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Floristic relationships between inselbergs and mountain habitats in the central Namib

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granite + dolerite
inselbergs

Abstract

Floristic relationships between isolated mountains (i.e. inselbergs) and adjacent mountain habitats were investigated in an arid landscape in Namibia. Six dolerite ridges, three granite inselbergs, the Brandberg and the Erongo Mountain (as the two "mainland" mountain habitats) were included in this analysis. Spatial arrangement, correlation with geology and landform as well as attributes of the species shared between inselbergs and the mountains were analysed. Of relevance to identifying ecological patterns and processes of importance for conservation planning in this area are the following findings: (1) Granite inselbergs showed closer links to mountain habitats than dolerite ridges. (2) Higher inselbergs had closer links with mountain habitats than low inselbergs. (3) Many species, largely with broad habitat requirements, are shared between inselbergs and mountain habitats. (4) Likely more transient populations of short-lived species are shared between dolerite ridges and potential mainland, compared to longer-lived plants forming more stable communities on granite inselbergs. As a result, the function of granite inselbergs and dolerite ridges in this arid landscape may differ. Granite inselbergs appear to be important sources of remnant populations from perhaps wetter conditions in the past, while dolerite ridges may be more important as species pools of plain species, many of which are of rangeland importance. In practical terms granite inselbergs per se as well as "linkage" corridors from these inselbergs to other mountain areas should be included as important variables indicative of ecological processes in conservation prioritisation procedures.

Zusammenfassung

Die Landschaft der zentralen Namib zeichnet sich durch eine Vielfalt von Inselbergen und relative Nähe zu zwei prominenten Bergmassiven aus. In dieser Studie wurden floristische Verwandtschaft zwischen Inselbergen der Spitzkoppegegend und Brandberg und Erongo Massiv untersucht. Sechs Dolerit und drei Granitinselberge, das Erongomassiv und der Brandberg dienten als Untersuchungsgebiete. Die Artenzusammensetzung der Granitinselberge ist ähnlicher zu Erongobergen und

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Brandberg, als die der Doleritinselberge. Im Vergleich zu den Doleritinselbergen, herrschen auf den Granitinselbergen Pflanzengesellschaften mit länger lebenden Arten vor (z.B. Bäume und Sträucher). Granit- und Doleritinselberge scheinen somit eine unterschiedliche Funktion in der Landschaft einzunehmen. Während die Granitinselberge viele Arten beherbergen, die charakteristisch für mehr humide Bedingungen sind, scheinen auf den Doleritinselbergen mehr Pflanzen des umgebenden Flachlandes zu wachsen. Die Doleritinselberge könnten somit Refugia für Arten darstellen die durch Überweidung in der Umgebung eliminiert wurden, während die Granitinselberge Refugia für Arten, die durch Klimaveränderung beeinträchtigt werden könnten, bieten. Granitinselberge stellen daher wichtige Korridore zu Berggegenden dar, die bei Naturschutzplanung mit einbezogen werden sollen.

Keywords: Brandberg, conservation, Erongo, Namibia, plant diversity, species pools, Spitzkoppe

Nomenclature follows Craven (1999)

Introduction

Arid regions, particularly at the interface of biomes, are potentially first to be affected by global climate change (Hoffman *et al.* 1990; Steffen *et al.* 1996). Mountains, through their altitude gradient, have often been considered to provide a buffer in the event of climate change (Bond & Richardson 1990). Isolated mountains in a desert landscape could thus prove of considerable importance by either (a) maintaining adequate species pools to supply drying up lowlands or (b) providing shelter for species no longer able to survive on increasingly arid plains. Spatially connected species pools are thus important (Cornell 1993; Zobel 1997).

Understanding the linkages and thus potential gene flow between populations will provide a solid framework for developing practical guidelines aimed at retaining ecological patterns and processes in an ideal conservation network (Cowling *et al.* 1999). It is in this context that the current study provides a contribution by investigating (a) the linkages between inselberg and neighbouring mountain plant species pools and (b) attributes of species shared between these habitats to elucidate potential mechanism of species migration and gene flow.

The central Namib Desert is characterised by a steep coast-inland climatic gradient (Jürgens *et al.* 1997), continuous aridity since the late Tertiary (Ward *et al.* 1983) and a varied landscape with vast gravel plains, dotted with isolated mountains (i.e. inselbergs) and dissected by a network of dry rivers (Giess 1981). The northern tip of the central Namib is framed by two extensive mountains to the north (Brandberg Mountain) and east (Erongo Mountain). This area forms a mosaic-like transition between the Desert, Nama Karoo and Savanna biome in Namibia (Irish 1994). In this

complex, arid landscape the question of relationships between biological communities of isolated mountains with larger mountain complexes (i.e. the Brandberg and Erongo Mountains) is not only of academic interest but may also provide directives for conservation planning.

In Namibia granite outcrops and granite mountain areas had been identified of conservation importance due to high level of endemism and high species diversity amongst all groups of taxa (Barnard 1998). In practical terms conservation planning on regional and national level is currently in progress in Namibia with particular emphasis on the study area. A master (land use) plan for the Erongo Region is in progress, conservancies and a research field station with the view to become part of Namibia's Long-term Ecological Research Network are planned in the Erongo Mountains (P. Barnard, pers. comm.) and community-based tourism ventures are presently expanded in the Spitzkoppe area, which is very popular with tourists. All these activities call for an integration of biodiversity research with wise environmental and conservation planning.

At the background of the broad question of ecological patterns and processes that deserve particular attention in conservation planning in this area, the following question were asked:

- What are the linkages between inselbergs and the species pools of larger mountain complexes?
- Are these linkages affected by elevation of inselberg, distance to mainland, or lithology and landform?
- What are the attributes of species shared between inselbergs and potential mainland?

Methods

Study area

The study area is positioned in the northern part of the central Namib Desert and comprises inselbergs in the Spitzkoppe area as well as the Brandberg and Erongo Mountains (Figure 1). The centre of the study area is approximately at 21°30' latitude South and 15°00' longitude East. The Brandberg rises to 2573 m, with an elevation of approximately 1800 m above the surrounding plains. The Erongo Mountains' highest peak is 2310 m, rising some 1200 m above the plains at its western edge. The studied inselbergs range from 10 to 460 m in elevation (Table 1).

The study area lies in a transitional zone between the desert, a narrow strip of the Nama Karoo and the savanna biome in Namibia (Irish 1994). Rainfall decreases from east to west, with a long-term annual average of 290 mm at Omaruru, east of the Erongo Mountains, dropping to 134 mm at Usakos and decreasing to as little as 15 mm near the coast (Weather Bureau, Windhoek). Most rains fall in the late summer

months (January – March) and rains are unpredictable, highly variable between years and extremely patchy.

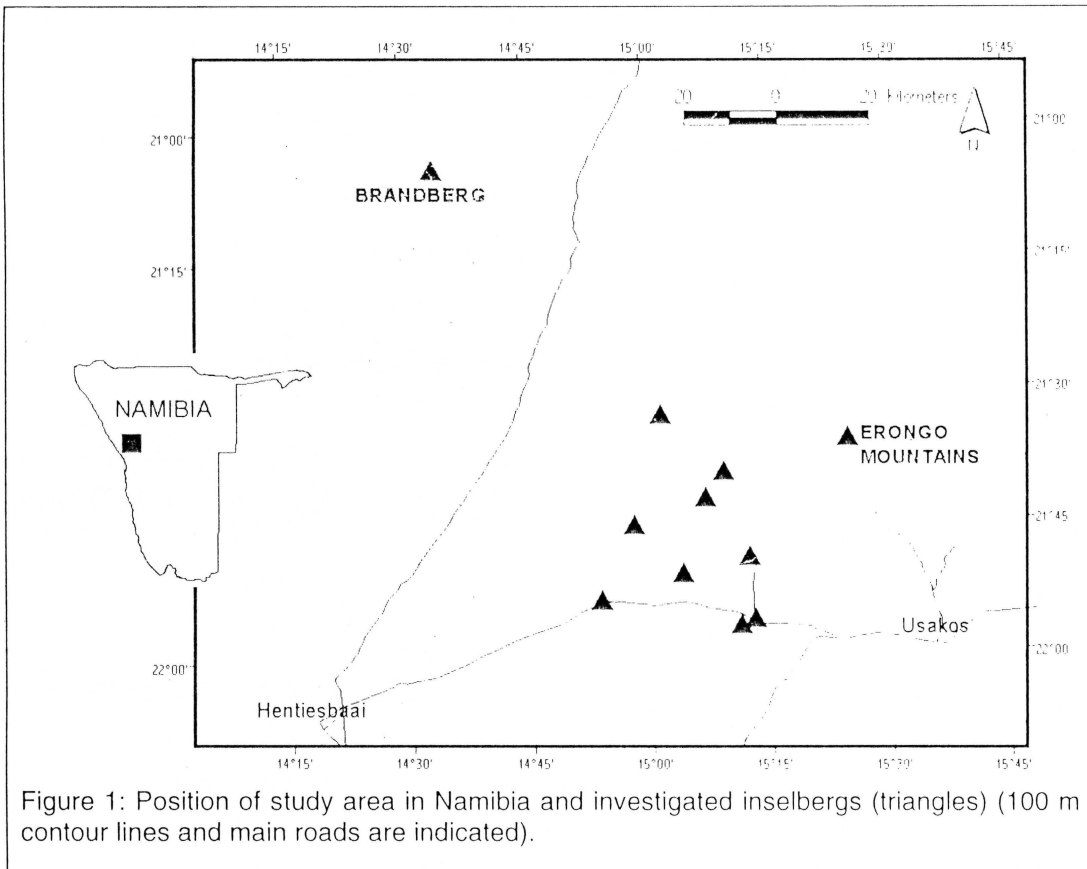


Table 1: Studied inselbergs in the Spitzkoppe area, their positions and rock type.

Name of inselberg	Geographic position	Lithology
Black Range	21°57' S / 15°10' E	dolerite
Gross Spitzkoppe	21°49' S / 15°09' E	granite
Klein Spitzkoppe	21°51' S / 15°03' E	granite
Klipspringkop	21°33' S / 15°01' E	granite
Nameless small outcrop	21°54' S / 14°53' E	dolerite
Schwarz Spitzkoppe	21°39' S / 15°08' E	dolerite
Small Schwarz Spitzkoppe	21°42' S / 15°06' E	dolerite
Small Black Range	21°56' S / 15°12' E	dolerite
Swartberge	21°45' S / 14°57' E	dolerite

Gravel plains and inselbergs of different lithology provide the main landforms in the study area. The studied inselbergs are either granite domes or dolerite dykes of Cretaceous origin (Geological Survey 1997). The granite inselbergs are characterised by steep slopes with an overall rounded appearance and many boulders, particularly around the bases of these mountains. The dolerite ridges are aligned in a south-west

to north-easterly direction, and, apart from contrasting chemical composition of the substrate (Burke 2002b), form narrow ridges with steep slopes covered with loose rocks and stones. Three granite inselbergs and six dolerite ridges were selected for this study. The Brandberg is largely composed of granite, while the Erongo Mountains are composed of volcanic material, largely rhyolite and undifferentiated basalt lava flows as well as granite (Geological Survey 1997).

The zonal vegetation in this area has been described as *Calicorema capitata* and *Euphorbia damarana* zone (Hachfeld 2000) with savanna species, such as *Acacia reficiens* becoming more prominent towards the east (pers. obs.).

Data preparation and analysis

Included in this analysis were data from field surveys of flora undertaken by the author of Spitzkoppe inselbergs and in the Erongo Mountains during the growing season of 1998 and 2001, published sources and database information. The methodology of the field surveys has been described in detail in earlier publications and will thus not be repeated here (Burke 2002a). However, summarised briefly, plant species abundance was recorded along transects from bottom to top of inselberg or mountain. Species occurring in the general area, but not directly on these transects were also recorded. For the purpose of this study, detailed information on plant species – abundance, available from these field surveys, was summarised to present species lists per inselberg. A species list for the Brandberg was based on published information (Craven & Craven 2000), while a species list for the Erongo Mountains was generated using own observations and data from the specimens database of the National Botanical Research Institute.

To investigate the relationship between inselbergs and potential mainland sources similarity matrices were prepared with the computer programme PRIMER (Carr 1997) using the Bray Curtis similarity index and 4th root transformation of the original data. The influence of (a) elevation and (b) distance to mainland was explored by regression analysis, the influence of (c) geology using Analysis of Variance (Zar 1984). F-tests were used to determine whether or not differences between similarities of inselbergs with (a) the Brandberg or (b) the Erongo Mountains were significant (Zar 1984).

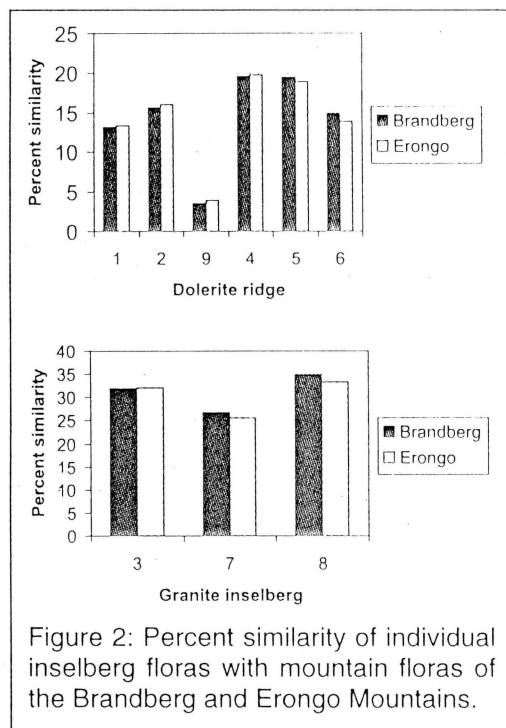
As an indication for potential processes of species migration and exchange, attributes of plant species shared between inselbergs and the mountain complexes (i.e. Brandberg and Erongo Mountains) were investigated with regard to dispersal spectra and growth form. Growth forms were classified into the simple categories tree, stem-succulent, shrub, leaf-succulent, herb, grass, geophyte, evergreen and dwarf stem-succulent (< 0.2m). Dispersal mode was defined according to obvious morphological adaptations (van der Pijl 1969) and also included dual dispersal modes.

Results

Inselberg – mountain relationships

Overall, 770 plant species were included in this analysis. This presents 18 % percent of the total flora of the country, a remarkable diversity within an approximately 60 km radius of land surface. Distances from inselbergs to potential mainland ranged between 30 and 120 km, with inselbergs being overall closer to the Erongo Mountains than the Brandberg. The similarity indices ranged from 3 to 35 percent plant species shared between inselbergs and respective mountain areas.

With regard to the arrangement of floristic affinities in the spatial landscape, patterns were remarkably similar when the similarity indices with the Brandberg and those of the Erongo Mountains were compared (Figure 2). In both instances the granite inselbergs (sites 3, 7 and 8) had the highest affinities with the potential mainland sources (26 – 35 % for the Brandberg; 25 – 34 % for Erongo), low dolerite ridges the lowest (3 – 20 % for Brandberg; 4 – 20 % for Erongo). The values only differed slightly and were not significantly different (for dolerite $F=1.08$, $p > 0.46$; for granite $F=0.99$, $p > 0.49$). The ranking of affinities from high to low remained identical. The Brandberg and Erongo Mountains shared approximately 56 % of their plant species.



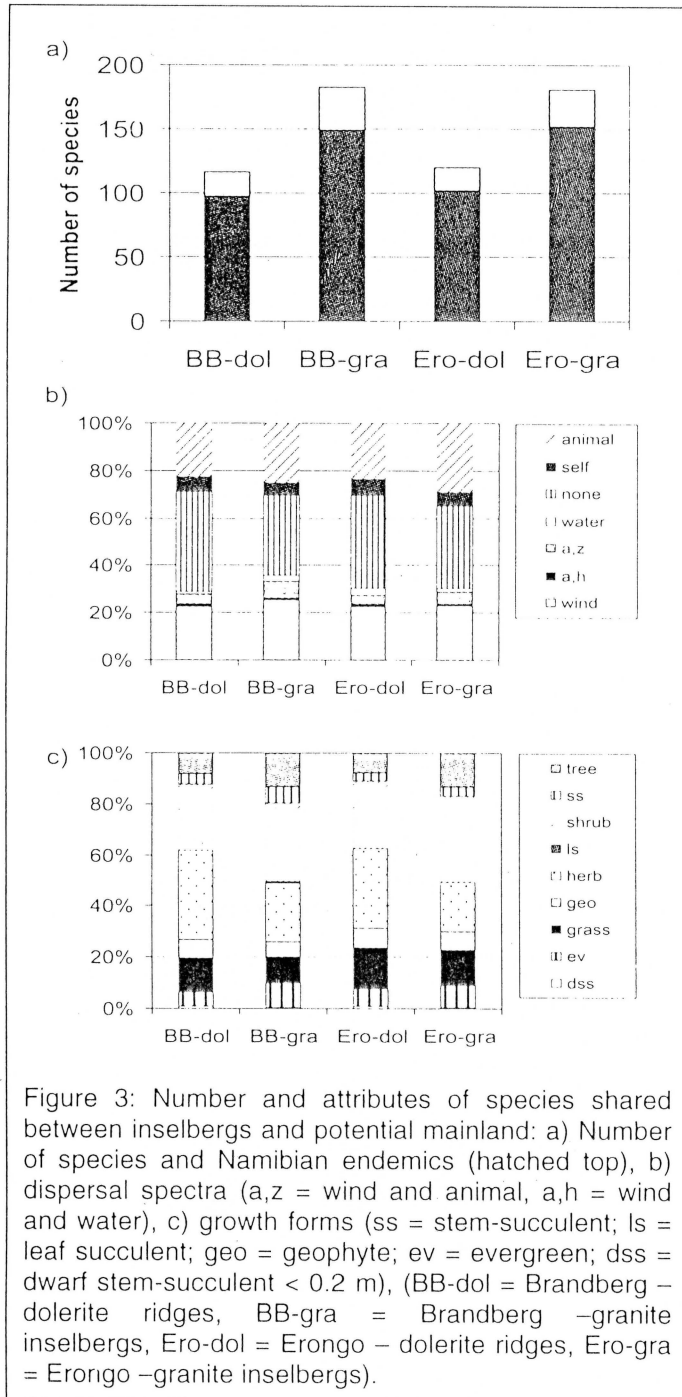
Are floristic affinities related to elevation? Yes, elevation of inselberg influenced affinities with potential mainland sources. This was statistically supported for both, Brandberg ($r^2=0.86$, $p < 0.0004$) and Erongo Mountains ($r^2=0.88$, $p < 0.0002$), with higher inselbergs (those above 140 m) showing closer affinities than lower inselbergs.

Are floristic affinities related to distance to mainland? No, as emerging from the interpretation of spatial patterns, distance to mainland in this study did not affect similarities between inselberg and potential mainland floras. Correlation coefficients were low and not significant for both, Brandberg ($r^2=0.02$, $p=0.685$) and Erongo Mountains ($r^2=0.23$, $p=0.191$). However, a slightly better relationship was indicated for the Erongo Mountains.

Are floristic affinities affected by geology? Yes, geology influenced the relationship with potential mainland sources in this study, for both Brandberg (ANOVA: $F=18.3$,

$p < 0.0004$) and Erongo Mountains (ANOVA: $F=19.0$, $p < 0.0004$) the difference was significant. As indicated above, the flora of granite inselbergs shared a remarkably higher number of species with the potential mainland sources than dolerite ridges.

Attributes of shared species



A total of 198 species were shared between the mountains and the investigated inselbergs. These included many widespread, opportunistic species, such as *Aristida adscensionis* and *Geigeria alata*, weedy species, for example *Geigeria ornativa* and *Zygophyllum simplex*, but also Namibian endemics such as *Elephantorrhiza suffruticosa*, *Petalidium canescens* and *Monechma genistifolium* (Appendix 1).

The number of species shared between granite inselbergs and mainland was 173, that of dolerite ridges 111. Further broken down as per individual mountain area, dolerite ridges shared 97 species with the Brandberg and 102 species with the Erongo Mountains. The granite inselbergs shared 149 species with the Brandberg and 152 species with the Erongo Mountains (Figure 3a). The proportion of Namibian endemics amongst the shared species was slightly lower for species shared with the Erongo Mountains than for those shared with the Brandberg. Although some

of the shared species (36 %) occurred in both mainland areas, the remaining species were only shared with one of the potential mainland areas. Some examples for species only shared between the Brandberg and inselbergs are *Aloe dichotoma*, *Anthiphiona fragrans* and *Helichrysum roseo-niveum*; examples for species only shared between Erongo Mountains and the inselbergs are *Dichrostachys cinerea*, *Helinus spartioides* and *Talinum caffrum*. Interestingly, 68 % of the shared species also occurred on plains and in dry river habitats surrounding the inselbergs.

Despite the fact that total numbers and the composition of the species differed, dispersal spectra of shared species were remarkably similar (Figure 3b). Species with no obvious adaptation for seed dispersal comprised the largest group, followed by animal and wind dispersal. Self dispersal and the combination of animal and wind dispersal were evident, while water and the combination of water and wind dispersal was only found in few species.

Growth forms of shared species, however, differed between the groups. The species from dolerite ridges shared with both, Erongo Mountain and Brandberg, were largely herbs, followed by shrubs and grasses, and then guilds of plants which were less well represented such as trees, geophytes, stem-succulents, evergreen shrubs and dwarf stem-succulents. Species shared between granite and potential mainland habitats on the other hand, were foremost shrubs, followed by herbs and then grasses and trees (Figure 3c).

Discussion

Inselberg – mountain relationships

Irrespective of position in the local landscape, granite inselbergs showed the highest floristic affinities, dolerite ridges and lower mountains the lowest affinities with potential "mainland" habitats (Figure 2). This was statistically supported for both, lithology and elevation. Unfortunately no isolated, low granite inselbergs occurred in the study area to enable a clear separation of the effect of elevation from lithology (only medium and high, isolated granite inselbergs were present), but it is expected that this would not change the detected trends. There was a slightly better correlation with distance indicated for the Erongo Mountains. This could mean that those inselbergs closer to the Erongo Mountains may be more similar in floristic composition than those further away from these mountains. But this trend was not statistically supported and could also be related to a sampling effect, as higher inselbergs (more likely to show better correlation) were overall closer to the Erongo Mountains.

A study on basalt mesas (flat-topped inselbergs) to the north of the study area showed in one respect a similar, in another an opposing trend. Distance had no effect on floristic affinities between these mesas and the escarpment, the closest similar mountain habitat, but neither had elevation (A. Burke, unpublished data 2001).

However, similarities were overall much higher, averaging at about 50 %, and although the study area was comparable in size, it presents generally a more mountainous landscape where mesas are far less isolated than the inselbergs in the Spitzkoppe study area. Closer links amongst the floras of neighbouring mesas may so have resulted in the persistence of a mesa flora very similar to the escarpment to the east.

The fact that higher inselbergs showed closer affinities with the potential mainland can likely be explained by a larger contingent of inselberg specialists (i.e. species adapted to mountain habitats) which were less frequent on lower inselbergs (A. Burke, unpublished data 2001). Altitudinal effects may also play a role on higher inselbergs, providing cooler and perhaps moister conditions in the higher reaches of these mountains. Convectional rains, but also fog could contribute to this effect. Although at 70 km distance from the coast, fog influence is low (Hachfeld 2000), fog was observed occasionally during the field surveys, particularly covering the top of the inselbergs.

Higher affinities between granite inselbergs and potential mainland habitats could well be related to similarity in lithology and derived substrate. The Brandberg is largely composed of granite, while granite intrusions are also present in the Erongo Mountains, although accompanied by rhyolite and basalt lava flows (Geological Survey 1997). The chemical and physical properties of soils derived from these rocks are likely similar to those on granite inselbergs, and could thus support a similar assemblage of plant species. The specific landform of granite inselbergs, as compared to the dolerite dykes, is believed to provide more favourable microhabitats through intensive re-distribution of runoff (Shmida *et al.* 1986) as well as shady and sheltered habitats beneath and in the vicinity of the large boulders. On granite inselbergs water runs off bare rock surfaces and collects in depressions and channels where moisture is stored for many months into the dry season. Although these rock surfaces are not colonised, plants growing in rock crevices between these granite sheets and in depressions and channels so receive additional moisture. This may enable species normally growing in higher rainfall regimes to survive on these inselbergs. Runoff on the steep slopes of the dolerite dykes is believed to be re-distributed in a different fashion. Here no extensive rock surfaces are present and runoff will likely be more evenly distributed. Moisture conditions on the dolerite ridges are still more favourable than on the surrounding plains, but moisture stored at a particular spot may be less than in soil pockets on granite inselbergs. Soils derived from dolerite are much finer than the coarse, granite derived soils (Burke 2002b), perhaps an additional factor resulting in less storage of soil moisture under arid conditions (Seely 1991).

The investigated floras are likely examples of unsaturated, non-interactive communities and may thus present "sink" habitats for species at the edge of their distribution ranges (Cornell 1993). The fact that rainfall conditions largely determine species composition in the broader area (Hachfeld 2000) and many species of the mountain habitats in the study area have only been recorded in exceptionally good

rainy seasons (Craven & Craven 2000) supports such a notion. A reasonable overlap between species of inselbergs, particularly higher granite domes, and the larger mountain massifs (approximately a quarter to one third of the species) indicates that there are certainly floristic links. However, without longer term monitoring of populations of selected species, it will be difficult to explain whether or not "source-sink" effects exist and in which way these operate.

Attributes of shared species

With regard to attributes that may enable species migration and gene flow between populations, about half of the species shared between inselbergs and neighbouring mountain habitats showed adaptations for long-range seed dispersal, such as wind and animal dispersal (Figure 3b). Amongst those that were restricted to mountain habitats (i.e. not occurring on plains) were also equal portions of species with long-range and short-range dispersal. If seed dispersal was the main factor responsible for determining which species are common to both inselbergs and neighbouring mountain massifs, one would certainly expect long-range dispersers to be the most prominent group. This is not the case, but a near equal distribution occurred which, (a) could be a reflection of the regional species pool in the area (Caley & Schluter 1997), (b) indicate that other factors such as ecological and habitat requirements of the species involved may be more important (Bazzaz 1991) or (c) point towards other intrinsic selective forces that impose on seed dispersal (Dieckmann *et al.* 1999).

More than two thirds of the species shared between inselbergs and neighbouring mountain habitats also occurred on the plains and dry rivers surrounding the inselbergs. This indicates that most of these are adapted to grow in many different habitats and thus have broad ecological tolerance limits. In an ideal scenario species most able to "migrate" (i.e. colonise new habitats) would be those with long-range dispersal and broad habitat and ecological requirements.

With regard to growth forms, high proportions of short-lived species are expected to indicate fluctuating, more transient populations, thus pointing towards a "source-sink" effect (e.g. Kadmon & Shmida 1990; Dias 1999) or a dynamic metapopulation (e.g. Tilman *et al.* 1997). The results of this study differ between inselbergs of different lithology, however. On dolerite ridges short-lived species such as herbs, grasses and geophytes (for convenience included, although it is recognised that some geophytes can be fairly long-lived) dominate. On granite inselbergs long-lived species, such as shrubs and trees were clearly more prominent (Figure 3c). One could hypothesise that species composition on dolerite ridges is more transient, while communities on granite inselbergs may form more stable communities, with closer floristic links to neighbouring mountain habitats. A study of changes in community composition over time would be able to answer this question.

Although this has not been the focus of this study, a closer look at the species shared between inselbergs and the two different mountain massifs revealed that different

floral elements are involved (only some 56 % of the species are common to the Brandberg and the Erongo Mountains). The Brandberg harbours many Namib Desert elements as well as species occurring in the Cape and Namibia (Nordenstam 1974; Craven & Craven 2000). Savanna elements, such as various *Acacia* species are more prominent in the Erongo Mountains.

Implications for conservation and land use planning

The study area is characterised by comparatively high plant species diversity that emphasises its importance for conservation. Amongst the studied inselbergs it was confirmed that granite areas showed higher diversity and linkages to other mountain habitats further emphasising their conservation importance (Barnard 1998). The granite inselbergs showed closer links with neighbouring mountain habitats and may thus provide an important gene pool for species at the edge of their distribution range. In view of on-going land use and conservation planning activities in the study area the findings of this study resulted in three main recommendations. (1) To adequately preserve ecological patterns and processes granite areas should receive a high priority rating amongst habitats. (2) As floral linkages with other mountain habitats in the area exist, and are likely important in maintaining inselberg communities, "linkage" corridors between inselbergs and larger mountain areas, ideally containing several inselbergs and/or smaller rock outcrops should be included as important variables indicative of ecological processes in iterative conservation prioritisation procedures (Cowling *et al.* 1999). (3) The established sites in the Spitzkoppe area provide an ideal baseline for studies of environmental change and should be formalised (i.e. receive protection), expanded to include permanent sites in the Erongo Mountain conservancy area, and monitored. At the same time inclusion of other taxa such as indicators for insect communities should also be considered.

Due to increasing pressure the semi-nomadic pastoralism practised in the parts of the study area, increasing influx of people and their livestock is expected to negatively affect the grazing resources in this area in the long-term. Inselbergs harbour many palatable grazing and fodder species providing a "back-up" source pool should these decline on the surrounding plains. Inselbergs should thus receive a high protection status including protection from grazing, especially where degrading conditions in the surrounding may force livestock to move into reasonably accessible mountain areas. At present livestock grazing only affects the more accessible bases of these mountains, as the upper reaches are inaccessible to livestock and populations of inselberg and mountain-adapted plant species are so naturally protected. However, some granite inselbergs have become popular destinations for rock climbers and commercial mineral collectors. Particularly activities of the latter may negatively impact on the granite inselberg vegetation.

Conclusion

In summary, the following findings may be of relevance to resource and conservation planning:

- Granite inselbergs showed closer links to the nearby mountain habitats than dolerite ridges.
- Higher inselbergs had closer links with mountain habitats than low inselbergs.
- Many species, largely with broad habitat requirements, are shared between inselbergs and potential mainland habitats.
- Likely more transient populations of short-lived species are shared between dolerite ridges and potential mainland, compared to longer-lived plants on granite inselbergs.

The function of granite inselbergs and dolerite ridges in this arid landscape may thus differ fundamentally. Granite inselbergs appear to be important for maintenance of remnant populations, while dolerite ridges may be more important as source pools of plain species. To adequately address conservation of patterns and processes, granite areas and "linkage" corridors between inselbergs and neighbouring mountains should be prioritised in conservation planning activities.

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Appendix 1. Plant species shared between Spitzkoppe inselbergs (1998 survey) and Brandberg (BB) and Erongo (Ero) (x = indicating occurrence on Spitzkoppe inselbergs and respective mountain area; ss = stem-succulent, ls = leaf succulent, geo = geophyte, ev = evergreen, dss = dwarf stem-succulent; a,z = wind and animal dispersal, a,h = wind and water dispersal).

Plant species	Dolerite		Granite		Growth form	Dispersal
	BB	Ero	BB	Ero		
<i>Abutilon pycnodon</i> Hochr.	x	x	x	x	shrub	none
<i>Acacia erioloba</i> E.Meyer			x	x	tree	animal
<i>Acacia erubescens</i> Welw. ex Oliver				x	tree	animal
<i>Acacia reficiens</i> Wawra ssp. <i>reficiens</i>	x	x	x	x	tree	animal
<i>Adenia pechuelii</i> (Engl.) Harms			x	x	ss	none
<i>Adenolobus garipensis</i> (E.Mey.) Torre & Hillc.	x	x	x	x	tree	none
<i>Adenolobus pechuelii</i> (Kuntze) Torre & Hillc. subsp. <i>pechuelii</i> (Torre & Hillc.) Brummit & Ross	x	x			shrub	none
<i>Aloe dichotoma</i> Mass.			x		ss	none
<i>Amaranthus praetermissus</i> Brenan	x	x			herb	animal
<i>Amphiasma divaricatum</i> (Engl.) Bremek.				x	shrub	none
<i>Anthiphiona fragrans</i> (Merm.) Merxm.			x		shrub	wind
<i>Anthehora pubescens</i> Nees			x	x	grass	a,z
<i>Anthehora schinzii</i> Hack.	x	x	x	x	grass	a,z
<i>Anticharis ebracteata</i> Schinz	x		x		herb	none
<i>Anticharis imbricata</i> Schinz	x				shrub	none
<i>Aptosimum arenarium</i> Engl.		x		x	shrub	none
<i>Aristida adscensionis</i> L.	x	x	x	x	grass	a,z
<i>Aspilia eenii</i> S. Moore			x	x	shrub	wind
<i>Barleria lancifolia</i> T.Anders			x	x	shrub	self
<i>Berkheya spinosissima</i> (Thunb.) Willd. subsp. <i>spinosissima</i>	x	x	x	x	shrub	wind
<i>Blepharis grossa</i> (Nees) T.Anderson	x	x	x	x	herb	self
<i>Blepharis obmitrata</i> C.B. Clarke			x	x	shrub	self
<i>Boerhavia coccinea</i> Mill.			x	x	shrub	animal
<i>Boscia albitrunca</i> (Burchell) Gilg & Benedict	x	x	x	x	tree	animal
<i>Boscia foetida</i> Schinz subsp. <i>foetida</i>	x	x	x	x	ev	animal
<i>Bulbostylis hispidula</i> (Vahl) R. Haines				x	grass	none
<i>Cadaba aphylla</i> (Thunb.) Wild				x	ev	animal
<i>Calicorema capitata</i> (Moq.) Hook.f.	x	x	x	x	ev	wind
<i>Cardiospermum pechuelii</i> Kuntze			x	x	shrub	wind
<i>Catophractes alexandri</i> D.Don.				x	shrub	wind
<i>Chamaesyce glanduligera</i> (Pax) Koutn.	x	x	x	x	herb	none
<i>Chamaesyce inaequilatera</i> (Sond.) Sojak	x	x	x	x	herb	none
<i>Chascanum garipense</i> E.Mey.	x		x		shrub	none

<i>Chloris virgata</i> Swartz				x	grass	wind
<i>Citrullus eccirrhosus</i> Cogn.	x				geo	animal
<i>Cleome angustifolia</i> Forsskal subsp. <i>diandra</i> (Burchell) Kers	x	x			herb	none
<i>Cleome suffruticosa</i> Schinz	x	x	x	x	herb	none
<i>Clerodendron dekindtii</i> Guerke				x	shrub	animal
<i>Coccinea rehmannii</i> Cogn.	x	x	x	x	geo	animal
<i>Codon schenkii</i> Schinz			x	x	ev	none
<i>Commiphora glaucescens</i> Engl.	x	x	x	x	tree	animal
<i>Commiphora pyracanthoides</i> Engl.			x	x	ss	animal
<i>Commiphora saxicola</i> Engl.	x	x	x	x	shrub	animal
<i>Commicarpus squarrosus</i> (Heimerl) Standley	x	x	x	x	shrub	animal
<i>Commiphora tenuipetiolata</i> Engl.	x	x	x	x	tree	animal
<i>Commiphora virgata</i> Engl.	x	x	x	x	ss	animal
<i>Corallocarpus welwitschii</i> (Naud.)Hook.f.ex Welw.	x	x	x	x	geo	animal
<i>Corbichonia decumbens</i> (Forssk.)Exell	x	x	x	x	shrub	none
<i>Cordia sinensis</i> Lam.			x	x	tree	animal
<i>Crotalaria damarensis</i> Engl.	x	x	x	x	herb	none
<i>Croton gratissimus</i> Burchell var. <i>gratissimus</i>			x	x	tree	none
<i>Cucumella aspera</i> (Cogn.) C.Jeffrey	x	x	x	x	geo	animal
<i>Cucumella cinerea</i> (Cogn.) C. Jeffrey			x	x	geo	animal
<i>Cucumis sagittatus</i> Peyr.			x	x	geo	animal
<i>Curroria decidua</i> Planch. ex Hook.f. & Benth.	x	x	x	x	shrub	wind
<i>Cuscuta planiflora</i> Ten. var <i>planiflora</i>	x	x			herb	none
<i>Cyperus marginatus</i> Thunb.		x			grass	none
<i>Cyphostemma currori</i> (Hook. f.) Desc.			x		ss	animal
<i>Cyphostemma omburense</i> (Gilg. & Brandt) Desc.			x	x	shrub	animal
<i>Dactyloctenium aegyptium</i> (L.) Willd.				x	grass	none
<i>Dactyliandra welwitschii</i> Hook.f.	x	x	x	x	geo	animal
<i>Dichrostachys cinerea</i> subsp. <i>africana</i> Bren. & Brum. var. <i>africana</i>				x	tree	animal
<i>Dicoma capensis</i> Less.			x		herb	wind
<i>Dicoma tomentosa</i> Cass.	x	x	x	x	herb	wind
<i>Dipcadi glaucum</i> (Burchell ex Ker Gaw.) Baker	x	x	x	x	geo	none
<i>Dombeya rotundifolia</i> (Hoechst.) Planch.			x	x	tree	none
<i>Dyerophytum africanum</i> (Lam.) Kuntze	x	x	x	x	shrub	wind
<i>Elephantorrhiza suffruticosa</i> Schinz			x	x	tree	animal
<i>Emilia marlothiana</i> (O.Hoffm.)C.Jeffrey	x	x	x	x	herb	wind
<i>Enneapogon desvauxii</i> Beauv.	x	x	x	x	grass	none
<i>Enneapogon scaber</i> Lehm. var. <i>scaber</i>	x	x	x	x	grass	none
<i>Eragrostis annulata</i> Rendle ex Scott	x	x			grass	none

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<i>Eragrostis nindensis</i> Fical.& Hiern	x	x		x	grass	none
<i>Eragrostis rotifer</i> Rendle			x	x	grass	none
<i>Eriocephalus dinteri</i> S.Moore			x		ev	a,z
<i>Euclea pseudebenus</i> E.Mey. ex A.DC.			x	x	tree	animal
<i>Euclea undulata</i> Thunb. var. <i>myrtina</i> (Burch.) Hiern			x	x	ev	animal
<i>Euphorbia gariiepina</i> Boiss. subsp. <i>gariiepina</i>	x		x		dss	none
<i>Euphorbia guerichiana</i> Pax	x	x	x	x	tree	none
<i>Euphorbia mauritanica</i> L. var. <i>mauritanica</i>	x		x		ss	none
<i>Euphorbia virosa</i> Willd.	x	x	x	x	ss	none
<i>Ficus cordata</i> Thunb. ssp. <i>cordata</i>			x	x	tree	animal
<i>Ficus ilicina</i> (Sonder) Miq.			x	x	ev	animal
<i>Forsskaolea candida</i> L.f.	x	x	x	x	herb	animal
<i>Galenia africana</i> L. var. <i>africana</i>			x		ev	water
<i>Geigeria acaulis</i> Benth. & Hook.f. ex Oliver & Hiern	x	x	x	x	herb	water
<i>Geigeria alata</i> (DC) Benth.& Hook.f.ex Olivier & Hiern	x	x	x	x	herb	a,h
<i>Geigeria ornativa</i> O.Hoffm.			x	x	herb	water
<i>Gisekia africana</i> (Lour.) Kuntze var. <i>africana</i>	x	x			herb	none
<i>Grewia bicolor</i> Juss.			x	x	shrub	animal
<i>Grewia tenax</i> (Forssk.) Fiori				x	shrub	animal
<i>Heliotropium hereroense</i> Schinz	x	x	x	x	shrub	none
<i>Heliotropium ovalifolium</i> Forsk.		x		x	herb	none
<i>Helichrysum roseo-niveum</i> Marl.& O.Hoffm.			x		herb	wind
<i>Helinus spartioides</i> (Engl.) Schinz ex Engl.				x	shrub	none
<i>Helichrysum tomentosulum</i> (Klatt) Merxm. ssp. <i>tomentosulum</i>	x	x	x	x	shrub	wind
<i>Hermannia modesta</i> (Ehrenb.) Mast.	x	x	x	x	ev	none
<i>Hibiscus elliotiae</i> Harv.			x	x	shrub	a,z
<i>Hibiscus engleri</i> Schum.			x	x	herb	none
<i>Hirpicium gazanioides</i> (Harv.) Roessl.			x	x	herb	wind
<i>Hoodia currorii</i> (Hook.) Decne subsp. <i>currorii</i>		x		x	dss	wind
<i>Indigofera auricoma</i> E.Mey.	x	x			herb	self
<i>Indigofera pechuelii</i> Kuntze			x	x	shrub	self
<i>Ipomoea verbascoidea</i> Choisy			x		ev	none
<i>Kissenia capensis</i> Endl.	x	x	x	x	ev	wind
<i>Kleinia longiflora</i> DC.			x	x	ev	wind
<i>Kohautia caespitosa</i> Schnitzl. subsp. <i>brachyloba</i> (Sond.) D.Mant.	x	x	x	x	herb	none
<i>Lapeirousia coerulea</i> Schinz				x	geo	none
<i>Launea intybacea</i> (Jaqu.) Beauv.	x	x	x	x	herb	wind

<i>Lepidium africanum</i> (Burm.F.) DC. subsp. <i>divaricatum</i> (Aiton) Jonsell	x				herb	none
<i>Leucosphaera bainesii</i> (Hook.f.) Gilg.	x	x			shrub	a,z
<i>Limeum argute-carinatum</i> Warwa & Peyr. var. <i>argute-carinatum</i>	x	x	x	x	herb	none
<i>Limeum dinteri</i> Schellenb.			x	x	shrub	none
<i>Lotononis platycarpa</i> (Viv.) Pic.Serm.	x	x			herb	self
<i>Lycium eenii</i> S.Moore			x	x	shrub	animal
<i>Lycium oxycarpum</i> Dunal		x		x	ev	animal
<i>Maerua parvifolia</i> Pax	x	x	x	x	tree	animal
<i>Maerua schinzii</i> Pax	x	x	x	x	tree	animal
<i>Marcelliopsis splendens</i> (schinz) Schinz			x		shrub	a,z
<i>Melhania damarana</i> Harv.			x	x	shrub	none
<i>Melinis repens</i> (Willd.)Zizka ssp. <i>repens</i>		x		x	grass	wind
<i>Merremia bipinnatipartita</i> (Engl.) Hallier f.		x			geo	none
<i>Microloma calycinum</i> E. Meyer subsp. <i>calycinum</i>			x		ev	wind
<i>Microcharis disjuncta</i> (G.B. Gillet) Schrire var. <i>discuncta</i>	x	x	x	x	herb	none
<i>Mollugo cerviana</i> (L.) Ser.ex DC. var <i>cerviana</i>	x	x	x	x	herb	none
<i>Monechma cleomoides</i> (S. Moore) C.B.Cl.	x	x	x	x	shrub	none
<i>Monechma genistifolium</i> (Engl.) C.B. Clarke ssp. <i>genistifolium</i>		x		x	shrub	none
<i>Monsonia umbellata</i> Harvey	x	x	x	x	geo	wind
<i>Montinia caryophyllacea</i> Thunb.			x	x	shrub	none
<i>Moringa ovalifolia</i> Dinter & Berger	x	x	x	x	ss	none
<i>Myrothamnus flabellifolius</i> Welw.	x	x	x	x	shrub	none
<i>Nelsia quadrangula</i> (Engl.) Schinz			x	x	herb	animal
<i>Obetia carruthersiana</i> (hiern) Rendle			x		tree	none
<i>Ondetia linearis</i> Benth.			x	x	herb	wind
<i>Osteospermum microcarpum</i> (Harv.) Norl. ssp. <i>septentrionale</i> (Norl.) Norl.	x	x	x	x	herb	wind
<i>Othonna brandbergensis</i> B.Nord.			x		ss	wind
<i>Oxalis purpurascens</i> Salter			x	x	geo	none
<i>Ozoroa crassinervia</i> (Engl.) R. & A. Fernandes			x		tree	animal
<i>Parkinsonia africana</i> Sond.			x	x	tree	animal
<i>Pavonia rehmanii</i> Szysyl.(Pax) S.Moore			x	x	shrub	none
<i>Pegolettia oxyodonta</i> DC.			x	x	herb	wind
<i>Pegolettia senegalensis</i> Cass.	x		x		herb	wind
<i>Pelargonium otaviense</i> Knuth			x		shrub	wind
<i>Peliostomum leucorrhizum</i> E. Mey. ex Benth. var. <i>leucorrhizum</i>		x		x	herb	none
<i>Pennisetum foermeranum</i> Leeke			x	x	grass	a,z
<i>Pentatrachia petrosa</i> Klatt			x	x	shrub	wind

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<i>Pergularia daemia</i> (Forssk.) Choiv. var. <i>daemia</i>		x		x	ev	wind
<i>Petalidium canescens</i> (Engl.) C.B.Clarke	x	x			shrub	self
<i>Petalidium variabile</i> (Engl.) C.B.Cl. var. <i>variabile</i>	x	x	x	x	ev	self
<i>Phyllanthus pentandrus</i> Schumach. & Thonn.	x	x	x	x	herb	none
<i>Polygala guerichiana</i> Engl.			x	x	shrub	none
<i>Portulaca oleracea</i> L.			x	x	herb	none
<i>Protasparagus denudatus</i> (Kunth.) Oberm.		x		x	shrub	animal
<i>Ptychobium biflorum</i> (E. Mey.) Brummit subsp. <i>biflorum</i>		x		x	shrub	self
<i>Pupalia lappacea</i> (L.) A.Juss. var. <i>lappacea</i>			x		herb	a,z
<i>Rhus marlothii</i> Engl.			x	x	shrub	animal
<i>Ruellia diversifolia</i> S.Moore			x		shrub	self
<i>Salvia garipensis</i> E.Mey.ex Benth.	x	x	x	x	shrub	none
<i>Salvadora persica</i> L.	x	x	x	x	shrub	animal
<i>Sarcocaulon marlothii</i> Engl.	x	x	x	x	shrub	wind
<i>Sarcostemma viminale</i> (L.) R.Br.			x	x	ev	wind
<i>Seddera schizantha</i> Hallier f.	x	x			shrub	none
<i>Senecio alliriifolius</i> O.Hoffm.	x		x		shrub	wind
<i>Senna italica</i> Mill. subsp. <i>arachoides</i> (Burch.) Lock	x	x			herb	none
<i>Sericocoma heterochiton</i> Lopr.			x	x	shrub	a,z
<i>Sericorema sericea</i> (Schinz)Lopr.	x	x	x	x	herb	a,z
<i>Sesamum capense</i> Burm.f.	x		x		herb	none
<i>Sesamum marlothii</i> Engl.	x		x		herb	none
<i>Sesamum rigidum</i> Peyr. subsp. <i>rigidum</i>			x	x	shrub	none
<i>Setaria appendiculata</i> (Hack.) Stapf		x		x	grass	none
<i>Solanum capense</i> L.				x	shrub	animal
<i>Solanum rigescentoides</i> Hutch.	x	x	x	x	shrub	animal
<i>Sterculia africana</i> (Lour.) Fiori			x	x	tree	none
<i>Stipagrostis ciliata</i> (Desf.) De Winter var. <i>capensis</i> (Trin.& Rupr.) De Winter	x	x	x	x	grass	wind
<i>Stipagrostis hirtigluma</i> (Trin. & Rupr.) De Winter ssp. <i>hirtigluma</i>	x	x	x	x	grass	wind
<i>Stipagrostis hochstetteriana</i> (Beck ex Hack.) De Winter var. <i>hochstetteriana</i>	x	x	x	x	grass	wind
<i>Stipagrostis hochstetteriana</i> var. <i>secalina</i> (Hern.) De Winter	x	x	x	x	grass	wind
<i>Stipagrostis obtusa</i> (Del.) Nees	x	x			grass	wind
<i>Stipagrostis uniplumis</i> (Licht.) De Winter var. <i>intermedia</i> (Schweik) De Winter	x	x	x	x	grass	wind

Burke

<i>Stipagrostis uniplumis</i> (Licht.) De Winter var. <i>uniplumis</i>	x	x	x	x	grass	wind
<i>Talinum cafferum</i> (Thunb.) Eckl. & Zeyh.		x		x	geo	none
<i>Tapinanthus oleifolius</i> (Wendl.) Danser	x	x	x	x	shrub	animal
<i>Tephrosia dregeana</i> E. Mey.	x	x	x	x	shrub	self
<i>Tephrosia monophylla</i> Schinz			x	x	shrub	self
<i>Tephrosia oxygona</i> Welw. ex Baker subsp. <i>oxygona</i>				x	shrub	self
<i>Terminalia pruinoides</i> Lawson			x	x	tree	wind
<i>Tetragonia arbuscula</i> Fenzl			x		ls	wind
<i>Thamnosma africana</i> Engl.			x	x	shrub	none
<i>Trianthema parvifolia</i> E. Mey. ex Sond. var <i>parvifolia</i>		x			herb	water
<i>Trianthema triquetra</i> Rottl. ex Willd.		x			herb	water
<i>Tribulus terrestris</i> L.	x	x			herb	animal
<i>Tribulus zeyheri</i> Sond. subsp. <i>zeyheri</i>	x	x	x	x	shrub	animal
<i>Trichodesma africanum</i> (L.) Lehm.	x	x	x	x	herb	none
<i>Tricholaena capensis</i> (Licht. ex Roem. & Schant.) Nees subsp. <i>arenaria</i> (Nees) Zizka				x	grass	wind
<i>Triraphis ramosissima</i> Hack.	x	x	x	x	grass	wind
<i>Vernonia obionifolia</i> O. Hoffm. subsp. <i>obionifolia</i>			x	x	shrub	wind
<i>Xerophyta viscosa</i> Bak.			x	x	shrub	a,z
<i>Zygophyllum simplex</i> L.	x	x	x	x	herb	none