversity hotspot (B. Huntley pers. comm.), and the Bié Plateau almost certainly qualifies as an Escarpment centre of endemism (Figueiredo 2010). There may even be a suite of local centres equivalent to those in eastern South Africa, Lesotho and Swaziland, given that the Angolan Escarpment is the same length and has comparable rainfall and edaphic diversity. Both botanically and faunally much fieldwork and inventory compilation is required on the Angolan Escarpment before patterns of endemism and richness can be reliably assessed, and only recently has an Angolan national list of plant species become available (Figueiredo et al. 2009).

Conservation challenges along the Angolan Escarpment vary. The major threats to the forests are deforestation and fires, while charcoal-making is a huge problem in the woodlands adjacent to large towns such as Lubango (V.R. Clark pers. obs.). As Angola's economy recovers after decades of civil war, there is/will probably be an increase in prospecting and mining. Commercial agriculture (such as coffee plantations) and subsistence agriculture in Escarpment zones is a significant threat to local biodiversity (Huntley and Matos 1994) and will need to be designed and managed sensitively. As the Angolan Escarpment and the Bié Plateau are the headwater sources of the Okavango and Kunene River systems—and also constitute large portions of the Zambezi and Congo catchments—careful environmental management will be essential to maintaining the integrity of these water supplies.

Except for one small reserve on the central Angolan Escarpment and marginally in the south as part of the Parque Nacional do Iona, the Angolan Escarpment does not fall into any protected areas (Huntley and Matos 1994; Dean 2001), and key areas of biological diversity such as the Kumbira Forest near Gabela and the *Podocarpus* forests of central and southern Angolan Escarpment need urgent formal protection (Huntley and Matos 1994; Cohen et al. 2004; Sekercioglu and Riley 2005).

Namibia

The Namibian Escarpment is a focal area for faunal and botanical endemism in Namibia (Barnard et al. 1998; Griffin 1998; Robertson et al. 1998; Simmons et al. 1998; Van Wyk and Smith 2001). The Namibian Escarpment is the most arid section of the Escarpment in southern Africa.

The Kaokoveld Escarpment (including the adjacent section in southern Angola) is the richest section of the Namibian Escarpment in terms of endemic biodiversity (Barnard et al. 1998; Maggs et al. 1998). It forms the mountainous component of the Kaokoveld Centre of plant endemism (Maggs et al. 1998; Van Wyk and Smith 2001), and there is the parallel faunal endemism of two bird, two mammal, one amphibian, and at least 10 reptile species (notably geckos). Several other endemic avifaunal species are shared between the Escarpment and the Otavi–Waterberge (Robertson et al. 1998; Hockey et al. 2005). The Tiras–Richtersveld Escarpment in the south falls into the botanically rich Sperrgebiet area (Barnard et al. 1998; Maggs et al. 1998), which is associated with Van Wyk and Smith's (2001) Gariep Centre. The Khomas Hochland is also rich in local plant endemics (Maggs et al. 1998). Of the many Escarpment-associated inselbergs the most spectacular in terms of endemism is the Brandberg, with eight endemic plants species (Maggs et al. 1998) and its own endemic reptile (Brandberg Thick-toed Gecko *Pachydactylus gaiasensis*; Branch 1998). The flagship Namibian Escarpment species is Hartmann's Mountain Zebra *Equus zebra hartmannae*, although it formerly also occurred on the Namaqualand Escarpment in South Africa (Moodley and Harley 2005). Four endemic frogs occur on the Namibian Escarpment (Simmons et al. 1998). Simmons et al. (1998) indicates that insect endemism is high along the Escarpment, many of these being plesiomorphs (phylogenetic relicts isolated for millennia).

Although better explored than the Angolan Escarpment, there are still areas of the Namibian Escarpment that are poorly known biologically. The least-well collected area botanically is the Tiras mountains in the south (Burke and Strohbach 2000), and even the Windhoek Escarpment around the capital city is poorly known (Maggs et al. 1998; Burke and Wittneben 2008). Apart from research on avifauna and Hartmann's Mountain Zebra, there does not appear to have been much research on Namibian Escarpment fauna and new species can be anticipated (Simmons et al. 1998).

Very little of the Namibian Escarpment falls into any protected areas (Maggs et al. 1994; Barnard et al. 1998), with only small portions falling into the Ai-Ais–Huntsberg Reserve Complex, the Namib–Naukluft Park, Daan Viljoen Nature Reserve, and Etosha National Park (Griffin 1998; Robertson et al. 1998). The entire Kaokoveld Escarpment previously fell into the since deproclaimed Game Reserve No. 2, which at that time was one of the largest conservation areas in the world (Barnard et al. 1998). Despite community conservancy initiatives this area requires urgent conservation (Barnard 1998; Van Wyk and Smith 2001). Fifty-nine percent of the Namibian Escarpment is owned by rural communities with most of the remainder falling into commercially owned farm- and rangeland (Robertson et al. 1998). Currently, private game reserves and conservancies are the most effective means of environmental protection for much of the Escarpment in Namibia (Barnard et al. 1998; Griffin 1998), and co-operation with local landowners and rural communities is probably the only way in which the high local biodiversity of the Escarpment will be protected indefinitely (Barnard et al. 1998). Overgrazing in communal lands in the north and unsustainable hunting are of main concern. Namibia will also have to carry the preservation responsibilities for those endemics shared with Angola until such time as Angola has a more extensive protected area network (Barnard 1998; Simmons et al. 1998).

South Africa, Lesotho and Swaziland

The arid western Escarpment in South Africa has localised but low faunal endemism (Fig. 3A) and high plant endemism, the particularly on the Richtersveld (part of the Gariep

Centre), Namaqualand (the Kamiesberg Centre, a sub-centre of the CFR) and Hantam–Roggeveld (the core of the Hantam–Roggeveld Centre; Van Wyk and Smith 2001; Helme and Desmet 2006; Helme 2008; Clark et al. 2011b). These are the most arid components of the Escarpment in South Africa, but receive reliable winter rainfall and form part of the very species-rich Succulent Karoo and Fynbos Biomes (Low and Rebelo 1998; Mucina and Rutherford 2006; Desmet 2007). The Nuweveldberge has a much lower endemism than the rest of the Escarpment in South Africa, attributable to its unreliable rainfall regime (Clark et al. 2011c).

The Cape Midlands Escarpment—comprising the Sneeuberg, Great Winterberg–Amatolas and Stormberg—is one of the most fragmented sections of Escarpment and forms a transition zone between the arid west and the moister east (Van der Walt 1980). The climatic gradient, together with the fragmented topography and large altitudinal variations, has rendered it an area of local endemism (Clark et al. 2009, 2011a). Nordenstam (1969) defined the Cape Midlands Escarpment as the 'Sneeuwbergen Centre' (later picked up by Hilliard 1994), but the area is still poorly explored botanically. It might thus be possible in future to define separate centres of endemism for the Sneeuberg (as done by Clark et al. 2009), Great Winterberg–Amatolas and Stormberg. An alternative would be to place these mountains as sub-centres under the DAC, as done by Mucina and Rutherford (2006) for the Stormberg and Great Winterberg–Amatolas.

The eastern Escarpment (Drakensberg Regional Mountain System *sensu* White 1978) in South Africa, Lesotho and Swaziland forms part of the Afromontane Region. It is a floristic and faunal link between the CFR and the remainder of the Afromontane archipelago (Stuckenberg 1962; Goldblatt 1978; Oliver et al. 1983; Linder 1990; Carbutt and Edwards 2001; Galley et al. 2007, etc.). This eastern section is the best studied section of Escarpment and hosts the most centres of plant endemism (i.e. the Drakensberg Alpine, Barberton, Sekhukhuneland and Wolkberg Centres of Van Wyk and Smith 2001, these being part of Mucina and Rutherford's 2006 'Northern sourveld endemics' concept). It also hosts many faunal endemics (many of which are endangered and a few considered extinct; Branch 1998), harbours important populations of faunal species that are not Escarpment endemics but are shared by the Escarpment and the CFR (e.g. Forest Buzzard *Buteo trizonatus* and Cape Mole-rat *Georychus capensis*), or to the Escarpment and the adjacent Highveld plateau and/or KZN Midlands (e.g. Blue Korhaan *Eupodotis caerulescens*, Buff-streaked Chat *Oenanthe bifasciata*, Dark-footed Forest Shrew *Myosorex cafer*, Plaintive Rain Frog *Breviceps verrucosus*, Long-toed Tree Frog *Leptopelis xenodactylus*, etc.; Channing 2001; Minter et al. 2004; Hockey et al. 2005; Skinner and Chimimba 2005). Other species occurring more widely in the Afromontane region in Africa are in southern Africa restricted to this Escarpment (e.g. Black-fronted Bush-shrike *Telephorus nigrifrons* and Orange Ground-Thrush *Zoothera gurneyi*; Sinclair and Ryan 2003; Hockey et al. 2005). An interesting Escarpment breeding-endemic is the Mountain Pipit *Anthus hoeschi*, which breeds on the Main Drakensberg Escarpment and winters in south-central Africa (Sinclair and Ryan 2003; Hockey et al. 2005). For other, historically less-restricted species, this Escarpment hosts important remnant populations as it provides suitable habitat, food resources and comparatively lower persecution than in their original ranges (e.g. Bearded Vulture *Gypaetus barbatus*; Sinclair and Ryan 2003; Hockey et al. 2005). Despite being relatively close to major population centres such as Gauteng, Bloemfontein and Durban, this Escarpment remains botanically poorly explored in many places, with new species still being discovered even in relatively well-collected areas (McMurtry et al. 2006; Van Bruggen 2006; Edwards et al. 2008). There are clear biogeographical links between this Escarpment and the Witwatersrand, Waterberg and Soutpansberg (Van Wyk and Smith 2001; Brand et al. 2010).

Shroyer and Blignaut (2003) provide a detailed overview of the current status of mountain conservation, threats and relevant legislation in South Africa. In western South Africa the Escarpment has very little formal protection (Cowling et al. 1995). Several small national parks, nature reserves and numerous private game reserves and conservancies cover sections of the eastern Nuweveldberge (Western Karoo) and Cape Midlands Escarpment, but this southern Escarpment is currently vulnerable to uranium and shale-gas mining proposals. The eastern section of the Escarpment has the largest number of protected areas than any other section, but human pressure on the Escarpment here is much higher, and conservation concerns compete with mining, agriculture, large-scale commercial forestry, invasive alien vegetation, dams and dense rural settlements (Shroyer and Blignaut 2003; Wessels et al. 2003; Neke and Du Plessis 2004; O'Connor and Kuyler 2009). South Africa's montane grasslands are critically endangered (Olson and Dinerstein 1998), are poorly protected (Neke and Du Plessis 2004), and the endemic fauna and flora is at huge risk from land transformation e.g. afforestation (Allan 2001; Allan et al. 2001; Van Wyk and Smith 2001). As a result, extended conservation areas and management of natural habitat/restoration on private and community land are urgently needed to protect the Escarpment's biodiversity and ecological services (such as water supply) (Matthews et al. 1992a, b; Cowling and Hilton-Taylor 1994; Emery et al. 2002). The National Grasslands Biodiversity Programme aims to consolidate conservation initiatives (Mucina and Rutherford 2006). The most urgent areas for conservation, rehabilitation and environmental education are undoubtedly those affected by African rural land-use with its associated extirpation of most local wildlife, severe overgrazing and soil erosion, and rural urbanisation (Blignaut and Moolman 2006). Key areas for such focus are parts of the former homelands (such as the Ciskei, Transkei, KwaZulu, etc.) and Lesotho and Swaziland (Van Wyk and Smith 2001; Mucina and Rutherford 2006). Ecological restoration work has been proposed for certain key water-source areas on the Escarpment in the Eastern Cape and KZN (Blignaut and Moolman 2006; Blignaut et al. 2008, 2010). As for the Namibian Escarpment, private game reserves and conservancies are the most effective means of environmental protection for much of the Escarpment in eastern South Africa, Lesotho and Swaziland.

Zimbabwe–Mozambique

The Chimanimani–Nyanga Highlands are the most isolated component of the Escarpment. The entire Nyanga component is in Zimbabwe, while much of the Chimanimani component is in Mozambique. As for the Bié and Eastern Great Escarpments, the Chimanimani–Nyanga Highlands form part of the Afromontane region, and are a floristic and faunal link between the Escarpment to the south in eastern South Africa, and the East African mountains and Great Inselberg Archipelago of Malawi and northern Mozambique to the north and north-east (White 1983; Van Wyk and Smith 2001; Schneider et al. 2005). A floristic centre in its own right, the Chimanimani–Nyanga Escarpment has a floristic endemism of 6.7% (Van Wyk and Smith 2001). It shares one avifaunal endemic with the Escarpment in eastern South Africa (Gurney's Sugarbird *Promerops gurneyi*), and has one of its own avifaunal endemics (Roberts's Warbler *Oreophilias robertsii*). There are seven reptile, two mammal and seven frog endemics. Mount Gorongosa, 130 km to the east in Mozambique, shares numerous floral and faunal endemics with the Chimanimani–Nyanga Escarpment (and it should almost certainly be included in the Chimanimani–Nyanga Centre; Burgess et al. 2004; World Wildlife Fund and McGinley 2008c).

Formal conservation of the Chimanimani–Nyanga Escarpment is represented by two substantial national parks and numerous forest reserves in Zimbabwe. Despite the selective dissolution of law and order in Zimbabwe since 2000 Chimanimani National Park staff have curbed illegal gold panning in the Park, but this is still a problem in adjacent Mozambique. Important forest sites—such as the Chirinda Forest near Mount Selinda—are also still protected and deforestation in such protected areas appears to be minimal (V.R. Clark pers. obs.). The greatest threat is alien plant invaders, with forest invasive species a particular problem in the Bvumba (e.g. Zingiberaceae) and grassland invasive species in Nyanga (*Pinus patula* Schiede and Deppe and *Acacia mearnsii* De Wild.). Urgent and sustained measures on the scale of the Working for Water programme in South Africa are required to combat this problem. Apart from the Chimanimani National Reserve there is limited formal protection of that portion of the Chimanimanis occurring in Mozambique (Schneider et al. 2005) despite the Chimanimani Transfrontier Conservation agreement.

International conservation collaboration

With more endemic Escarpment plants and animals occurring across borders than within single countries (e.g. Fig. 3c) international co-ordination of Escarpment conservation efforts is essential. To date international collaboration has been achieved with the Ai-Ais/Richtersveld Transfrontier National Park between Namibia and South Africa (it includes some of the Tiras–Richtersveld Escarpment), the Maloti–Drakensberg Transfrontier Park between South Africa and Lesotho (Main Drakensberg Escarpment), and the Chimanimani Transfrontier Conservation Area between Zimbabwe and Mozambique (Chimanimani–Nyanga Escarpment) (Mucina and Rutherford 2006; Peace Parks Foundation 2010). The Iona–Skeleton Coast Transfrontier Conservation Area may conserve some of the Kaokoveld Escarpment in Angola and Namibia (Barnard et al. 1998; Peace Parks Foundation 2010). The greatest long-term threat to the biodiversity of the Escarpment is political incentive driving economic expedience and development at the cost of sustainability and conservation (Barnard et al. 1998; Shroyer and Blignaut 2003).

Conclusion

The Escarpment provides a wealth of opportunity for biodiversity exploration and subsequent ecological and systematic research. Local and regional efforts, such as the Great Escarpment Biodiversity Programme (GEBP; http://thegreatescarpment.110mb.com/) based at Rhodes University (which has to date focused on the southern Escarpment) will help to reduce this research vacuum. However a larger scale effort is urgently required of which the main research needs are:

- Intensive field-collecting and the compilation of biodiversity inventories (Huntley and Matos 1994; Maggs et al. 1994). Such research is not hypothesis driven and thus perhaps unfashionable (and even non-fundable by some funding agencies), but it is fundamental to accurate floristic, faunistic and biogeographical analysis, systematic studies, taxonomy, and conservation planning (Kruckeberg and Rabinowitz 1985; Huntley and Matos 1994; Kahindo et al. 2007). The compilation of a complete (and accurate) Escarpment flora would be a major step in firmly determining plant diversity and endemism, and provide an opportunity for detailed floristic analysis between different Escarpment sections and with other high-altitude areas. Likewise for fauna, although for invertebrates this may indefinite. Data from focused inventorying exercises can feed into existing databases operated by various national and provincial custodians of biodiversity, such as the Namibian National Botanical Research Institute (NBRI), the South African National Botanical Institute (SANBI), the South African National Parks Board (SANParks), Ezemvelo KZN Wildlife, the Zimbabwe Wildlife and Parks Authority, etc. Biodiversity database initiatives, such as those operated by SANBI (e.g. PRECIS; Prentice and Arnold 1998), South African Institute for Aquatic Biodiversity (SAIAB) at Rhodes University, and the Animal Demography Unit at the University of Cape Town (e.g. the South African Bird Atlas Projects 1 and 2, the Mozambique Bird Atlas Project, the Birds in Reserves Project, the Southern African Frog Atlas Project, Southern African Reptile Conservation Assessment, Southern African Butterfly Conservation Assessment), successfully incorporate interested public in obtaining biodiversity data in specified formats. This approach needs to be expanded to poorly known Escarpment areas.

- Well-sampled systematic studies that include Escarpment taxa. These are needed in order to test hypotheses of palaeo- and neo-endemism (Nekola 1999), for which there is often little evidence (Kruckeberg and Rabinowitz 1985), and migration routes and refugia (Poynton 1983; Griffin 1998; Simmons et al. 1998; Prendini 2005; Galley and Linder 2007; Devos et al. 2010). Creation and interpretation of such phylogenies will add greatly to the debate regarding Escarpment connections (past and present) with the CFR and other highland areas in Africa (Galley and Linder 2007; Galley et al. 2007; Bergh and Linder 2009; Clark 2010), as well as with the adjacent southern African coastal lowlands and the significance of intervals along the Escarpment. Phylogenies obtained can provide valuable data on genetic diversity, cryptic species (Bickford et al. 2006), the effect of past climates and tectonic events (Midgley et al. 2001; Jetz et al. 2004; Bergh et al. 2007; Linder 2008), and the role of various parameters on Escarpment speciation (Jetz et al. 2004; Nosil et al. 2009). The extensive work done on the CFR (Linder and Mann 1998; Linder 2001, 2006; Cowling and Lombard 2002; Cowling et al. 2005; Hardy and Linder 2005; Procheş et al. 2006; Van der Niet and Johnson 2009; Verboom et al. 2009, etc.) could be taken as a model for future work on the Escarpment.
- Research on climate change and its effect on Escarpment endemics and species assemblages. Over the next 50 years many localised endemics may be forced into small refugia or suffer wholesale extinction (McDonald et al. 2002; Simmons et al. 1998). Modelling and predicting the impact of climate change should thus be an important element in Escarpment research and conservation planning (Eggermont and Verschuren 2007; Tolley et al. 2009).
- Research on and protection of the Escarpment's ecological functioning and integrity is urgently required in order to maintain essential ecological services (Blignaut et al. 2008, 2010). The most important example is water supply, with virtually all of southern Africa's freshwater water arising on the Escarpment. Ecological services and resources provided by the Escarpment should be quantified in economic terms in order to emphasise the value of the Escarpment to regional and local activities.
- All of the above should result in more effective conservation planning (Shroyer and Blignaut 2003). Despite its length, the Escarpment is a narrow entity with very steep and vulnerable environmental gradients and consequently narrow stretches of any particular habitat. These montane habitats are more vulnerable to disturbance than the adjacent, larger lowlands and inland African plateau habitats. Careful planning is

required in combination with effective ground measures that include inter alia formal conservation areas (including wilderness and non-invasive recreation), private land and community conservation programmes and restoration initiatives (e.g. erosion and alien invader control) (Donaldson et al. 2003; Shroyer and Blignaut 2003; Blignaut and Moolman 2006; Blignaut et al. 2008).

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References

Airy Shaw HK (1947) The vegetation of Angola. J Ecol 35:24–48

Allan DG (2001) Breeding and vocalizations of Rudd's Lark—the vanishing ventriloquist. Bird Numbers 10:29–35

Allan DG, Harrison JA, Navarro RA et al (2001) The impact of commercial afforestation on bird populations in Mpumalanga Province, South Africa—insights from bird-atlas data. Biol Conserv 79:173–185

Artyushkov EV, Hofmann AW (1998) Neotectonic crustal uplift on the continents and its possible mechanisms. The case of southern Africa. Surv Geophys 19:369–415

Barboza du Bocage JV (1895) Herpétologie d'Angola et du Congo. Imprimerie Nationale, Lisbon

Barnard P (1998) Biological diversity in Namibia: a clash of sea and land, fog and dust. Biodivers Conserv 7:415–417

Barnard P, Brown CJ, Jarvis AM et al (1998) Extending the Namibian protected area network to safeguard hotspots of endemism and diversity. Biodivers Conserv 7:531–547

Bergh NG, Linder HP (2009) Cape diversification and repeated out-of-southern-Africa dispersal in paper daisies (Asteraceae–Gnaphalieae). Mol Phylogenet Evol 51:5–18

Bergh NG, Hedderson TA, Linder HP et al (2007) Palaeoclimate-induced range shifts may explain current patterns of spatial and genetic variation in renosterbos (*Elytropappus rhinocerotis*, Asteraceae). Taxon 56:393–408

Bickford D, Lohman DJ, Sodhi NS et al (2006) Cryptic species as a window on diversity and conservation. Trends Ecol Evol 22:148–155

BirdLife International (2010) http://www.birdlife.org. Accessed 23 Nov 2010

Birkenhauer J (1991) The Great Escarpment of southern Africa and its coastal forelands—a re-appraisal. Institut für Geographie der Universität, Müchen

Blignaut J, Moolman C (2006) Quantifying the potential of restored natural capital to alleviate poverty and help conserve nature. J Nat Conserv 14:237–248

Blignaut J, Aronson J, Mander M et al (2008) Investing in natural capital and economic development: South Africa's Drakensberg Mountains. Ecol Restor 26:143–150

Blignaut J, Mander M, Schulze R et al (2010) Restoring and managing natural capital towards fostering economic development: evidence from the Drakensberg, South Africa. Ecol Econ 69:1313–1323

Branch B (1998) Field guide to snakes and other reptiles of southern Africa, 3rd edn. Struik, Cape Town

Brand RF, PJ, Brown LR, Du Preez PJ (2010) A floristic analysis of the vegetation of Platberg, eastern Free State, South Africa. Koedoe 52. doi:10.4102/koedoe.v52i1.710

Burgess N, D'Amico Hales J, Underwood E et al (2004) Terrestrial ecoregions of Africa and Madagascar: a conservation assessment. Island, Washington
Burke K, Gunnell Y (2008) The African erosion surface: a continental-scale synthesis of geomorphology, tectonics, and environmental change over the past 180 million years. Mem Geol Soc Am 201:1–66
Burke A, Strohbach BJ (2000) Review: vegetation studies in Namibia. Dinteria 6:1–24
Burke A, Wittneben M (2008) The vegetation of the Auas Mountains. Dinteria 30:41–91
Burke A, Jürgens N, Seely M (1998) Floristic affinities of an inselberg archipelago in the southern Namib desert—relict of the past, centre of endemism or nothing special? J Biogeogr 25:311–317
Carbutt C, Edwards T (2001) Cape elements on high-altitude corridors and edaphic islands: historical aspects and preliminary phytogeography. Syst Geogr Plants 71:1033–1061
Channing A (2001) Amphibians of central and southern Africa. Comstock, New York
Clark VR (2010) The phytogeography of the Sneeuberg, Nuweveldberge and Roggeveldberge (Great Escarpment): assessing migration routes and endemism. Dissertation, Rhodes University
Clark VR, Barker NP, Mucina L (2009) The Sneeuberg: a new centre of floristic endemism on the Great Escarpment, South Africa. S Afr J Bot 75:196–238
Clark VR, Barker NP, Mucina L (2011a) The Boschberg (Somerset East, Eastern Cape)—a floristic cross-roads of the southern Great Escarpment. S Afr J Bot 77:94–104
Clark VR, Barker NP, Mucina L (2011b) The Roggeveldberge—notes on a botanically hot area on a cold corner of the southern Great Escarpment, South Africa. S Afr J Bot 77:112–126
Clark VR, Barker NP, Mucina L (2011c) A phytogeographic assessment of the Nuweveldberge, South Africa. S Afr J Bot 77:147–159
Cohen C, Mills M, Spottiswoode C (2004) Angolas mountain endemics emerge. Birds & Birding, Africa
Cowling RM, Hilton-Taylor C (1994) Patterns of plant diversity and endemism in Southern Africa: an overview. In: Huntley BJ (ed) Botanical diversity in southern Africa. Proceedings of a conference on the conservation and utilization of southern African botanical diversity, Cape Town, September 1993. Strelitzia 1. National Botanical Institute, Pretoria, pp 31–52
Cowling RM, Lombard AT (2002) Heterogeneity, speciation/extinction history and climate: explaining regional plant diversity patterns in the Cape Floristic Region. Divers Distrib 8:163–179
Cowling RM, Pressey RL, Lombard AT et al (1995) From representation to persistence: requirements for a sustainable system of conservation areas in the species-rich mediterranean-climate desert of southern Africa. Divers Distrib 5:51–71
Cowling RM, Ojeda F, Lamont BB et al (2005) Rainfall reliability, a neglected factor in explaining convergence and divergence of plant traits in fire-prone mediterranean-climate ecosystems. Glob Ecol Biogeogr 14:509–519
Darwall WRT, Smith KG, Tweddle D, Skelton P (2009) The status and distribution of freshwater biodiversity in southern Africa. IUCN/SAIAB, Gland/Grahamstown
De Busk GH (1998) A 37 500-year pollen record from Lake Malawi and implications for the biogeography of Afromontane forests. J Biogeogr 25:479–500
Dean WRJ (2001) Angola. In: Fishpool LDC, Evans MI (eds) Important Bird Areas in Africa and associated islands. Priority sites for conservation. BirdLife Conservation Series no 11. Pisces/BirdLife International, Newbury/Cambridge, pp 71–91
Desmet PG (2007) Namaqualand—a brief overview of the physical and floristic environment. J Arid Environ 70:570–587
Devos N, Barker NP, Nordenstam B et al (2010) A multi-locus phylogeny of *Euryops* (Asteraceae, Senecioneae) augments support for the 'Cape to Cairo' hypothesis of floral migrations in Africa. Taxon 59:57–67
Dombo A, Da Costa E, Neto G (2002) Angola. In: Golding J (ed) Southern African Red Data Lists. Southern African Botanical Diversity Network Report no 14. SABONET, Pretoria, pp 8–11
Donaldson JS, Mills A, O'Farrell P et al (2003) Conservation farming with biodiversity in South Africa: a preliminary evaluation of ecosystem goods and services in the Bokkeveld Plateau. In: Lemons J, Victor R, Schaffer D (eds) Conserving biodiversity in arid regions: best practices for developing nations. Kluwer, Boston, pp 41–54
Dupont L, Behling H (2003) Land-sea linkages during deglaciation: high-resolution records from the eastern Atlantic off the coast of Namibia and Angola (ODP site 1078). Quat Internsh 148:19–28
Dupont LM, Ning S, Jahns S et al (1996) Podocarpus in West Africa during the Late Pleistocene. Paleoecol Afr 24:85–101
Du Preez L, Carruthers V (2009) A complete guide to the frogs of southern Africa. Struik Nature, Cape Town
Edwards T, Hughes M, Möller M et al (2008) New *Streptocarpus* species (Gesneriaceae) from South Africa. Bot J Linn Soc 158:743–748

Eggermont H, Vershuren D (2007) Taxonomy and diversity of Afroalpine Chironomidae (Insecta: Diptera) on Mount Kenya and the Ruwenzori Mountains, East Africa. J Biogeogr 34:69–89

Emery AJ, Lötter M, Williamson SD (2002) Determining the conservation value of land in Mpumalanga. Mpumalanga Parks Board, Nelspruit

Figueiredo E (2010) Diversity and endemism of Rubiaceae in Angola. In: Van der Burgt X, Van der Maesen J, Onana J-M (eds) Systematics and conservation of African plants. Royal Botanic Gardens, Kew, pp 15–22

Figueiredo E, Smith GF (2008) Plants of Angola/Plantas de Angola. Strelitzia 22. South African National Biodiversity Institute, Pretoria

Figueiredo E, Smith GF, César J et al (2009) The flora of Angola: first record of diversity and endemism. Taxon 58:233–236

Galley C, Linder HP (2007) The phylogeny of the *Pentaschistis* clade (Danthonioideae, Poaceae) based on chloroplast DNA, and the evolution and loss of complex characters. Evolution 61:864–884

Galley C, Bytebier B, Bellstedt DU et al (2007) The Cape element in the Afrotemperate flora: from Cape to Cairo? Proc R Soc Lond B Biol 274:535–543

GeoCommunity (2009) http://www.geocomm.com/. Accessed Nov 2009

GeoNetwork (2000) http://www.fao.org/geonetwork/srv/en/metadata.show?id=12&currTab=summary. Accessed Nov 2009

Gilchrist AR, Kooi H, Beaumont C (1994) Post-Gondwana geomorphic evolution of southwestern Africa: implications for the controls on landscape development from observations and numerical experiments. J Geophys Res 99:12211–12228

Goldblatt P (1978) An analysis of the flora of southern Africa: its characteristics, relationships, and origins. Ann Mo Bot Gard 65:369–436

Griffin M (1998) The species diversity, distribution and conservation of Namibian mammals. Biodivers Conserv 7:483–494

Grimshaw JM (1998) Disturbance, pioneers and the Afromontane archipelago. In: Huxley CR, Lock JM, Cutler DF (eds) Chorology, taxonomy and ecology of the floras of Africa and Madagascar, chap 15. Royal Botanic Gardens, Kew, pp 207–220

Hall BP (1960) The faunistic importance of the scarp of Angola. Ibis 102:420–442

Hardy CR, Linder HP (2005) Intraspecific variability and timing in ancestral ecology reconstruction: a test case from the Cape Flora. Syst Biol 54:299–316

Helme N (2008) A description of the endemic flora and vegetation of the Kamiesberg uplands, Namaqualand. PlantLife 37 & 38:12–43

Helme N, Desmet PG (2006) A description of the endemic flora and vegetation of the Kamiesberg uplands, Namaqualand. Report for CEPF/SKEP

Herbert DG (2006) Revision of the genus *Prestonella* (Mollusca: Gastropoda: Orthalicoidea: Bulimulidae *s.l.*) a distinctive component of the African land snail fauna. Afr Invertebr 47:1–23

Hilliard OM (1994) The Manuleae: a tribe of Scrophulariaceae. Edinburgh University Press, Edinburgh

Hockey PAR, Dean WRJ, Ryan PG (eds) (2005) Roberts–Birds of Southern Africa, 7th edn. The Trustees of the John Voelcker Bird Book Fund, Cape Town

Huntley BJ, Matos EM (1994) Botanical diversity and its conservation in Angola. In: Huntley BJ (ed) Botanical diversity in southern Africa. Proceedings of a conference on the conservation and utilization of southern African botanical diversity, Cape Town, September 1993. Strelitzia 1. National Botanical Institute, Pretoria, pp 53–74

International Union for Conservation of Nature and Natural Resources (IUCN) (1990) Biodiversity in Sub-Saharan Africa and its islands: conservation, management, and sustainable use. Occasional Papers of the IUCN Species Survival Commission no 6. IUCN, Switzerland

Jetz W, Rahbek C, Colwell RK (2004) The coincidence of rarity and species richness and the potential signature of history in centres of endemism. Ecol Lett 7:1180–1191

Kahindo C, Bowie RCK, Bates JM (2007) The relevance of data on genetic diversity for the conservation of Afromontane species. Biol Conserv 134:262–270

Kirk-Spriggs AH, McGregor G (2009) Disjunctions in the Diptera (Insecta) fauna of the Mediterranean Province and southern Africa and a discussion of biogeographical considerations. Trans R Soc S Afr 64:32–52

Klopper RR, Matos S, Figueiredo E, Smith GF (2009) Aloe in Angola (Asphodelaceae: Alooideae). Bothalia 39:19–35

Kooi H, Beaumont C (1994) Escarpment evolution on high-elevation rifted margins: insights derived from a surface processes model that combines diffusion, advection, and reaction. J Geophys Res 99:12191–12209

Kruckeberg AR, Rabinowitz D (1985) Biological aspects of endemism in higher plants. Annu Rev Ecol Syst 16:447–479

Krüger M (2007) Composition and origin of the geometrid fauna (Lepidoptera) of the Sneeuberg, Eastern Cape, with descriptions of new taxa. Ann Transvaal Mus 44:25–66

Linder HP (1990) On the relationships between the vegetation and floras of the afromontane and the Cape regions of Africa. In: Proceedings of the 12th plenary meeting of AETFAT, symposium 7. Mitteilungen aus dem Institut für Allgemeine Botanik 23b, pp 777–790

Linder HP (2001) On areas of endemism, with an example from the African Restionaceae. Syst Biol 50:892–912

Linder HP (2006) Investigating the evolution of floras: problems and progress—an introduction. Divers Distrib 12:3–5

Linder HP (2008) Plant species radiations: where, when, why? Philos Trans R Soc Lond B 363:3097–3105

Linder HP, Mann DM (1998) The biogeography and phylogeny of *Thamnochortus* (Restionaceae). Bot J Linn Soc 128:319–357

Low AB, Rebelo AG (eds) (1998) Vegetation of South Africa, Lesotho and Swaziland. Department of Environmental Affairs and Tourism, Pretoria

Maggs GL, Kolberg HH, Hines CJH (1994) Botanical diversity in Namibia—an overview. In: Huntley BJ (ed) Botanical diversity in southern Africa. Proceedings of a conference on the conservation and utilization of southern African botanical diversity, Cape Town, September 1993. Strelitzia 1. National Botanical Institute, Pretoria, pp 93–104

Maggs GL, Craven P, Kolberg HA (1998) Plant species richness, endemism, and genetic resources in Namibia. Biodivers Conserv 7:435–446

Marx H (1956) A new lacertid lizard from Angola. Fieldiana Zool 39:5–9

Matmon AM, Bierman P, Enzel Y (2002) Pattern and tempo of great escarpment erosion. Geology 30:1135–1138

Matthews WS, Bredenkamp GJ, Van Rooyen N (1992a) The vegetation of the dry dolomitic regions of the north-eastern mountain sourveld of the Transvaal Escarpment, South Africa. Phytocoenologia 20:467–488

Matthews WS, Bredenkamp GJ, Van Rooyen N (1992b) The phytosociology of the high altitude hygrophilous vegetation regions of the north-eastern mountain sourveld of the Transvaal, South Africa. Phytocoenologia 20:559–574

McCarthy T, Rubidge B (2005) The story of earth and life. Struik, Cape Town

McDonald DJ, Midgley GF, Powrie L (2002) Scenarios of plant diversity in South African mountain ranges in relation to climate change. In: Körner C, Spehn EM (eds) Mountain biodiversity: a global assessment. Parthenon, Boca Raton, pp 261–266

McMurtry D, Edwards TJ, Bytebier B (2006) A new species of *Disa* (Orchidaceae) from Mpumalanga, South Africa. S Afr J Bot 72:551–554

Meadows ME, Linder HP (1993) A palaeoecological perspective on the origin of Afromontane grasslands. J Biogeogr 20:345–355

Mertens R (1958) Bitis heraldica, eine oft verkannte Otter aus Angola. Senck Biol 39:145–148

Midgley GF, Hannah L, Roberts R et al (2001) Have Pleistocene climatic cycles influenced species richness patterns in the greater Cape Mediterranean Region? J Mediterr Ecol 2:137–144

Mills MSL (2010) Angola's central scarp forests: patterns of bird diversity and conservation threats. Biodivers Conserv 19:1883–1903

Ministry of Environment and Tourism (2002) Atlas of Namibia Project. http://209.88.21.36/Atlas/Atlas_web.htm. Accessed Nov 2009

Minter LR, Burger M, Harrison JA et al (eds) (2004) Atlas and Red Data Book of the frogs of South Africa, Lesotho and Swaziland. SI/MAB Series no 9. Smithsonian Institution, Washington

Moodley Y, Harley EH (2005) Population restructuring in mountain zebras (*Equus zebra*): the molecular consequences of divergent demographic histories. Conserv Genet 6:953–968

Moore A, Blenkinsop T (2006) Scarp retreat versus pinned drainage divide in the formation of the Drakensberg escarpment, southern Africa. S Afr J Geol 109:599–610

Moore A, Blenkinsop T, Cotterill F (2009) Southern African topography and erosion history: plumes or plate tectonics. Terra Nova 21:310–315

Morrone JJ (2004) On the identification of areas of endemism. Syst Biol 43:438–441

Mucina L, Rutherford MC (eds) The vegetation of South Africa, Lesotho and Swaziland. Strelitzia, vol 19. South African National Biodiversity Institute, Pretoria

Neke KS, du Plessis MA (2004) The threat of transformation: quantifying the vulnerability of grasslands in South Africa. Conserv Biol 18:466–477

Nekola JC (1999) Paleorefugia and neorefugia: the influence of colonization history on community pattern and process. Ecology 80:2459–2473
Njabo KY, Sorenson MD (2009) Origin of Bannerman's Turaco *Tauraco bannermani* in relation to historical climate change and the distribution of West African montane forests. Ostrich 80:1–7
Nordenstam B (1969) Phytogeography of the genus *Euryops* (Compositae). A contribution to the phytogeography of southern Africa. Opera Bot 23:7–77
Nosil P, Harmon LJ, Seehausen O (2009) Ecological explanations for (incomplete) speciation. Trends Ecol Evol 24:145–156
O'Connor TC, Kuyler P (2009) Impact of land use on the biodiversity integrity of the moist sub-biome of the grassland biome, South Africa. J Environ Manag 90:384–395
Oliver EGH, Linder HP, Rourke JP (1983) Geographical distribution of Cape taxa and their phytogeographical significance. Bothalia 14:427–440
Olson DM, Dinerstein E (1998) The Global 200: a representation approach to conserving the Earth's most biologically valuable ecoregions. Conserv Biol 12:502–515
Partridge TC, Maud RR (1987) Geomorphic evolution of southern Africa since the Mesozoic. S Afr J Geol 90:179–208
Peace Parks Foundation (2010) http://www.peaceparks.org/Content_1020000000_Peace+Parks.htm. Accessed April 2010
Pickford M, Mein P, Senut B (1992) Primate bearing Plio-Pleistocene cave deposits of Humpata, southern Angola. J Hum Evol 7:17–33
Poynton JC (1983) The dispersal versus vicariance debate in biogeography. Bothalia 14:455–460
Prendini L (2005) Scorpion diversity and distribution in southern Africa: pattern and process. In: Huber BA, Sinclair BJ, Lampe K-H (eds) African biodiversity Molecules organisms, ecosystems. Springer, Berlin, pp 49–50
Prentice CA, Arnold TH (1998) PRECIS Specimen Database user guide. Southern African Diversity Network Report no 3. SABONET, Pretoria
Procheş S, Cowling RM, Goldblatt P et al (2006) An overview of the Cape geophytes. Biol J Linn Soc 87:27–43
Robertson A, Jarvis AM, Brown CJ (1998) Avian diversity and endemism in Namibia: patterns from the Southern African Bird Atlas Project. Biodivers Conserv 7:495–511
Schneider MF, Buramuge VA, Aliasse L et al (2005) Checklist and centres of vertebrate diversity in Mozambique [CD-ROM]. The World Conservation Union (IUCN Mozambique), Mozambique
Schönhofer AL (2008) On harvestmen from the Soutpansberg, South Africa, with description of a new species of *Monomontia* (Arachnida: Opiliones). Afr Invertebr 49:109–126
Sekercioglu ÇH, Riley A (2005) A brief survey of the birds in Kumbira Forest, Gabela, Angola. Ostrich 76:104–110
Shi N, Dupont LM, Bueg H-J et al (1998) Vegetation and climate changes during the last 21 000 years in SW Africa based on marine pollen record. Veg Hist Archaeobot 7:127–140
Shroyer ME, Blignaut P (2003) Mountain conservation in South Africa. USDA Forest Service Proceedings RMRS-P-27, pp 26–33
Simmons RE, Griffin M, Griffin RE et al (1998) Endemism in Namibia: patterns, processes and predictions. Biodivers Conserv 7:513–530
Sinclair I, Ryan P (2003) Birds of Africa south of the Sahara. Struik, Cape Town
Skelton P (2001) A complete guide to the freshwater fishes of southern Africa. Struik, Cape Town
Skinner JD, Chimimba CT (2005) The mammals of the southern African subregion. Cambridge University Press, Cambridge
Steenkamp Y, Van Wyk AE, Smith GF et al (2005) Floristic endemism in southern Africa: a numerical classification at generic level. In: Friis I, Balslev H (eds) Plant diversity and complexity patterns: local, regional and global dimensions, vol 55. Biologiske Skrifter, Copenhagen, pp 253–271
Stuckenberg BR (1962) The distribution of the montane palaeogenic element in the South African invertebrate fauna. Ann Cape Prov Mus 2:190–205
Tolley KA, Makokha JS, Houniet DT et al (2009) The potential for predicted climate shifts to impact genetic landscapes of lizards in the South African Cape Floristic Region. Mol Phylogenet Evol 51:120–130
Van Bruggen AC (2006) *Gulella johannae* spec. nov. (Gastropoda, Pulmonata, Streptaxidae), a new land snail from the Drakensberg range in Limpopo Province, South Africa, with notes on *G. johannesburgensis* (M. & P.). Zool Med Leiden 80–1:63–72
Van der Niet T, Johnson SD (2009) Patterns of plant speciation in the Cape floristic region. Mol Phylogenet Evol 51:85–93
Van der Walt PT (1980) A phytosociological reconnaissance of the Mountain Zebra National Park. Koedoe 23:1–32

Van Wyk AE, Smith GF (2001) Regions of floristic endemism in Southern Africa. Umdaus Press, Hatfield
Van Zinderen Bakker EM (1962) Botanical evidence for quaternary climates in Africa. Ann Cape Prov Mus 2:16–31
Van Zinderen Bakker EM (1983) The late Quarternary history of climate and vegetation in east and southern Africa. Bothalia 14:369–375
Verboom GA, Archibald JK, Bakker FT et al (2009) Origin and diversification of the Greater Cape flora: ancient species repository, hot-bed of radiation, or both? Mol Phylogenet Evol 51:44–53
Wessels KJ, Reyersb B, Van Jaarsveld AS et al (2003) Identification of potential conflict areas between land transformation and biodiversity conservation in north-eastern South Africa. Agric Ecosyst Environ 95:157–178
White F (1978) The afromontane region. In: Werger MJA (ed) Biogeography and ecology of southern Africa. Dr. W. Junk, The Hague, pp 415–463
White F (1983) The vegetation of Africa. A descriptive memoir to accompany the UNESCO/AETFAT/UNSO Vegetation map of Africa. Natural Resources Research 20. UNESCO, Paris
Woodhall S (2005) Field guide to butterflies of South Africa. Struik, Cape Town
World Wildlife Fund, McGinley M (2008a) Angolan montane forest-grassland mosaic. In: Cleveland CJ (ed) Encyclopedia of Earth. Environmental Information Coalition, National Council for Science and the Environment, Washington. http://www.eoearth.org./article/Angolan_montane_forest-grassland_mosaic. Accessed Nov 2009
World Wildlife Fund, McGinley M (2008b) Angolan scarp savanna and woodlands. In: Cleveland CJ (ed) Encyclopedia of Earth. Environmental Information Coalition, National Council for Science and the Environment, Washington. http://www.eoearth.org/article/Angolan_scarp_savanna_and_woodlands. Accessed Nov 2009
World Wildlife Fund, McGinley M (2008c) Eastern Zimbabwe montane forest-grassland mosaic. In: Cleveland CJ (ed) Encyclopedia of Earth. Environmental Information Coalition, National Council for Science and the Environment, Washington. http://www.eoearth.org/article/Eastern_Zimbabwe_montane_forest-grassland_mosaic. Accessed Nov 2009