

Succulent plants on arid inselbergs



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ABSTRACT

Succulent plants in arid areas are believed to be often associated with high altitudes, except where they form the dominant, zonal vegetation such as in the Succulent Karoo Biome of southern Africa. To test this hypothesis the contribution of perennial succulents to inselberg floras was investigated on twenty-two isolated mountains (inselbergs) at four study sites (Etendeka–Barab: 19°34' S/13°42' E; Spitzkoppe: 21°49' S/15°09' E; Namibrand: 25°17' S/15°47' E; and Sperrgebiet: 27°43' S/16°04' E) along a nearly 1000 km bioclimatic gradient in the Namib Desert and adjacent areas, from the Succulent Karoo in the south to the northern Namib, and along altitude gradients.

The contribution of succulents to the flora clearly increased with altitude at the two central study sites, thus showing a hump-shaped trend along the bioclimatic gradient. No such correlation was found at the northern and southern end of the bioclimatic gradient. The surrounding (rocky) lowlands likely resulted in a more even distribution of succulents throughout the landscape in the north, while the position in the heartland of the succulent flora in southern Africa at the southern-most site, levelled out potential patterns related to altitude. Nevertheless, even here, a fair number of succulents restricted to mountain habitats occur. This is the case in all other study sites, where succulents restricted to mountain habitats are always present.

Some perennial succulents, such as *Aridaria noctiflora*, *Euphorbia gummifera* and *Tetragonia reduplicata* indicate an upward movement with increasing distance from the Succulent Karoo, by growing on plains and lowlands in the Succulent Karoo, but only on inselbergs at study sites north of the Succulent Karoo.

Many of the mountain specialist succulents are sought after by plant collectors, such as species of *Conophytum*, *Crassula* and *Lithops*. Protecting and monitoring vulnerable populations as well as growing these in horticulture may help to alleviate the pressure on some of these rare species in nature. Preserving genetic material of isolated populations from mountain tops *ex situ* is another important conservation measure, and particularly important in the view of anticipated climatic change.

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Introduction

Although well adapted to arid conditions, succulent plants are believed to require a more regular moisture supply than non-succulents to survive in arid areas (Ellenberg, 1981; Ihlenfeldt, 1989; Von Willert et al., 1992). They are therefore often found in more favourable microhabitats, such as in the shelter of other plants (Dean et al., 1992; Flores-Torres and Montaña, 2012; Nobel and Bobich, 2002), shaded by rocks and rock overhangs (Martorell and Patiño, 2006; Peters et al., 2008) or in higher altitudes (Nobel and Zutta, 2007).

The most diverse succulent flora on our planet is located in the arid winter-rainfall region of south-western Africa. This unique area with an abundance of leaf-succulents delineated as the

Succulent Karoo Biome, is believed to have a more regular moisture regime during the year than the adjoining desert and arid savanna to the east and north, which receive summer rainfall (Cowling et al., 1998). The biogeographic influence of this biodiversity hotspot (Mittermeier et al., 2004), however, extends far beyond its borders and pockets of succulent-dominated or succulent-interrupted vegetation occur outside the Succulent Karoo Biome

Many isolated mountains (inselbergs) along the Namib Desert are home to an array of succulent plant species, both leaf- and stem-succulents. The occurrence of succulents in the flora could be related to biogeographic as well as local aspects. This has to date neither been reported, nor have factors contributing to this pattern been investigated. This paper studied the distribution of succulents on inselbergs and adjoining lowland habitats along a north-south, nearly 1000 km long, bioclimatic gradient from the Northern Namib Desert to the Succulent Karoo. The hypothesis that the influence of biogeographic factors, *i.e.* the distance to the succulent heartland – the Succulent Karoo Biome – is the most important

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factor in explaining the contribution of succulents to the flora was investigated.

Methods

The study area

Twenty-two isolated mountains (inselbergs) in four distinct landscapes were investigated in this study. These occur across the Namib Desert and adjacent areas, range in height from 70 to 845 m above the surrounding, and, from north to south, comprise flat-top basalt mountains, granite domes and mountains, and mountains of metasedimentary and volcanic origin (Fig. 1). The altitude of the surrounding lowlands is 900–1200 m above mean sea level at Etendeka–Barab (centre at approximately 19°34' S/13°42' E), 800–1000 m at Spitzkoppe (approximately 21°49' S/15°09' E), 900–1200 m at Namibrand (approximately 25°17' S/15°47' E) and 500–700 m at the Sperrgebiet study site (approximately 27°43' S/16°04' E). The Namibrand study site includes inselbergs on the Namibrand Nature Reserve, but also in the adjoining, state-owned Namib-Naukluft Park.

The basalt inselbergs in the north (Etendeka–Barab) are the remainders of volcanic activities in the Triassic to Jurassic late Karoo Period (Erlank, 1985; Geological Survey, 1980); the granite inselbergs (Spitzkoppe) in the central area belong to the Damara period (650–470 million years) and the granites of the southern inselbergs (Namibrand) belong to the much older Namaqua Metamorphic complex (1400–1050 million years) (Geological Survey, 1980). The southern-most inselbergs (Sperrgebiet) comprise gneisses and

quartzites of the Gariiep complex (1000–570 million years), except for the volcanic intrusion of phonolithe at Namitsis, which is 37 million years old (Geological Survey, 2000).

The climate of the Namib Desert is characterised by low rainfall, ranging from 10–100 mm long-term annual average, and moderate temperatures, dampened by the coastal influence of the cold Benguela current (mean annual average 15–25 °C). While the northern and central part of the study area receives largely summer rainfall, the southern part of the Namib Desert falls into the Succulent Karoo Biome and receives winter-rainfall (Burke et al., 2004). Moreover, mountains and inselbergs in the Namib Desert often receive more rainfall, because of orographic effects (Günster, 1995). Long-term climate data for individual inselbergs are not available.

The vegetation in the study area responds to north-south and west-east (coast–inland) gradients, supporting different vegetation types ranging from ephemeral grassland, sparse dwarf shrubland and perennial grassland in the north to succulent dwarf shrubland in the south (Giess, 1971). The investigated inselberg landscapes are positioned along a bioclimatic gradient of Desert-, Nama Karoo- and Succulent Karoo Biomes in southern Africa (Fig. 1). All selected inselbergs are in areas managed for conservation such as National Parks, conservancies and private nature reserves.

Field survey

Four inselberg landscapes in the Namib Desert were investigated—from north to south: Etendeka–Barab (8 inselbergs), Spitzkoppe (6 inselbergs), Namibrand (4 inselbergs) and

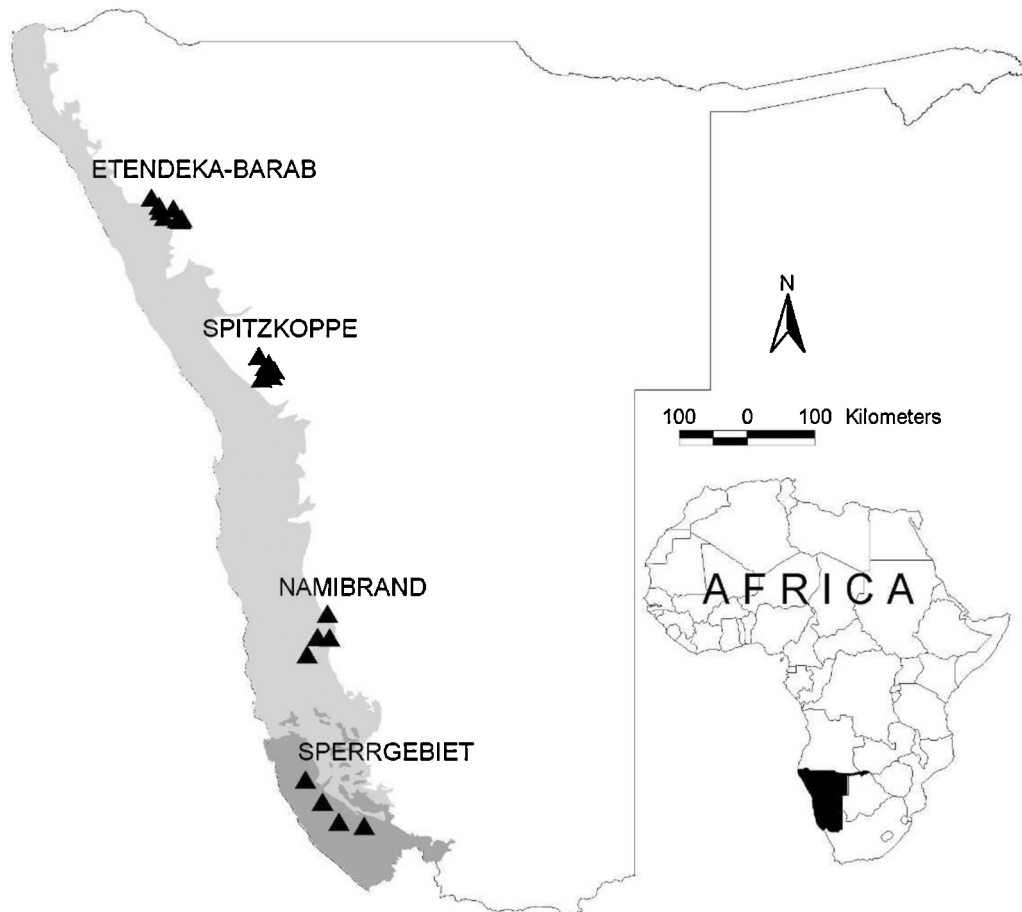


Fig. 1. Position of inselbergs included in this study in relation to the Namib Desert and Succulent Karoo Biomes (grey shading = Succulent Karoo; light grey shading = Namib Desert).

Sperrgebiet (4 inselbergs) – Fig. 1. Plant surveys were carried out on annual research trips during 1998–2011, timing the surveys so that the study sites had received average to above-average rainfall to obtain the best approximation of the flora. Plant data were collected along transects, laid in a south-east to north-west direction over the peak of an inselberg at the end of the growing season. Each transect was divided into plain, foot-slope, mid-slope, upper slope and top. Plant species were recorded in approximately 100 m × 2 m belt transects within each habitat, but additional species outside the belt areas in each habitat were also recorded. A higher number of transects were surveyed on larger inselbergs to obtain adequate coverage. Where the terrain was difficult or inaccessible, the transect direction was adapted. Species-area curves in these arid mountain habitats were not practical, due to difficult access. The collected data, although strived to be as comprehensive as possible, are an approximation of a specific inselberg/mountain flora and cannot be considered to accurately present the complete flora. This would require repeated sampling over several vegetation seasons—a formidable task over such a vast geographic range and variable environment. Additional observations for each sample included geographic position, altitude, aspect and slope angle. Height above surrounding was determined by subtracting the altitude on plains from the altitude of the inselberg habitat. Voucher specimens of doubtful plant species were collected for identification and lodged at the National Botanical Research Institute in Windhoek. The nomenclature for plants follows Craven (1999), with later amendments for the Sperrgebiet (Burke and Mannheimer, 2004).

Data analysis

Plant species lists were compiled for the plain, foot-slope, mid-slope, upper slope and top of the inselberg for each individual inselberg. The number of succulent species was then counted and expressed as a percentage of total species recorded for this habitat. Succulents were defined as plants with water storage tissue, which included stem- and leaf-succulents. Annual leaf succulents were excluded from the analysis, since these are mostly weedy species which occur in a wide range of habitats across the Namib and adjoining biomes. These included species like *Hypertelis sal-soioides*, *Mesembryanthemum guerichianum*, *Portulaca oleracea* and *Zygophyllum simplex*. After testing for normality, the percentage succulents was then regressed against height above surrounding (later in text referred to as altitude) for each of the four investigated inselberg landscapes. A 5% level was used as a significance threshold (Fowler and Cohen, 1992).

Results

A total of 152 perennial succulent species was recorded in the four study sites (Appendix 1). They included stem-, leaf-succulent, combinations of these two categories and dwarf stem-succulents. There was a clear increase in succulent species richness towards the south, and thus into the Succulent Karoo Biome, but the two northern study sites showed no obvious decline towards the north (Table 1). Per inselberg habitat, the percentage of perennial succulent species ranged between 0 (several plain habitats) and 70.5% (inselbergs in the Sperrgebiet). However, in the three northern and central study sites, the contribution of succulents to the inselberg flora never exceeded 30%. Distance to the Succulent Karoo Biome's northern boundary ranged between 0 and 800 km (with 100–180 km at Namibrand and 510–550 km at Spitzkoppe). There were no perennial succulents which only occurred in the lowlands surrounding the inselbergs, except in the Sperrgebiet, but many species were restricted to inselbergs and mountains in some of the

Table 1

Number of plant species, perennial succulent plant species and perennial succulents restricted to inselbergs at four study sites in the Namib Desert and adjacent desert margin.

Study site	Total plant species	Perennial succulents (% of total flora)	Perennial succulents on inselbergs only (% of all perennial succulents)
Etendeka–Barab	313	31 (9.9)	21 (68)
Spitzkoppe	286	25 (8.7)	13 (52)
Namibrand	301	41 (13.6)	30 (73)
Sperrgebiet	237	96 (40.5)	60 (63)

study sites (Table 1). Those restricted to inselbergs ranged from 52% at Spitzkoppe to 73% of perennial succulents at Namibrand. Even in the Sperrgebiet a high portion of perennial succulents (62.5%) was only recorded on inselbergs, a similar percentage to the northern-most site (67.7% at Etendeka–Barab) (Table 1).

Attributes of perennial succulents on inselbergs

The perennial succulents recorded on inselbergs in this study belonged to a range of plant families, including Apocynaceae, Asphodelaceae, Asteraceae, Burseraceae, Crassulaceae, Geraniaceae, Mesembryanthemaceae (or Aizoaceae, depending on which taxonomic classification is adopted), Portulacaceae and Zygophyllaceae. Quite a number of Namib and Namibian endemic species were amongst the succulents, e.g. *Adenia pechuelii*, *Ceraria longipedunculata*, *Cyphostemma bainesii* and *Hoodia ruschii*. Although some of these are rare, none were restricted to one single inselberg only.

Effect of altitude along a bioclimatic gradient

While no obvious correlation between altitude and the contribution of perennial succulents to the inselberg flora was evident at the northern-most and southern-most study sites (Figs. 2 and 3), this was clearly the case at the central study sites. Positive, linear, moderately strong and clearly significant correlations were detected, both at Spitzkoppe (Fig. 2, bottom) and Namibrand (Fig. 3, top).

Discussion

Overall, perennial succulent plants in the study area in the Namib Desert clearly showed a strong affinity with mountain habitats. This is supported by the high percentage of succulent species which are restricted to mountains in all four study sites (Table 1), but also by an evident correlation between perennial succulents and altitude at two of the four study sites (Figs. 2 and 3). Observations from other arid mountains, for example in South Africa (Cowling and Pierce, 2000), Saudi-Arabia (Masrahi et al., 2011), Madagascar (Fischer and Theisen, 2000) and New Mexico (Mata-González et al., 2002) also indicate that succulents clearly contribute to inselberg and mountain floras in these arid areas.

In the Namib Desert the succulents could be remnants of formerly more widespread Succulent Karoo vegetation, for example during the Pleistocene (Chase and Meadows, 2007; Midgley et al., 2001) or they have evolved *in situ* in response to specific microhabitat conditions. Phylogenetic and palynological studies would be required to shed light on this aspect. At a global scale, regular, seasonal precipitation between an annual mean total of 75–500 mm, specific habitat conditions such as stony ground and little competition from other plants are key factors favouring stem-succulents around the world (Ellenberg, 1981). Stem-succulents form an important component of the succulent flora on many Namibian inselbergs and mountains and species such as *Aloe dichotoma*, many *Commiphora* species and *Cyphostemma currorii* are conspicuous.

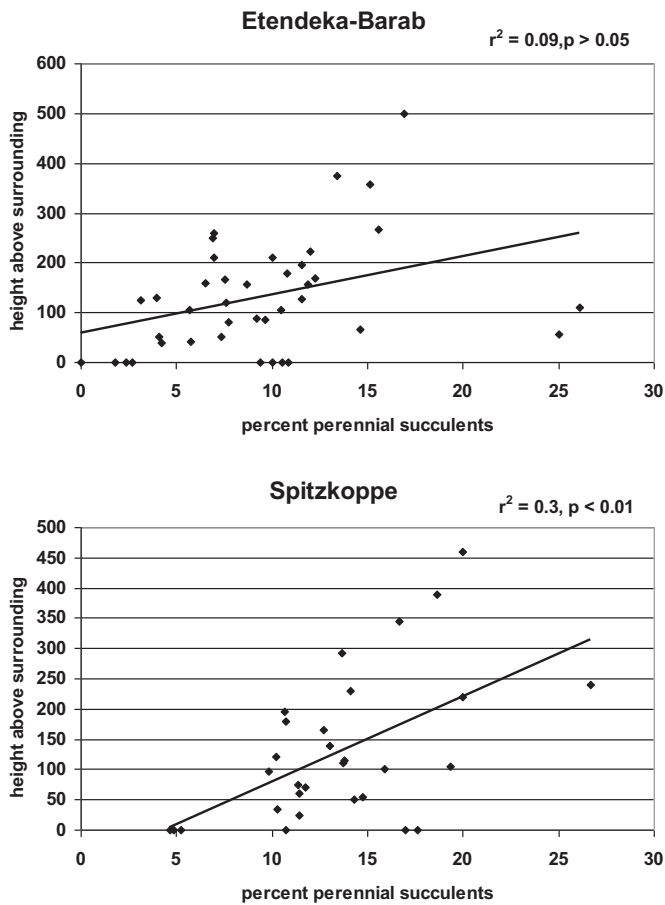


Fig. 2. Contribution of perennial succulent plants to the total flora of each inselberg habitat plotted against height (m) above surrounding at the Etendeka–Barab study site (top; $n = 40$) and Spitzkoppe study site (bottom; $n = 30$).

Their occurrence on Namibian inselbergs certainly conforms with Ellenberg's (1981) predictions.

Perennial succulents are also important components of zonal (plain) vegetation in the Namib Desert, not only in the Succulent Karoo Biome, where they contribute up to 50% of the species to lowland vegetation (Fig. 3), but also at the other study sites. Succulents such as *Euphorbia damarana*, *Commiphora pyracanthoides*, *C. saxicola*, *C. virgata* and many *Salsola* species (Appendix 1) can thus be found on mountains as well as on plains, in some instances forming the dominant vegetation. Three species were not recorded on plains in the vicinity of the studied inselbergs, *Eberlanzia sedoides*, *Zygophyllum cordifolium* and *Z. stapffii*, but they have been observed on plains in the broader vicinity of the selected study sites. This slight sampling bias, however, does not detract from the overall observed pattern and trends.

Effect of altitude along a bioclimatic gradient

A hump-shaped trend, with correlations between altitude and perennial succulents peaking at the central study sites, emerged along the bioclimatic gradient from the arid northern Namib to the Succulent Karoo in the South (Figs. 2 and 3). Whether this is indeed a trend driven by broad bioclimatic parameters, or influenced by other factors, deserves a closer look. If bioclimatic parameters are solely responsible for this trend, then the decline of succulent contribution to the mountain flora at the northernmost study site could be explained by the influence of the tropical Sudano-Zambezi floristic region (White, 1983), where succulents are believed to be of lesser importance in the flora (Newton, 1989) and conversely at the

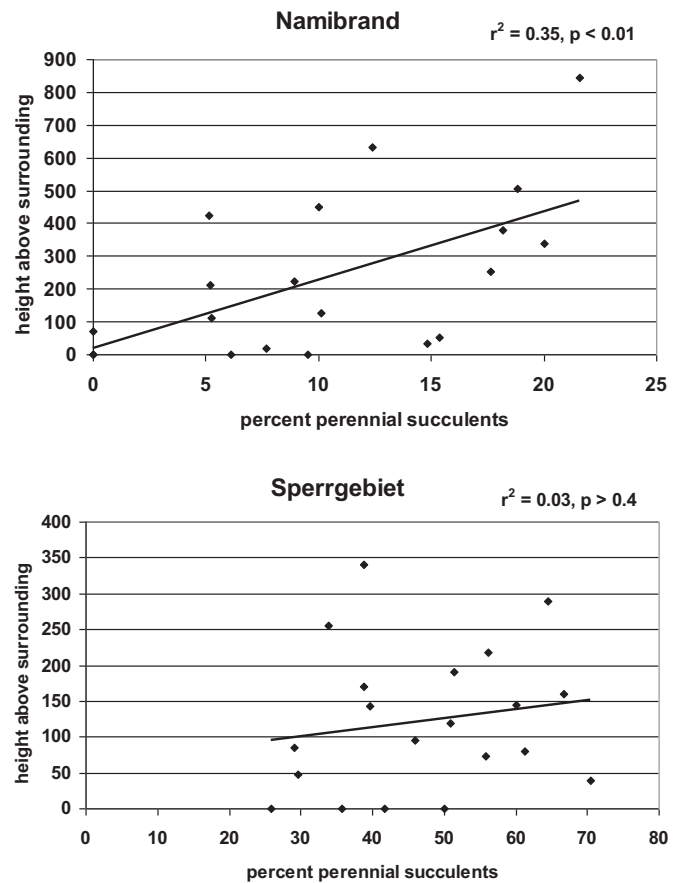


Fig. 3. Contribution of perennial succulent plants to the total flora of each inselberg habitat plotted against height (m) above surrounding at the Namibrand study site (top; $n = 20$) and Sperrgebiet study site (bottom; $n = 20$).

greatest distance from the heartland of the succulent flora in southern Africa. However, the contribution of succulents to the total flora is greater at the Spitzkoppe site, more to the south, (Table 1) and thus no gradual decline in succulent species is indicated from south to north. This could be explained by succulents being more evenly spread throughout the landscape at the northernmost site and not necessarily favouring only mountain habitats here. The lowlands surrounding the flat-topped mesas in the north are generally rocky and often undulating, low hills, rather than proper “desert plains” as at the southern study sites (Fig. 4). Similar microhabitats, e.g. rocks favoured as shelters by succulents (Peters et al., 2008) can thus also be found in the lowlands and the only difference to mountains would be cooler and wetter conditions higher up. This indicates that local habitat conditions may be more important here than the study site's position along a bioclimatic gradient.

At the other extreme of the bioclimatic gradient—the Sperrgebiet study site in the Succulent Karoo Biome—succulents are such an important component of the general vegetation that their contribution to the mountain flora does not increase with altitude. Yet there are nevertheless many mountain specialists among the perennial succulents in the Succulent Karoo, in fact as many as at the other study sites, but then there are also more perennial succulents on plains.

Likely bioclimatic parameters are not the only explanation for the observed trends and the nature of the study sites and individual inselbergs also deserve attention. The inselbergs in the Etendeka–Barab study site are flat-topped mesas of volcanic origin, with basalt being the most prevalent rock type. The soils and also microclimatic conditions on these mesas differ from the other three



Fig. 4. The basalt mesas at the Etendeka–Barab site provide a different set of environmental variables than the other study sites: more heterogeneous lowlands and different soils – the stem-succulent *Euphorbia damarana* in the foreground.

inselberg landscapes. A level, often wind-swept plateau, which offers little shelter and steep slopes, comprised of medium to small rock-fragments characterise the mesas. Granites and gneisses are the dominant rock types in the three other study sites and they result in very different types of inselbergs. The granite intrusions erode into massive rock boulders along fissures that already developed underground during the formation of the granite domes (Viles and Goudie, 2013). These inselbergs are today composed of heaps of large boulders, or have accumulations of large boulders around their bases. The Spitzkoppe study site also includes two dolerite dykes with steep, continuous slopes similar to the mesas, but with a ridge at the top, instead of a level plateau. The granites and gneisses result in soils that are chemically and physically quite different from the basalt- and dolerite-derived soils (Burke, 2002). Soil properties and available microhabitats are therefore different on granite/gneiss- and basalt/dolerite-derived inselbergs. This will invariably affect plant available moisture, since large run-off rock surfaces, such as on granite inselbergs, result in considerable amounts of water being redirected to the available soil pockets, especially the coarse sandy substrate that accumulated around the base of these inselbergs. The vegetation here is usually dense, indicating that this may well be a favoured habitat with respect to the average moisture conditions. In addition, more rock overhangs and thus shelter is offered on the granite–gneiss inselbergs. In the Sahara, in Niger, granite boulders on inselbergs have been reported as refuges for species with higher water requirements (Anthelme et al., 2008), whereas due to the CAM metabolism followed by many succulents (Rundel et al., 2004), these plants are prone to overheating due to lack of daytime transpiration (Martorell and Patiño, 2006). Overhangs and cliffs provide a cool refuge during the hottest time of the day (Lüttge, 2004; Martorell and Patiño, 2006), which could contribute to explaining the higher proportion of succulents on granite inselbergs than on plains observed in this study.

There is also the influence of altitude *per se*. Although the study attempted to collate a comparable sample of inselbergs at each study site, an even distribution of altitudes was not always possible. The Namibrand inselberg landscape is characterised by a couple of very high mountains, the highest in this study at 854 m above surroundings, while the highest inselberg at the Sperrgebiet study site is only 340 m. The Sperrgebiet study site also had the lowest altitude overall. A longer altitude gradient at the Sperrgebiet site may have indicated a trend, but could not be measured. This is, however, a theoretical consideration only, as there are no substantially higher inselbergs in the Sperrgebiet. In contrast, the very clear

correlation at Namibrand was likely fostered by the presence of a very high mountain (Fig. 3).

Species-specific aspects

All Crassulaceae (*Crassula* and *Tylecodon* species) recorded in this study were restricted to inselbergs and mountains. No other plant family showed such constancy. Being habitat specialists makes them more vulnerable, but also fascinating, as peripheral populations may provide insights into the nature of adaptations (Holt and Keitt, 2005). More detailed physiological studies on these plants may contribute to understanding their niche preferences, while phylogenetic research could enlighten their evolutionary development.

Stem-succulents like *Aloe dichotoma*, *Commiphora* and *Cyphostemma* species make a conspicuous contribution to the studied inselberg and mountain floras in the Namib Desert. Remarkably, this is also the case under reverse ecological conditions – xeric islands in a tropical matrix (Burke, 2003). For example on granite inselbergs in Venezuela the genus *Commiphora* is present (Groeger, 2000). However, many *Commiphora* species in the Namib are not only restricted to inselbergs and mountains, and this is clearly not a family-wide trait in this group.

Some of the studied succulent species appear to move upwards in altitude with distance from the Succulent Karoo Biome. For example *Aridaria noctiflora*, *Euphorbia gummifera*, *Kleinia longiflora* and *Tetragonia reduplicata* grow in lowlands and on inselbergs in the Sperrgebiet, but only on inselbergs or mountains in the study sites outside the Succulent Karoo. More detailed investigations may elucidate particular traits that have enabled these species to extend their distribution ranges in this manner. An inverse pattern was observed in South America (Patagonia), where many cold-adapted outcrop specialists, believed to be relicts of cold-adapted glacial palaeoflora, were found in lowlands areas in cooler regions further south (Speziale and Ezcurra, 2012).

Implications for management

Succulents in the Namib Desert face two eminent threats: (1) Illegal succulent collecting has decimated some populations of rare plants targeted by collectors, such as the stone plants, *Conophytum* and *Lithops* and many *Crassula* species (Loots, 2005). Growing in inaccessible mountain habitats may help surviving to some extent, but does not always deter determined collectors. Protecting and



Fig. 5. The leaf succulent *Aloe hereroensis* is not uncommon on the escarpment and in highland areas of Namibia, but these plants on the Awasis Mountain in the southern Namib are the western-most outposts of their recorded range.

monitoring vulnerable populations on more accessible inselbergs, such as Spitzkoppe, is therefore recommended, for example the population of the rare *Othonna brandbergensis*. Introducing some of these rare, and often attractive succulents in horticulture may be another means of alleviating the pressure on these special species. (2) Leaf succulents are predicted to be more susceptible to climate change (Midgley and Thuiller, 2007), although on the other hand, mountain habitats are widely believed to present a buffer, as plants could move upwards along altitude gradients into cooler regions (e.g. Bond and Richardson, 1990; Loarie et al., 2009). Whether this process may indeed function, is speculation at present, but it would certainly not hold for those species already growing at the very top of a mountain (Fig. 5). These may disappear like the glaciers in the Alps. At a minimum, genetic material of populations of high altitude specialists should be preserved *ex situ*, particularly if other management options such as transplanting are not feasible.

Conclusion

Namib inselbergs support a diverse succulent flora with many habitat specialists worth being protected. A clear trend of increasing contribution of succulents with altitude was indicated in two inselberg landscapes in the central and southern Namib. The study site at the greatest distance from the Succulent Karoo Biome showed no increasing succulent contribution with altitude. Here the nature of the surrounding lowlands – rocky plains and low, undulating hills, as compared to the level, expansive “desert plains” in the central and southern study sites – may offer an explanation

for the given situation. This would indicate that at the northern site heterogeneity of habitat may be more important than altitude *per se*.

This study along an extensive bioclimatic gradient in the Namib Desert indicates that different drivers may be responsible for the distribution of succulents on inselbergs and lowlands, depending on geographic position, with surrounding landscape and altitude likely being the two key determining factors.

Acknowledgements

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Appendix 1.

Perennial succulents recorded on inselbergs in the Namib Desert (study sites: Ete-Bar = Etendeka–Barab, Spk = Spitzkoppe, NR = Namibrand, Sperr = Sperrgebiet; m = species occurring on inselbergs and surrounding lowlands, ins = species occurring on inselbergs and mountains only).

Plant species	Ete-Bar	Spk	NR	Sperr
<i>Adenia pechuelii</i> (Engl.) Harms		m	m	
<i>Adromischus schuldianus</i> (Poelln) Poelln subsp. <i>schuldianus</i>			ins	
<i>Adromischus</i> species				ins
<i>Aloe dichotoma</i> Masson		ins	m	ins
<i>Aloe hereroensis</i> Engl. var. <i>hereroensis</i>			ins	
<i>Aloe namibensis</i> Giess	ins			
<i>Aloe ramosissima</i> Pillans				ins
<i>Aloe sladeniana</i> Pole Evans			ins	
<i>Aloe striata</i> Haw. subsp. <i>karasbergensis</i> (Pillans) Glen & D.S. Hardy			ins	
<i>Amphibolia saginata</i> (L. Bolus) H.E.K. Hartmann				ins
<i>Antimima aurasensis</i> H.E.K. Hartmann				ins
<i>Antimima buchubergensis</i> (Dinter) H.E.K. Hartmann				ins
<i>Antimima</i> species				ins
<i>Aridaria noctiflora</i> (L.) Schwantes subsp. <i>noctiflora</i>			ins	m
<i>Brownanthus arenosus</i> (Schinz) Ihlenf. & Bittrich				m
<i>Cephalophyllum ebracteatum</i> (Schltr. & Diels) Dinter & Schwantes				m
<i>Ceraria fruticulosa</i> Pearson & Stephens				ins
<i>Ceraria longipedunculata</i> Merxm. & Podl.	m			
<i>Ceraria namaquensis</i> (Sonder) Pearson & Steph.				ins
<i>Cheiridopsis robusta</i> (Haw.) N.E.Br.				m
<i>Commiphora dinteri</i> Engl.		ins	m	
<i>Commiphora giessii</i> Van der Walt	m			
<i>Commiphora glandulosa</i> Schinz	ins			
<i>Commiphora glaucescens</i> Engl.	m	m		
<i>Commiphora mollis</i> (Oliv.) Engl.	ins			
<i>Commiphora multijuga</i> (Hiern) Schum.	ins			
<i>Commiphora pyracanthoides</i> Engl.	ins	m		
<i>Commiphora saxicola</i> Engl.	m	m	m	
<i>Commiphora tenuipetiolata</i> Engl.	ins	m	ins	
<i>Commiphora virgata</i> Engl.	m	m		
<i>Commiphora wildii</i> Merx.	ins			
<i>Conophytum taylorianum</i> (Dinter & Schwantes) N.E.Br. subsp. <i>ernianum</i> (Loesch & Tischer) de Boer ex S.A.Hammer				ins
<i>Conophytum pageae</i> (N.E.Br.) N.E.Br.				ins
<i>Conophytum taylorianum</i> (Dinter & Schwantes) N.E.Br. subsp. <i>taylorianum</i>				ins
<i>Conophytum</i> species				ins
<i>Cotyledon orbiculata</i> L. var. <i>orbiculata</i>				ins
<i>Crassula aurusbergensis</i> G. Will.				ins
<i>Crassula brevifolia</i> Harv. subsp. <i>brevifolia</i>				ins

<i>Crassula deceptor</i> Schoenland & Baker f.					ins
<i>Crassula deltoidea</i> Thunb.					ins
<i>Crassula expansa</i> Dryand. subsp. <i>pyrifolia</i> (Compton) Toelken					ins
<i>Crassula fusca</i> Herre					ins
<i>Crassula muscosa</i> L. var. <i>muscosa</i>					ins
<i>Crassula sericea</i> Schoenland var. <i>sericea</i>			ins		ins
<i>Crassula tomentosa</i> Thunb. var. <i>tomentosa</i>					ins
<i>Crassula</i> species					ins
<i>Cyphostemma bainesii</i> (Hook.f.) Descouings			ins		
<i>Cyphostemma currori</i> (Hook. f.) Desc.	ins		ins		
<i>Cyphostemma uter</i> (Exell & Mend.) Desc.	ins				
<i>Dracophilus delaetianus</i> (Dinter) Dinter & Schwantes					m
<i>Dracophilus</i> species					m
<i>Drosanthemum pauper</i> (Dinter) Dinter & Schwantes					m
<i>Drosanthemum luederitzii</i> (Engl.) Schwantes					m
<i>Drosanthemum subcompressum</i> (Haw.) Schwantes				ins	
<i>Eberlanzia clausa</i> (Dinter) Schwantes					m
<i>Eberlanzia sedoides</i> (Dinter & A. Berger) Schwantes				ins	ins
<i>Euphorbia avasmontana</i> Dinter				m	
<i>Euphorbia cibdela</i> N.E.Br.				ins	ins
<i>Euphorbia damarana</i> Leach	m		m		
<i>Euphorbia dregeana</i> E.Meyer ex Boiss.					m
<i>Euphorbia gariiepina</i> Boiss. subsp. <i>gariiepina</i>	m		m		
<i>Euphorbia guerichiana</i> Pax	ins		ins		
<i>Euphorbia gummifera</i> Boiss.				ins	m
<i>Euphorbia lignosa</i> Marloth				m	
<i>Euphorbia mauritanica</i> L. var. <i>corallothamnus</i> Dinter ex A.C. White, R.A. Dyer & B. Sloane				m	
<i>Euphorbia mauritanica</i> L. var. <i>mauritanica</i>	m		ins		ins
<i>Euphorbia virosa</i> Willd.	m		ins		ins
<i>Galenia fruticosa</i> (L.f.) Sond.					m
<i>Galenia pruinosa</i> Sond.					m
<i>Heliophila carnosa</i> (Thunb.) Steud.					ins
<i>Hereroa puttkamerana</i> (Dinter & A. Berger) Dinter & Schwantes				ins	
<i>Hoodia currorii</i> (Hook.) Decne. subsp. <i>currorii</i>	ins		m		
<i>Hoodia parviflora</i> N.E.Br.	ins				
<i>Hoodia ruschii</i> Dinter				ins	
<i>Juttadinteria attenuata</i> Walgate					ins
<i>Juttadinteria</i> species 1					ins
<i>Juttadinteria</i> species 2					m
<i>Kalanchoe brachyloba</i> Welw. ex Britten	ins				
<i>Kleimia longiflora</i> DC.	ins		ins		ins
<i>Lampranthus hoerleinianus</i> (Dinter) Friedrich					m
<i>Lampranthus otzenianus</i> (Dinter) Friedrich					ins
<i>Lavrania marlothii</i> (N.E.Br.) Bruyns				ins	
<i>Lavrania</i> species					m
<i>Leipoldtia weigangiana</i> (Dinter) Dinter & Schwantes subsp. <i>weigangiana</i>					m
<i>Lithops schwantesii</i> Dinter				ins	
<i>Lopholaena cneorifolia</i> (DC.) S. Moore				ins	ins
<i>Lycium cinereum</i> Thunb.	ins				ins
<i>Moringa ovalifolia</i> Dinter & Berger	ins		ins		ins
<i>Othonna brandbergensis</i> B. Nord.			ins		
<i>Othonna cylindrica</i> (Lam.) DC.					m
<i>Othonna furcata</i> (Lindl.) Druce					m
<i>Othonna lasiocarpa</i> (DC.) Sch.Bip.				ins	ins
<i>Othonna opima</i> Merxm.					ins
<i>Othonna sedifolia</i> DC.					ins
<i>Pachypodium lealii</i> Welw.	m				
<i>Pelargonium ceratophyllum</i> L'Her.					m
<i>Pelargonium cortusifolium</i> L'Her.					ins
<i>Pelargonium crassicaule</i> L Herit					ins
<i>Pelargonium crithmifolium</i> J.E. Smith					ins
<i>Pelargonium grandicalcaratum</i> Knuth					ins
<i>Pelargonium otaviense</i> Knuth	ins				
<i>Pelargonium paniculatum</i> Jacq.					ins
<i>Pelargonium spinosum</i> Willd.					m
<i>Phyllobolus melanospermus</i> (Dinter & Schwantes) Gerbaulet					ins
<i>Phyllobolus</i> species					m
<i>Pollichia campestris</i> Aiton					ins
<i>Psammophora modesta</i> (Dinter & A. Berger) Dinter & Schwantes					m
<i>Psilocaulon salicornioides</i> (Pax) Schwantes	ins			m	
<i>Psilocaulon subnodosum</i> (A.Berger) N.E.Br.				ins	
<i>Pteronia glabrata</i> L.f					ins
<i>Ruschia muelleri</i> (L.Bolus) Schwantes					ins
<i>Ruschia namusmontana</i> Friedrich					ins
<i>Ruschia ruschiana</i> (Dinter) Dinter & Schwantes					ins
<i>Ruschia</i> species					ins
<i>Salsola aphylla</i> L.f.				ins	
<i>Salsola armata</i> C.S. Sm. ex Aellen				m	
<i>Salsola garubica</i> Botsch.				m	

<i>Salsola tuberculata</i> (Moq) Fenzl					m
<i>Salsola zeyheri</i> (Moq.) Bunge					m
<i>Salsola</i> species					m
<i>Sarcocaulon marlothii</i> Engl.	ins	ins	ins		
<i>Sarcocaulon patersonii</i> (DC.) G. Don					m
<i>Sarcocaulon salmoniflorum</i> Moffett				m	
<i>Sarcostemma viminalis</i> (L.) R.Br. subsp. <i>viminalis</i>		m	ins		m
<i>Senecio aloides</i> DC.					ins
<i>Senecio radicans</i> (L.f.) Sch.Bip.					ins
<i>Senecio sarcooides</i> C. Jeffrey					ins
<i>Stapelia longipedicellata</i> (A. Berger) N.E.Br.	ins				
<i>Stapelia similes</i> N.E.Br.				ins	
Stapelioid species					ins
<i>Sterculia africana</i> (Lour.) Fiori	ins	ins			
<i>Stoeberia beetzii</i> (Dinter) Dinter ex Schwantes var. <i>beetzii</i>					m
<i>Stoeberia frutescens</i> (L.Bolus) van Jaarsv.					ins
<i>Stoeberia gigas</i> (Dinter) Dinter & Schwantes					ins
<i>Stoeberia arborea</i> Van Jaarsv.					m
<i>Tetragonia arbuscula</i> Fenzl			ins		
<i>Tetragonia reduplicata</i> Welw. ex Oliv.				ins	m
<i>Thesium lacinulatum</i> A.W. Hill.				ins	ins
<i>Tripteris crassifolia</i> O.Hoffm.					m
<i>Tylecodon aurusbergensis</i> G.Will.& Van Jaarsv.					ins
<i>Tylecodon hallii</i> (Toelken) Toelken					ins
<i>Tylecodon paniculatus</i> (L.f.) Toelken					ins
<i>Zygophyllum applanatum</i> Van Zyl					m
<i>Zygophyllum clavatum</i> Schltr. & Diels					ins
<i>Zygophyllum cordifolium</i> L.f.					ins
<i>Zygophyllum cylindrifolium</i> Schinz					
<i>Zygophyllum decumbens</i> Del. var. <i>megacarpum</i> A.Hosny		m		m	
<i>Zygophyllum leptopetalum</i> E. Mey. ex Sond.					m
<i>Zygophyllum prismatocarpum</i> E.Meyer ex Sonder					m
<i>Zygophyllum pubescens</i> Schinz				ins	
<i>Zygophyllum retrofractum</i> Thunb.					m
<i>Zygophyllum stapffii</i> Schinz		ins			

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