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Biodiversity Studies at Langer Heinrich Uranium Mine, Phase 2: Biodiversity Description of the Ml140 and Epl 3500 as Baseline for Future Planning - Vegetation Map and Description (June 2009)

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Abstract
The vegetation survey was conducted over the entire ML140 and EPL 3500, comprising the Langer Heinrich Uranium operations in order to develop an understanding of the vegetation communities present and of their sensitivity to disturbance. The descriptions are intended to optimize future planning of mining operations with respect to maximum environmental protections, whilst also providing guidelines and reference conditions of the vegetation for setting restoration goals after mining operations.
The vegetation survey followed the Braun-Blanquet approach. Rainfall events prior to the survey were sufficient for the germination of most of the ephemeral plant species expected to occur in this area, whilst most of the perennial vegetation had sufficient foliage and/or flowering material to allow a positive identification. Poor knowledge still exists on many geophytes expected to occur in the area, as only remnants of these plants could be found. However, some areas had a significant amount of such plant remnants, justifying further studies in this regard. During the survey 201 plant species could be observed, of which 56 species are endemic and two species alien invasive, the latter luckily single occurrences and excluded from all data analysis. According to standard statistical projection tools, between 217 and 222 species can be expected to occur in the area, excluding the geophytes. Of the endemic species 6 are restricted endemics, known only from the Central Namib, 28 are narrow endemics, occurring only in similar habitats within the Namib, while 30 are widespread endemics, occurring over a wider variety of habitats over larger areas of Namibia. Three of the endemic species have a 'vulnerable' red list status and 17 species within the study area are protected, either by Namibian legislation only or also being listed on CITES Appendix II.
The study area falls within the Stipagrostis hirtigluma plateau-edge and inselberg vegetation type as described by Nel (1983). The vegetation found within the study area is comprised of an intrinsic mosaic of 14 plant communities, whose distribution is determined by the unique characteristics of their habitats. Each community has been fully described together with a description of its habitat. Several overarching floristic traits of the communities were used to group the communities into 5 associations; however, these associations may have similar, but

not equal habitats. It is imperative to understand that despite the often very unique habitat characteristics, the plant communities do not exist in isolation and each habitat and its community forms an integral, sometimes irreplaceable component of a rather complex ecosystem. Contributing to the uniqueness and the exceptional species diversity of the study area is the relative high capability of the landscapes to channel and retain moisture compared to the wider Namib, which is overall a water-limited ecosystem.
Many aspects of the precise functioning of ecosystem processes and their related services remain poorly understood due to a lack of relevant knowledge (and studies). For a sensitivity rating of the plant community three aspects were taken into account: conservation value of species and habitat, the value of various ecosystem components, from the community to the species scale, to the overall functioning of the ecosystem, as well as the expected ability to restore these ecosystem components after a significant disturbance, based on available data and experience. A list of representative criteria was compiled, allocating relevant scores to specific community-, habitat- and species traits. The resultant score for a community determined whether it was rated as least sensitive, sensitive, highly sensitive or as irreplaceable. These ratings are relative to the communities found within the study area, and it is understood that they may rate much higher if viewed in a regional context, should sufficient data become available in the future. Therefore it must be understood that a 'least sensitive' rating simply implies that the overall impact on the ecosystem functioning will be least if these communities only are disturbed, it does not mean that the complete loss of such communities will be a negligible impact.

Keywords: Langer Heinrich Mine, plant communities, Braun-Blanquet, Gawib River, Namib Desert

Introduction

The Erongo Region of Namibia has long received world-wide attention due to its extensive Uranium ore occurrences. The current high price of Uranium has made it feasible for several mining companies to increase their exploration activities with the aim to start mining even low grade pockets of ore. The Langer Heinrich Uranium (LHU) Mine has only been operational since late 2005. It is situated in a constricted portion of the Gawib River System in the Central Namib, which, due to its topographically unique characteristics, forms more or less the centre of a dynamic and diverse ecosystem.
Mining at LHU is done by conventional open pit excavation, meaning that wherever ore is being found, all parts of the ecosystem will be removed as the pit is created and excavated. Apart from the pit area and infrastructure, additional sacrificial areas will be required for storing and/or dumping various types of materials:

- Tailings slurry: this needs to be spread on a relatively large, preferably flat area to enable the slurry to dry. The tailings are likely to contain high concentrations of salts and/ or minerals and may solidify into a hard and impenetrable surface, on which it will be almost impossible to establish any form of plant life. In addition, the resultant product is almost white, which does not blend in very well with the surrounding environment.

- Low Grade Ore: during the initial stage of the mine, primarily high grade ore is processed, as initial capital layouts of the mining operation need to be recovered, in addition to ongoing process costs. It is hoped that in future it will be economical to also process low-grade ore, but until then large quantities of this ore will first have to be stored.
- Waste Rock: a significant amount of material removed from the pit does not contain ore, and must be dumped. In addition to this barren materials coming from the processing plant must also be dumped.
- Top Soil: It is envisaged that the functionality of the vegetation of the actual Gawib River Bed will only be restorable if the same environment / habitat is re-created. This means that wherever new areas of the Gawib river channel are used for mining operations, topsoil should first be removed and stored until it can be used for rehabilitation, as there is no other source of such materials within the mining license.

The placement of these materials requires careful consideration of the rather complex ecology of the LHU mining area. Information regarding plant species and their distribution in the core area of the LHU mine was collected during the original environmental Impact Assessment (EIA) process in 2004. However, judging from the plant list compiled then, as well as the representative photographs, rainfall preceding that survey was not sufficient to allow the majority of the plant species to grow, neither did several perennial species have sufficient foliage to be correctly identified. Hence, plant groups could only be described on a rather coarse level, which does not give too much information about the complex habitats, thus also limiting the use of that information for rapid management decisions at the scale of the currently active mine.

Since the 2004 EIA survey, mining activities have significantly altered the Gawib River channel. Despite this, and due to the large rainfall events during 2008, enough vegetation remained, re-sprouted and germinated on adjacent habitats – small runoff channels and slopes north and south of the mine, to allow a more detailed description of the vegetation of the core area. It is envisaged that this more detailed description will aid the ecologically optimal placing of permanent dump sites required within the coming year. After that, a wider vegetation survey, covering the entire mining license area (Phase 2), will have to be conducted in order to guide decision making when mining expands into the other areas of the ML.

Scope of study

The aims of this study were to:

1. Conduct vegetation surveys in the designated study area (approximately 2.5km by 400m)

2. Develop a vegetation map made up of two layers, namely a landscape types / broad habitat map and a finer scaled vegetation community map that can overlay the landscape type map.
3. Compile a vegetation sensitivity map that can overlay the vegetation map.
4. Compile a report that describes the various landscape and community types, outlines plant species found in the various communities, describes the basic ecosystem dynamics of these communities and outlines why some areas are more sensitive to disturbance than others.

Study area

Surveys for this study (Phase 1) concentrated around the present core mining area (Figure 1); the latter is approximately 400 m wide and 2.5 km long. The edge of the schist outcrops, on which the NamWater Reservoirs are situated, were taken as the western limit of the survey, whilst the current explosives storage area was taken as the eastern limit of the study.
The area is situated in the narrowest section of the Gawib River system, which has its catch-

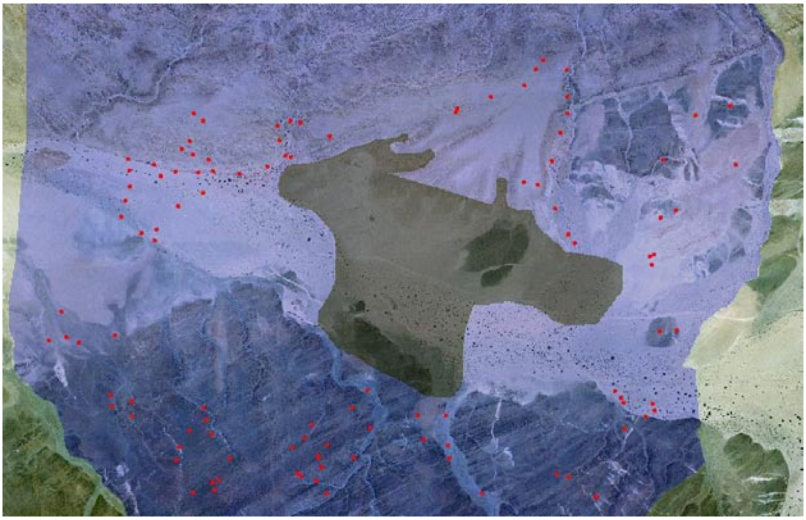

Figure 1: *Outline of the study area (blue overlay) around the approximate current mining area (black overlay). Also indicated are the actual survey sites of the vegetation survey (red dots).*

ment eastwards up to the Tinkas watershed. To the west of the study area the Gawib River opens up and drains in a northerly direction into the Swakop River. To the north, the study area is bordered by moderate to steep slopes of quartzite boulders of the Langer Heinrich Mountain, and also conglomerate deposits of old valley-fills. To the south, the Gawib River is bordered by biotite schist outcrops and ridges of the Schieferberg. Several tributaries reach the Gawib River within this short stretch from both northern and southern slopes. The river valley itself is a mixture between floodplains and deep sandy flood channels. The distribution of vegetation is strongly influenced by topography – steepness and aspect of the substrate. Surface texture – understood here as size and amount of boulders, pebbles and gravel as well as the physical nature of the substrate (geology) further determine soil type and depth and its moisture regime, and thus also the types and number of micro-habitats available for plant establishment.

Previous Work

A vegetation survey of the mining area was conducted during the original EIA in 2004 (Friend 2005). Vegetation was not as abundant during that period as during the current survey. For the current study area, only 8 broader plant communities could be described and delineated during the EIA. This already highlighted the higher species diversity of the northern slopes, but information to guide decisions on dumping sites on the southern slopes was limited.

Prior to the EIA, several studies had been conducted in the Central Namib Desert, but little of this information was available on the current study area. Popular floristic guides on the flora of the Namib Desert have been published (e.g. Burke 2003), but these only list the most conspicuous and/or commonly found species, without specific information on locality. Robinson (1976) described several communities for the Central Namib, but never produced a vegetation map or any detail of the localities of his vegetation types, nor is his original data available. Hachfeld (1996, 2000) did an extensive, but low-density survey of vegetation throughout the Central Namib. Her data is available from the NBRI, but only 2 of her relevés fall within the current study area – both of the riverine vegetation. Nel (1983) studied the availability and quality of fodder on the plains of the Central Namib, including the study area. He also provides a very rough description of the vegetation types of the Central Namib, in which he classifies the entire study area as part of the *Stipagrostis hirtigluma* plateau-edge and inselbergs. He further stated that this area was an important habitat for mountain zebra, while oryx, kudu, springbuck and ostrich occurred sporadically.

For the immediate purpose of providing a more accurate decision-making tool to guide the selection of sites for a new tailings facility, as well as rock-dumps, there was thus a clear deficit of available vegetation data.

Materials and Methods

Field Survey

Surveys were conducted according to the Braun-Blanquet approach (Mueller-Dombois and Ellenberger, 1974). A total of 110 sites were surveyed each comprising of a 20 x 25 m plot randomly selected across different terrains within the study area. For each site the estimated canopy cover of all species was recorded, also paying attention to the different layers (height-classes) of the species. Additionally, notes were taken on abiotic characteristics that could have a major influence on species survival or distribution, e.g. slope and substrate. These notes were used to derive the major habitat types. Specimens were collected for the majority of the plant species, to verify their identification. For every survey site a GPS reading was recorded, and a representative photo taken. The actual data derived from a survey site and used further for data analysis is referred to as a relevé.

Identification

Specimens were identified at the National Botanical Research Institute (NBRI) of Namibia, following the NBRI's latest use of nomenclature. The entire collection was submitted to the NBRI. Common names, where available, were derived from Burke (2003), Coates Palgrave (2002) and Klaassen and Craven (2003).

Mapping and GIS

Landsat images for the area from April 2000 and April 2005 were supplied by the Ministry of Agriculture, Water and Forestry. These images have a resolution of 30 x 30 m, which is relatively coarse for the small study area. Both images were segmented into polygons with similar reflectance, using the Definiens (e-Cognition) software. The Landsat image from 2000 appeared to yield the more realistic segmentation, as the 1999/2000 rainfall season was also relatively good in the area (Hachfeld 2000). Next, the locations of all survey sites were projected onto these segments, assigning each site to its respective association or community. The aim of a supervised classification of a satellite image is that it uses the reflectance-values of these sample sites (each assigned to a specific habitat-, vegetation- or community-type) to then classify segments with similar reflectance values as the. However, due to the very high level of ground reflectance and low resolution, no satisfactory image classification could be obtained, and could not be used further for this study. Such classification, in particular for a desert environment with a complex landscape but sparse vegetation, is best done when the image is taken as close as possible to the ground survey. Images with a higher resolution will be more suitable.

Thus, to map the approximate outline of the communities studied, a high resolution aerial photograph was used. The survey sites were projected onto this image. Based on observations during the survey, approximate outlines of the plant communities were digitised by hand, using Arc View. This approach was only possible due to the small size of the study area and the relatively detailed survey thereof, it will not be possible to map a larger area with such methodology.

For database purposes, the GPS positions of all survey sites, as well as a photo of all survey sites were submitted to the GIS specialist.

Data analysis

All data was entered into TurboVeg (Hennekens 1996, Hennekens and Schaminée 2001), which is used as a database by most larger botanical research institutes throughout the world, including the Namibian National Vegetation Survey of the NBRI (Strohbach 2001, and available from the NBRI). From there, data was exported to Juice (Tichý 2002), and classified using weighted TWINSPAN divisive clustering. Vegetation units are most commonly described as associations, which can be further divided into communities. Such associations and communities are defined based on a group of species of which at least 50% occur in every relevé belonging to that community or association. It may, however, also occur that within an association a community is defined in which a group of species it totally absent. Associations usually contain one to several differential species that are either totally absent or at the most present in low numbers in less than 20% of the relevés not allocated to that association (Barbour *et al.* 1999). Thus, some species are common throughout a study area, whilst other species do occur throughout the study area as well, but are typically denser and vigorous in certain habitats, one such example is *Commiphora saxicola*. Other species may be entirely restricted to a specific substrate or habitat, e.g. *Aloe namibensis* or *Acacia erioloba*, whilst other species may be restricted to a specific type of habitat, but variable geology, e.g. *Euphorbia virosa*, found on both schist and quartzite slopes.

Conservation status of species was derived from Craven *et al.* (1999), Gibbs Russell *et.al.* (1990), Golding (2002) and Loots (2005).

Results

Description of the different habitats

Habitats were identified from the vegetation perspective, paying attention to type and depth of soil, surface texture (size and amount of stoniness), niche availability and inferred moisture retention capability of the larger area. Within habitats, slope and aspect of the slope will create many more micro-habitats and niches. The approximate delineation of these habitats is shown in Figure 2.

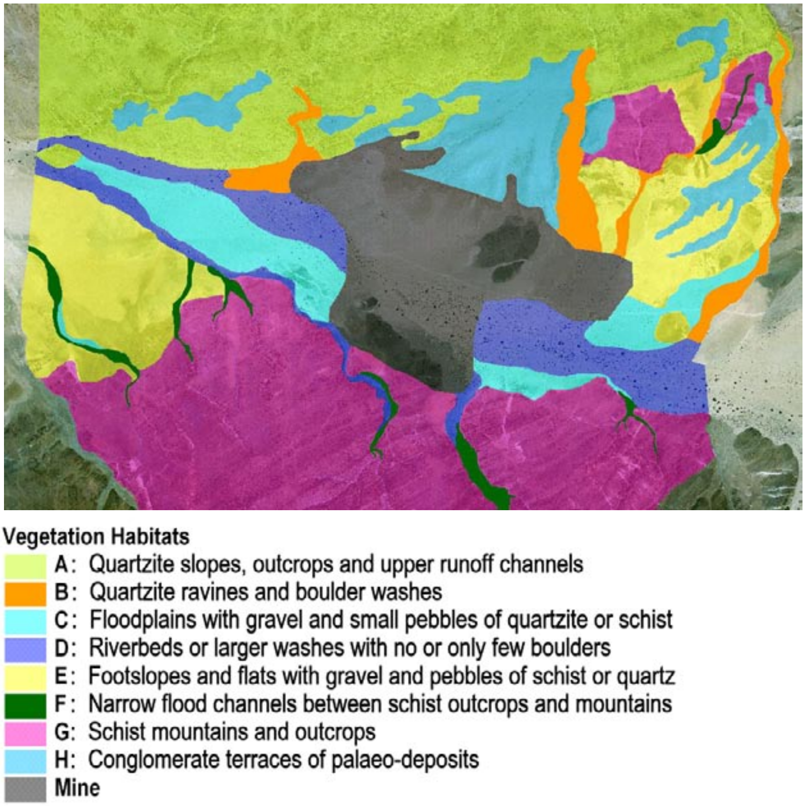

Figure 2: *Approximate delineation of the different vegetation habitats identified.*

A: Slopes, outcrops and runoff channels on quartzite

Location: bordering the Gawib River to the northwest of the current mining area, and then extending north and east as part of the Langer Heinrich Mountain.

This habitat has a relatively steep but varied topography with a very coarse surface texture, ranging from rock faces and boulders to pebbles and gravel. Accordingly, soil depth is very varied. Soils here accumulate in pockets on shallower areas and in runoff channels or rock-crevices. Similarly, moisture from occasional precipitation events will accumulate in crevices, runoff channels and soil pockets, where it may be protected from evaporation for considerable periods. Hence these slopes offer a wide variety of niches for plants to become established. Despite sporadic rainfall events, the moisture regime is relatively favourable, as can be seen in the high diversity of perennial plant species present on these slopes. Seeds of ephemeral species will also accumulate here, but will only grow for a short while after sufficient rains.

B: Ravines and boulder washes on quartzite
Location: northwest and northeast of the current mining area, towards and just below runoff channels from the Langer Heinrich Mountain.

The deep ravines channel vast amounts of runoff from the Langer Heinrich Mountain after large rainfall events, occasionally also with eroded material (boulders, sand), which are deposited just below the ravines in broad washes that drain into the Gawib River channel itself. The ravines are relatively narrow and steep, protecting water from rapid evaporation and thus helping maintain surface water for variable periods of time after a rainfall event. Seepage of water into the lower sandy soil-layers and rock crevices enables the persistence of species such as *Ficus cordata* (rock fig), which prefer to grow near water. Likewise, a favourable water regime in the boulder washes creates a habitat for a high diversity of shrubby perennial vegetation, which is complemented by an equally high diversity of ephemeral plant species after rainfall events. This habitat is most likely an important resource area for fauna as well.

C: Gravelly floodplains with mixed substrate
Location: in discontinuous patches adjacent and between the active flood channel of the Gawib River, spanning from east to the west of the core mining area.

The floodplains will only be flooded during extreme rainfall events. Soil depth and material is variable, but is covered with a 'spongy' mulch of gravel. These floodplains do not have a very favourable moisture regime, as can be seen from the low and patchy density of perennial vegetation. However, these plains can absorb quite a bit of moisture during rainfall events due to the porosity of the upper soil. Accordingly, dense stands of ephemeral vegetation can establish on these floodplains after rains, and their seeds get trapped in the soft sands between the gravel. Loss of this functionality due to compaction by vehicles (Figure 3) will result in more rapid runoff and thus loss of moisture and vegetation from the ecosystem.

Figure 3: *Excessive tracks on the gravelly floodplains. In all areas that fall outside the ore deposits, such tracks must be kept to an absolute minimum.*

D: Flood channels of the Gawib River
Location: wider, meandering river channels originating east of the mine, larger tributaries from north and south of the current mine, and running through the mine to continue westwards.

The soils are deep coarse sands, occasionally with a high amount of gravel. These sands absorb moisture quickly, and can retain a substantial amount of moisture in the deeper layers, while a large amount of moisture will seep into the groundwater. Within a desert-environment, this is the portion of the Gawib system with the most favourable moisture regime, enabling the establishment and persistence of large trees. The above-ground distribution of these trees appears sparse; however, their below-ground root systems occupy a soil and water reserve far exceeding their canopy area. These trees and associated shrubs create ‘islands of fertility’ in the desert, providing a suitable habitat for numerous other plants, accumulating sparse litter and thus also creating a rich environment for various types of fauna. Apart from that, the extensive root systems of the vegetation here stabilises the soils to some degree, and acting as a trap for more soils as well as seeds and debris from higher up, which would otherwise be lost from the system. Although these flood channels are very dynamic and can change drastically after a flood-event, the creation of this habitat – accumulation of eroded sands and the slow growth of the large trees – means that this habitat may be one of the most difficult to recreate without at least conserving every possible patch and storing the sandy soils of areas that will be excavated in future.

E: Gravel footslopes and associated small, shallow washes
Location: below eroded conglomerate terraces north-east of the mine, also in discontinuous patches just north of the schist outcrops of the Schieferberg west of the current mine.

The soils are relatively shallow, of mixed substrate, and covered with a dense layer of gravel and coarser pebbles. The steeper the slopes, the more gully erosion occurs; this is most conspicuous towards the east of the current mine. This is not a very favourable habitat for plant life. Perennial plants are concentrated towards the shallow washes, while the remainder of the footslopes only has a low diversity of short-lived ephemeral vegetation.

F: Narrow flood channels between the schist outcrops of the Schieferberg
Location: major tributaries of the Gawib river coming from the schist outcrops south and southwest of the current mine area.

Soils are fine-grained and thus dry out more rapidly, whilst soil depth varies between boulders and pebbles present in the flood channel. Moisture retention is thus much lower than in the Gawib river itself, which is reflected in the smaller size of trees found here (although they may be of equal age as in the Gawib River). However, this habitat is suitable for the low shrubs that are found in high densities in these tributaries. These shrubs again accumulate a lot of seeds and debris. Frequently observed and relatively fresh tracks of larger mammals indicate that these tributaries may be important corridors for animal movement.

G: Schist slopes, ridges and steeper runoff channels
Location: this is the Schieferberg south of the current mining areas, as well as smaller schist outcrops northeast of the mine.

Soils are generally very shallow and fine-grained, unable to retain much moisture. The surface texture is as rough and varied as the quartzite slopes (habitat A), yet the physical nature of the schist does not allow the same amount of water-accumulation, making this a much drier environment. Added to this, the dark colour of the substrate absorbs much more light-energy, leading to higher surface temperatures, which negatively impact on plant life. Not surprisingly, most perennial vegetation is concentrated towards steeper slopes and runoff channels, with single individuals present on the exposed, flatter ridges. Most of the perennial vegetation here has an ability to store water in their thick, fibrous or succulent stems. A high density of short-lived ephemeral plants may establish after sufficient rains, otherwise these outcrops are relatively bare.

H: Conglomerate terraces as remnants of old valley-fill deposits
Location: these occur in pockets south of the Langer Heinrich Mountain, directly north and northeast of the current mine pit. Some remnants of this deposit can also be found on top of the lower quartzite ridges northwest of the mine.

Soils are relatively shallow, occasionally small pockets of wind-blown sand do occur and support a denser stand of grasses. Typical is a large amount of quartz pebbles, under which fenster-algae can be found. Perennial vegetation is sparse and more concentrated towards the upper ends of runoff channels (which erode away lower down to expose quartzite slopes). A low and patchy but relatively stable grass layer is present on these ‘plateaus’, which may explain the high number of animal paths on these areas.

Overview of plant communities
An overview of the different plant communities, their associations and their habitats is given in Table 1. In addition, the conservation status and sensitivity rating of the different plant communities is also listed, according to the amount of species recorded, the conservation status of those species as well as their rate of establishment and growth until they reach sizes presently observed. For each species, more details are given in Appendix 1.

Table 1: *Overview of habitats and the plant associations and communities found in the current Langer Heinrich Core Area.*

Habitat	Description	Vegetation association	Community	Conservation status	Notes
A	Quartzite slopes, outcrops and upper runoff channels	*Monechma cleomoides – Hermannia helianthemum* sparse shrublands	1: *Commiphora* species *– Aptosimum lineare* quartzite slopes	86 species recorded 1 vulnerable endemic species 4 protected species 27 endemic species	many slow-growing shrubs many suitable niches for continued regeneration and persistence of plant populations **Sensitivity: 4**
B	Quartzite ravines and boulder washes		2: *Sterculia africana – Enneapogon scoparius* ravines	69 species recorded 3 protected species 22 endemic species	slow-growing shrubs and trees high potential for water to accumulate and remain available for the ecosystem for prolonged periods after a rainfall event **Sensitivity: 4**
			3: *Petalidium variabile – Stipagrostis hochstetteriana* boulder washes	112 species recorded 1 vulnerable endemic species 6 protected species 36 endemic species	community with highest species diversity many slow-growing trees and shrubs dynamic system, but with many suitable niches for continued regeneration of perennial and annual vegetation facilitates re-distribution and storage of runoff from higher areas **Sensitivity: 4**
C	Floodplains with gravel and small pebbles of quartzite or schist	*Calicorema capitata – Hermannia solaniflora* sparse shrublands with low trees	4: *Salsola tuberculata – Stipagrostis obtusa* gravel plains	36 species recorded 2 protected species 12 endemic species	relatively dynamic system, many annual species compaction of the topsoil by vehicle tracks will reduce infiltration of water, leading to a loss of water from the system during scare rainfall events, whilst accelerating erosion in adjacent river channels **Sensitivity: 2**

Habitat	Description	Vegetation association	Community	Conservation status	Notes
D	wider and relatively level riverbeds / washes with no or only few boulders		5: *Acacia erioloba – Zygophyllum stapffii* washes with sand and gravel	44 species recorded 1 protected species 16 endemic species	relatively dynamic system slow-growing trees facilitates re-distribution and storage of runoff from higher areas **compaction of topsoil by vehicle tracks should be avoided or minimised** **washes off schist mountains may not be blocked off** **Sensitivity: 3**
			6: *Acacia erioloba – Stipagrostis damarensis* sandy washes	82 species recorded 3 protected species 26 endemic species	many large specimens of very slow-growing trees relatively dynamic system, depends on run-on and seepage of moisture from higher-lying areas for continued function **identify areas that must be mined and restrict impact to those areas, retain key patches intact** **Sensitivity: 3**
E	footslopes and flats with gravel and pebbles of schist or quartz	*Stipagrostis obtusa – Aizoanthemum rehmannii* sparse grasslands	7: *Zygophyllum simplex – Monechma desertorum* schist footslopes	29 species recorded 12 endemic species	very dynamic system – mainly annual species relatively wide occurrence of species within Central Namib **Sensitivity: 1**
			8: *Adenolobus pechuelii – Commiphora saxicola* quartzite footslopes and small washes	44 species recorded 2 protected species 16 endemic species	relatively dynamic system, mostly annual species with low/patchy distribution of slow-growing shrubs most species should be able to regenerate fairly quickly from stored topsoil **Slow-growing shrubs and protected species should be relocated should the area be used for mining activities** **Sensitivity: 2**

Habitat	Description	Vegetation association	Community	Conservation status	Notes
F	narrow flood channels between schist outcrops and mountains, with schist gravel and/or boulders	*Zygophyllum stapffii – Sesamum marlothii* riverine shrublands	9: *Zygophyllum stapffii – Sesamum marlothii* riverine shrublands	50 species recorded 1 protected species 17 endemic species	very dynamic system important link of runoff from higher areas transported to lower-lying areas **Sensitivity: 3**
G	schist mountains and outcrops – upper ridges/rests and shallower slopes	*Trianthema triquetra – Stipagrostis hirtigluma* sparse grasslands	10: *Enneapogon desvauxii – Euphorbia phylloclada* schist ridges	31 species recorded 3 protected species 13 endemic species	dynamic system of annual species with solitary specimens of unique succulents and shrubs **Solitary succulents and shrubs can be relocated** **Sensitivity: 1**
			11: *Petalidium canescens – Commiphora saxicola* schist slopes and small runoff channels	41 species recorded 1 protected species 16 endemic species	perennial vegetation mostly clustered around upper and steeper edges of runoff channels good regeneration of *Commiphora saxicola* noted **Use of the area should exclude the higher edges of runoff channels, or should be restricted to one area only, and specimens relocated** **Sensitivity: 2**
H	Conglomerate terraces of palaeo-deposits		12: *Eragrostis nindensis – Trianthema triquetra* conglomerate flats and upper slopes	40 species recorded 1 protected species 12 endemic species	very dynamic and patchy system steeper areas are prone to gully erosion and have lowest sensitivity flatter areas create runoff that is collected in the more diverse upper quartzite runoff channels **Disturbance should be limited to the outer slopes of the system, else restricted to one part of the system, relocating the shrubs that are found on areas where runoff collects** ***Eragrostis nindensis* can be an important fodder plant during periods of prolonged drought** **Sensitivity: 2**

Sensitivity ratings:
1: least sensitive or of least concern
2: sensitive – mitigation measures to be implemented
3: highly sensitive – minimise disturbance as far as possible
4: NO GO area – very high conservation and ecological value

Explanation of sensitivity ratings used
Four sensitivity categories have been used, and are defined as follows:

1: Least sensitive or of least concern
Criteria: relatively low availability of niches that are favourable for plant persistence, overall low species diversity, dominated by ephemeral plants, few or no perennial plants, and the habitat or growth conditions can be re-created to some degree, low conservation status. In addition, loss of such areas will not have a major detrimental impact on the functionality of surrounding ecosystem components.

Management implications: areas where such communities occur should be looked at first as sites for permanent dumps. It may be possible to re-create some ecological functionality of such dumps by landscaping and matching soil surface conditions to resemble the original. The area will need to be scouted prior to preparation for dumping, to remove perennial plants where necessary, possibly also look for bulbous plants on lower-lying areas by searching through topsoil.

2: Sensitive – mitigation measures need to be implemented
Criteria: moderate but patchy availability of niches suitable for plant persistence, moderate species diversity, may be very patchy due to a localised amount of suitable niches, low conservation status, but the available niches will be difficult or impossible to re-create.

Management implications: most of the areas where such communities occur are adjacent to areas that are more sensitive. Should such area be needed for mining operations, efforts should be made to utilise only some of these areas so that similar areas are made available as habitat for transplanted plants. Ideally, planning should be done for the entire life-of-mine, before such areas are sacrificed. This will ensure that the smallest area possible is sacrificed.

3: Highly sensitive – minimise disturbance as far as possible
Criteria: high diversity and number of plant-favourable niches, moderate to high species diversity, moderate conservation status. Many very slow-growing trees and shrubs are present in these areas. Habitat difficult to recreate once disturbed unless properly planned. Further, some aspects of this community play a central role within the entire Gawib ecosystem.

Management implications: Disturbance should only be allowed in these areas, where absolutely necessary, in this case only if sufficient ore has been identified below such communities. Even then, disturbance should be kept to a minimum. Key areas, e.g. patches of relatively dense trees should be demarcated as definite no-go areas, which should also not be disturbed by vehicle tracks or other side-line mining activities (e.g. construction of buildings). If these areas are disturbed, some patches must be left intact and sufficient amounts of topsoil should be stored from disturbed areas. Research on the regeneration and establishment potential of plants species affected shall need to be initiated as soon as possible to assist with restoration planning.

4: NO GO area – very high conservation and ecological value
Criteria: high species diversity, high conservation status, availability of many diverse niches for fauna and flora, habitat difficult or impossible to re-create once disturbed.

Management implications: areas where these communities are found occur on the absolute fringes of ore body and outside the ore deposits. There is thus no justification to disturb these sites. This also means that vehicle tracks and any kind of pollution must be prevented and possible impacts from slow-falling dust after blasts are minimised.

Description of Plant Communities
Below follows a brief description of the communities found within the eight habitat types described and discussed above. The descriptions focus on species differentiating the individual communities. A detailed synoptic table listing all species of each community, as well as their frequency within a community and their fidelity value (indicating ecological significance) is given in the Appendix, together with a summary of this synoptic table, listing the constant and dominant species for each community. This list thus also provides an insight into other species commonly found in each community, which may also be common throughout the study area. The approximate delineation of the communities is shown in Figure 4.

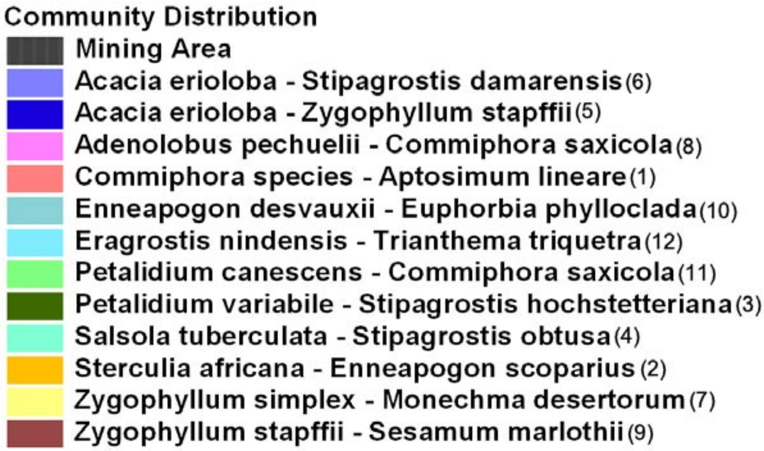

Figure 4: Distribution of the different plant communities identified from the survey data.

The *Monechma cleomoides – Hermannia helianthemum* association is subdivided into communities 1, 2 and 3 that occur on rough quartzite substrates. These communities consist of very patchily distributed low trees, higher shrubs as well as a large diversity of low semi-woody (suffrutex) shrubs. Total diversity will vary according to available moisture every year, trees and shrubs are complemented with a wide variety of short-lived perennial forbs as well as several ephemeral herbs.

2004 EIA: Communities 1, 2 and 3 were included in the *Commiphora* species – *Peliostomum viscosum*, and *Calicorema capitata – Monechma cleomoides* communities in the previous EIA.

1: *Commiphora* species – *Aptosimum lineare* community

The quartzite slopes and ridges (habitat A) to the northwest of the current mine, and extending east as part of the Langer Heinrich Mountain slopes, support a very high diversity of plants, also many perennial species. The most significant and well represented species found here is the succulent *Aloe namibensis* (Namib Aloe), which is endemic to the Central Namib, and regarded as vulnerable. The community is typified by many large specimens of *Commiphora glaucescens* (blue-leaved Commiphora), *Commiphora virgata* (slender or twiggy corkwood), and occasional specimens of *Sterculia africana* (tick tree), all low trees or shrubs with swollen, fibrous stems that can store water.

Other shrubs include *Boscia foetida* (smelly shepherd's tree) and *Euphorbia guerichiana* (paper-bark woody Euphorbia). A fair amount of nutritious grasses such as *Antephora pubescens* (wool grass), *Eragrostis nindensis* (eight-day love grass) and *Stipagrostis ciliata* (tall bushman grass) can be found on the slopes. Also conspicuous is the high diversity of sub-shrubs, most conspicuous are *Aptosimum lineare, Monechma cleomoides* (Namib perdebos), *Hermannia helianthemum, Petalidium variabile* (variable Petalidium)*, Tephrosia monophylla* (single-leaved Tephrosia)*, Barleria lancifolia* (blue Barleria) and *Zygophyllum cylindrifolium.*
The composition and density of plants in this community at specific sites is very variable, depending largely on the steepness and aspect of the slope. The overall high species diversity, as well as high number of endemic and protected species present, renders this community the highest sensitivity rating: 4.

2: *Sterculia africana – Enneapogon scoparius* community

Short but steep and narrow ravines (habitat B) have been eroded into the quartzite just north-west and northeast of the current mining area. Although these areas are relatively small, the short term availability of surface water in perched rock-pools, as well as a significant amount of subsurface moisture, makes these rather unique microhabitats for both flora and fauna. Here we find the rock fig, *Ficus cordata*, which will not be able to establish in any other habitat in the desert, as well as delicate herbs such as *Jamesbrittenia* species, and the sub-shrubs *Abutilon pycnodon, Camptoloma rotundifolium, Amphiasma divaricatum, Anticharis imbricata, Barleria merxmuelleri* and *Dyerophytum africanum* (desert statice). Further characteristic low trees are *Sterculia africana (tick tree)* and *Commiphora glaucescens*. Palatable perennial grasses found here are *Antephora pubescens* and *Enneapogon scoparius* (bottle-brush grass).
Similar to community 1, this community gets a sensitivity rating of 4, attributed to its high species diversity, high number of endemic species and uniqueness of habitat within a desert environment.

3: *Petalidium variabile – Stipagrostis hochstetteriana* community

Wherever occasional, fast-flowing floodwaters discharge onto more level ground below ravines or quartz slopes, they have also, over time, deposited large round boulders and deep sands (habitat B). This community is then found just below community 2 described above, as well as in the washes between the schist outcrops northeast of the mine. It is characterised by a high but variable density of high shrubs such as *Calicorema capitata* (grey desert-brush), *Commiphora virgata* and *C. glaucescens*, *Boscia foetida* and the sub-shrubs *Monechma cleomoides, Ruellia diversifolia, Asparagus pearsonii, Hermannia helianthemum, Petalidium variabile* and *Tephrosia monophylla*. *Stipagrostis ciliata* and *Stipagrostis hochstetteriana* (Gemsbuck tail grass) are common perennial grasses. These washes also host a wide variety of ruderal (weedy) annual species, of which the composition and density will change every year, according to rainfall events.

In these washes, the large boulders prevent perennial species from being washed away by flash-floods, whilst also trapping a large amount of debris and seed-material. It is thus not surprising that this community had the highest species diversity, including the highest number of endemic species. Although this community will be very dynamic – easily changed by occasional flash-floods, very patchy plant distribution and very variable amount and density of annual plants – it remains a very important source area for seeds to be trapped, regenerated and re-distributed. This community thus has a sensitivity rating of 4, and all available patches of this community should be preserved as far as is possible.

The *Calicorema capitata – Hermannia solaniflora* association is subdivided into the communities 4, 5 and 6 that are found on open floodplains and flood channels of the Gawib River itself.
2004 EIA: communities 4, 5 and 6 were incorporated into the *Calicorema capitata – Zygophyllum stapffii* rocky river terraces, *Calicorema capitata – Monechma cleomoides* washes and *Acacia erioloba – Stipagrostis damarensis* (referred to as *S. namaquensis*) riverbeds. Although the descriptions are very similar, these communities could be described and regrouped more efficiently, thus also changing the delineation of occurrence.

4: *Salsola tuberculata – Stipagrostis obtusa* community

This community is restricted to the floodplains (habitat C) adjacent to the sandy flood channel of the Gawib River. The most constant shrubs here are *Calicorema capitata* and *Salsola tuberculata*, with occasional stands of the grass *Stipagrostis ciliata*. After sufficient rains, as during the survey, a high number and density of annual plants can be found here, most commonly the grass *Stipagrostis obtusa* (small bushman grass) as dominant species, interspersed by *Stipagrostis hirtigluma* subsp. *hirtigluma* (Bloutwa), and the herbs *Hermannia solaniflora, Heliotropium oliveranum, Helichrysum candolleanum* and *Sesuvium sesuvioides* (desert pink). Occasionally *Acacia erioloba* (Camelthorn) or the shrub *Commiphora saxicola* (rock corkwood) can be found here.
Overall species diversity is relatively low, but may vary dramatically between seasons. Yet it remains an important albeit temporary resource area for fauna, whilst also not being isolated in its functionality within the ecosystems (see habitat description), thus has a sensitivity rating of 2.

5: ***Acacia erioloba – Zygophyllum stapffii*** **community**

This community is found on the lower, wider tributaries to the Gawib River, often with a fair amount of schist gravel and fine schist-derived soils, south and west of the current mine (habitat D). *Acacia erioloba* is a conspicuous but sparse tree here, but usually much smaller than their counterparts in community 6. The community is also characterised by low to moderate density of the shrubs *Calicorema capitata* and *Zygophyllum stapffii* (dollar bush), with the latter often becoming dominant, and moderate stands of the perennial grasses *Stipagrostis schaeferi* and *S. ciliata*. Further, a variety of ruderal annual species may be found, their density and diversity changing every year.

Although species diversity is moderate, this community forms an important link between upstream runoff of water and seeds, and lower-down resource deposition. Where this community occurs on the lower fringes of the tributaries off Schieferberg just south of the mine, many tracks of animals have been observed, thus also emphasizing that these 'resource pathways' should not be cut off by mining activities, and thus has been given a sensitivity rating of 3. West of the mine, *Acacia erioloba* trees are bigger and denser, but will probably make way for excavations in the future. Here it would be desirable to store adequate topsoil, to enable a habitat re-creation and gradual regeneration after mine closure, fed by runoff from higher-lying areas.

6: *Acacia erioloba – Stipagrostis damarensis* community

This community is found on the deep sands that have accumulated in the flood channel of the Gawib River (habitat D). The most conspicuous element of this community are large trees of *Acacia erioloba*, in varying density, also with *Maerua schinzii* (ringwood tree), *Euclea pseudebenus* (false ebony), *Parkinsonia africana* (green hair thorn) and the waxy-leaved shrub *Salvadora persica* (mustard tree). *Stipagrostis damarensis*, as well as *S. schaeferi* and *S. ciliata* are the most important perennial grasses, whilst the annual grass *Brachiaria glomerata* is also characteristic of this community. The above perennial species are the most constant feature, but are complemented by several other shrubby and many herbaceous species. The density and species composition of this community varies enormously, and will also do so from year to year, but species diversity is relatively high, with a large number of endemic species as well.

The community has a sensitivity rating of 3, as most of the tree species present here depend on the deep soils and moisture regime only found here, to be able to grow vigorously. Also, many of these large trees are most likely hundreds of years old, meaning that should all of this habitat be destroyed, it will be almost impossible to re-create it. These large trees also create important micro-habitats for an array of other plant species, accumulate litter and also create a special habitat and resource for a variety of fauna. Unfortunately a large expanse of this community occurs exactly over the ore, which means that all patches of this community that fall just on the outer fringe or outside the identified ore body (e.g. adjoining the quartzite ridges northwest of the mine), should be strictly protected and treated as a sensitivity 4 zone.

It will also be imperative that topsoil of this community be stored, otherwise re-creation of the habitat may be impossible. During a survey a fair number of seedlings of *Acacia erioloba* were observed, together with many seedlings of other low shrubs. It would be useful for future habitat re-creation to select some sites with such seedlings, permanently demarcate the area and monitor the progress and/or survival of these seedlings over the coming years.

The *Stipagrostis obtusa – Aizoanthemum rehmannii* association is subdivided into communities 7 and 8 that grow on low gravelly footslopes. Gravels are schist, quartz or quartzite (habitat E).
2004 EIA: These communities were incorporated into the *Calicorema capitata – Monechma cleomoides* washes and schist and quartz gravelly footslopes and terraces in the previous EIA.

7: *Zygophyllum simplex* - *Monechma desertorum* community

This community is most prominent on the low undulating plains off the schist outcrops west of the mine, south of the Gawib River. Smaller patches of this community occur east of the mine as well, and may extend further east into the mining area (to be surveyed during Phase 2). Only very few and sparse perennial shrubs occur, such as *Commiphora saxicola* and *Calicorema capitata*. The bulk of the plant species found here are short-lived ephemerals. The grasses *Stipagrostis ciliata* and *S. hirtigluma* subsp *hirtigluma* are often the dominant species during favourable seasons. The most conspicuous of these ephemerals is *Aizoanthemum rehmannii*, *Sesuvium sesuvioides, Monechma desertorum* and *Euphorbia phylloclada*. A fair number of remnants of bulbous geophytes have been observed here, but species could not be identified. Overall species diversity is, relative to the study area, very low, but needs further studies to identify the geophytes. During dry years these low footslopes may remain bare.
This is one of the few communities with a sensitivity rating of 1. However, it would be advisable to remove at least some portion of the topsoil (about 25-30 cm) prior to any dumping, and remove bulbs from this topsoil. Bulbs can easily be grown in a nursery for later relocation, and this will also provide ample opportunity to properly identify them, as geophytes are in general poorly studied in Namibia.

8: *Adenolobus pechuelii – Commiphora saxicola* community

This community is found most prominently on the gravelly slopes and small washes of eroded conglomerate deposits northeast of the mine. *Commiphora saxicola* and *Zygophyllum stapffii* are relatively common, albeit in low densities. The low shrub *Adenolobus pechuelii* (Namib neat's-foot), with its conspicuous yellow flowers and red pods is indicative of this community. A high number of seedlings of this shrub show that it should be possible to regenerate fair stands of this species from seeds. The sub-shrub *Monechma cleomoides* as well as the larger *Calicorema capitata* are further characteristic features, although more concentrated along drainage lines. The remainder of the species is mostly annual species, of which the grass *S. hirtigluma* subsp *hirtigluma* may become dominant during favourable seasons.

Species diversity is moderate, but may be very patchy and vary extremely during years. This community has been given a sensitivity rating 2, where slower-growing perennial vegetation can be relocated to other locations and even other habitats where necessary.

9: The *Zygophyllum stapffii – Sesamum marlothii* association

This association is not further divided and thus listed as community 9. These dense riverine shrublands prefer the narrow runoff channels between schist outcrops flowing into the Gawib River from the Schieferberg (habitat F), as well as from small schist outcrops northeast of the mine.

2004 EIA: This community has been incorporated into the *Calicorema capitata – Monechma cleomoides* washes and *Calicorema capitata – Zygophyllum stapffii* rocky river terraces.

Both the shrubs *Calicorema capitata* and *Zygophyllum stapffii* form the dominant part of this vegetation, often reaching a high density and surface cover. *Stipagrostis hirtigluma* subsp *hirtigluma* may be equally common during favourable seasons. Common sub-shrubs are *Anticharis imbricata, Petalidium canescens* and *Tephrosia dregeana*. Common herbs include *Euphorbia phylloclada, Sesamum marlothii* (with its large pink flowers) and *Zygophyllum simplex*.

Species diversity is moderate, yet patchy and variable between seasons. The finer-grained soils do not offer a very favourable moisture regime, yet this community may receive a high amount of runoff from surrounding slopes. Also, this narrow riverine environment often extends far south of the mining lease area, and are thus an important resource link and channel through the larger ecosystem. Testimony to this are the frequent fresh tracks of mammals found in these channels. The sensitivity rating of 3 indicates that development in these areas should be avoided as far as possible. The channels may not be blocked off, and natural flow of resources to the Gawib River itself should be restored after mine closure.

The *Trianthema triquetra – Stipagrostis hirtigluma* association is subdivided into communities 10, 11 and 12, occurring on the rocky surfaces of the schist outcrops and the conglomerate terraces. Perennial shrubs are concentrated towards steeper slopes or runoff channels, while the remainder of the ridges are covered with sparse grasslands, and may be relatively bare during the dry season.
2004 EIA: These communities had been incorporated into the *Salsola tuberculata* limestone outcrops and flats and *Petalidium setosum* schist outcrops and hills.

10: *Enneapogon desvauxii – Euphorbia phylloclada* community

This community is found on the upper and usually flatter schist ridges of the northern parts of the Schieferberg (habitat G), thus south of the mine. Solitary stem succulents *Hoodia currorii* (Namib Hoodia) and *Euphorbia virosa* (large milk bush) can be found, whilst occasional shrubs of *Euphorbia guerichiana* and *Commiphora saxicola* are also present. However, most of the vegetation is made up of short-lived ephemerals, of which *Stipagrostis hirtigluma subsp hirtigluma* often forms the dominant layer, with patches of *S. ciliata*. The succulent herb *Trianthema triquetra* are a common feature on these ridges, as are *Euphorbia phylloclada* and *Pegolettia senegalensis*.
Within the context of this study, the species diversity of this community is low, affording it a sensitivity rating of 1. However, not all of this community is expendable, as it is situated on an important runoff area, on which community 11 depends.

11: *Petalidium canescens – Commiphora saxicola* community

The presence of this community on the Schieferberg (habitat G) is dictated to a very large extend by topographical features such as steeper slopes, aspect of slope as well as runoff channels. The densest patches of this community are found in the upper edges of the runoff channels, where more water collects. The most conspicuous species here is the shrub *Commiphora saxicola*, of which numerous young individuals have been observed, as well as specimens with a considerable amount of fruit. Another common shrub is *Cryptolepis decidua*. The *sub-shrub*s *Anticharis imbricata*, *Petalidium cansecens, Psilocaulon salicornioides* and *Tephrosia dregeana* are common, occasionally in higher densities. *Stipagrostis* species often form the dominant layer of the vegetation, but during dry seasons only patches of *Stipagrostis uniplumis* and *S. ciliata* may remain.

Species diversity is moderate but highly patchy, yet should be awarded a sensitivity rating of 2. Together with community 10, the best new sacrificial area for mine dumps will be between the water reservoirs and the current telephone line. Several perennial shrubs and succulents that occur here as part of these communities can be relocated.

Warning: Should large, much-branched specimens of *Euphorbia virosa* occur on a selected sacrificial area, it is advised NOT to remove these specimens. Sacrificing these specimens will not endanger the survival of the species in any way, however, *Euphorbia virosa* is known as the most poisonous of the Euphorbia's. Its milky latex is severely caustic and may cause severe wounds and flows readily as the plant is injured; people have already died after using the wood of such dead plants for a barbeque. Attempts can be made to try and relocate the shrubby *Euphorbia guerichiana* and *Commiphora* species, whilst *Hoodia* species should be easy to relocate.

12: *Eragrostis nindensis – Trianthema triquetra* community

This community is most prominent on top of the conglomerates of the old valley fill deposits overlying various outcrops north and northeast of the current mining area (habitat H). These relatively level areas are rather exposed and have only few patches where water does accumulate, providing a relatively harsh environment. This is reflected in the very sparse shrubby vegetation present, mostly of the species *Salsola tuberculata* and *Calicorema capitata,* whilst *Commiphora* species occur along the upper edges of runoff channels. *Stipagrostis* species form the dominant plant layer, but these may disappear during unfavourable seasons. An important species remaining is *Eragrostis nindensis*, a very low, but hardy perennial grass, that is also capable of trapping and stabilising soil due to its dense basal tuft. According to Nel (1983), it can complete its entire annual growth cycle with only 20 mm of rain. Although it does not have a very high production, in the Namib it is readily consumed by animals, which is partly attributable to the fact that this is often the only grass species present, and also one of the first species to resprout after rains. Further species indicative on these plains are *Trianthema triquetra, Enneapogon desvauxii* and *Zygophyllum simplex*.
Species diversity is moderate, and based on that, the area has a sensitivity rating of 2. However, some of these plains are situated above very sensitive quartzite slopes (northwest of the mine), or form large continuous ‘plateaus’ (directly north of the mine), where they are occasionally frequented by animals, and these patches therefore have a sensitivity rating of 3. The more eroded areas between the current tailings dam and the explosive store may be regarded as a sensitivity 2 zone.

Fodder plants
The following information has been extracted from Nel (1983).

Most important fodder grasses:
Antephora pubescens: occurs only on the quartzite slopes, where it is often difficult to reach. As tufts do not form dense stands, this otherwise palatable grass is not utilised during favourable seasons. However, during periods of drought, it is very well utilised, as it then also has a high amount of dry standing biomass.

Enneapogon desvauxii: prefers shallow soils, and is very common on calcretes. Although very low and often sparse, it is one of the grasses well utilised by mountain zebra.

Eragrostis nindensis: it can complete its entire annual growth cycle with only 20 mm of rain. Although it does not have a very high production, in the Namib it is readily consumed by animals, which is partly attributable to the fact that this is often the only grass species present, and also one of the first species to resprout after rains. It is associated with shallow soils on level plateaus, as well as deeper soils on drainage lines. In the study area it is most prevalent on the northern gravelly and conglomerate plateaus.

Stipagrostis ciliata: this is regarded as the most important grazing component of the Central Namib. It prefers loose, coarse and sandy soils, but may also occur on calcretes. Once established, it can withstand longer periods of drought, but may behave as an annual. It is found throughout the study area.

Stipagrostis hirtigluma: can be found on a wide range of soils throughout the study area, but is most prevalent on otherwise relatively bare ridges and plateaus. It is annual, but can germinate after only 15 mm, and grows fast to provide a temporary source of fodder. However, copious amounts of seeds produced also provide food for various smaller forms of fauna.

Stipagrostis obtusa: this grass is often found in association with *S. ciliata*, but prefers the lower plains and footslopes, where it may become dominant. Although the leaves are rolled up in a tight basal tuft, in the dormant state it is softer than *S. ciliata* and then also the more palatable species during dry periods.

Stipagrostis uniplumis: it prefers more stable soils, either in the upper edges of runoff channels, or on deeper sandy soils. In the study area it usually grows on the schist ridges and runoff channels, but never forms significant stands. This grass is only palatable when actively growing, when the culms are relatively soft.

Low shrubs utilised by game:
Small shrubs and forbs are an important source of fodder for larger herbivores. Species that are utilised the most are:
Adenolobus pechuelii, Zygophyllum cylindrifolium and *Salsola* species. *Calicorema capitata, Monechma cleomoides* and *Petalidium variabile* have been shown to deliver a very high proportion of the diet of local herbivores (Nel 1983). These three species will also form the

bulk of herbivore diet during prolonged periods of drought. They are most common in all riverine systems throughout the study area, as well as on the quartzite slopes.

Herbs that are well utilized by game:
These include:
Indigofera auricoma, Cleome species, Zygophyllum simplex, Tribulus zeyheri (during early stages of growth), *Citrullus ecirrhosus*, *Cucumis* species and *Sesamum* species, especially *Sesamum marlothii* (Pers. Obs.).

Trees that are utilised by game:
Acacia erioloba is regarded as the most important fodder- and shade tree in the Central Namib. Its pods are available during the hottest period of the year, before the onset of rains. Further, it not only traps but also produces a large amount of debris, which acts as a source of humus to the surrounding soil, and traps seeds of various plants that then germinate there.

Boscia foetida is the shrub that endures the most vigorous utilisation within the Central Namib. Apart from its leaves and softer stem tips, the fruit, often produced in abundance, are another important source of food to fauna.

Euclea pseudebenus is another tree valued by game for its shade, leaves and berries, which are even eaten by black-backed jackal. Similar to *Acacia erioloba*, a significant amount of humus accumulates below its canopy, providing a favourable habitat for other species.

Commiphora leaves are relatively well utilised by springbuck and rock hyrax, where these animals can reach them, whilst the bark is popular with porcupines.

Ficus cordata fruit are well utilised by rosy-faced lovebirds and baboons, whilst baboons and porcupines also feed on the bark of this tree.

Maerua schinzii has been shown to be well utilised by oryx and kudu (Nel 1983; Pers. Obs.).

General Recommendations

Monitoring programs

There exists very little information on the establishment and growth-rate of seedlings of shrubs and trees in the Namib. Some information can, however, be collected now in the part of the mine, that will be most severely disturbed – i.e. the riverbed. Areas not envisaged to be excavated should be surveyed as soon as possible for the presence of seedlings, with priority given to *Acacia erioloba*. The methodology is relatively rapid, and surveys only need to be repeated every 3 or 4 months: a rectangular area with a fair amount of seedlings is selected, preferably of several species. The area should not be wider than 1m, but can be up to 10m long. The central line along that area is marked with permanently positioned pegs, between which a measuring tape can be stretched during every survey. During the initial survey, every seedling is assigned a number and its position recorded on a graph paper, where the monitor-

ing site can be drawn in according to scale. For every seedling, the approximate height (e.g. height classes of about 25 cm intervals) is recorded during every survey, as well as its vigour: growing well if full of leaves, dormant during the dry season or dead.
Such data will be very useful to determine growth rate and survival of various seedlings. This data will help to create realistic expectations for restoration plans after the mine completes operation in a particular area. The data may also give insights as to where and how much natural processes may have to be 'assisted', e.g. by occasional watering or the necessity to raise plants in a nursery.

Monitoring of establishment of transplanted plants
Although several plants have already been transplanted, feedback on the success of establishment varied probably indicating limited translocation success. In future, it would be advisable if a representative sample of transplanted plants, especially where protected species are concerned (including stem succulents), are actually planted along a linear transect (e.g. within 1 m of a demarcated line) to enable the same monitoring procedure as for seedlings. However, this will still necessitate such plants to be placed in similar habitats, and not planting them in a straight line.
Again, data collected here will not only show how well which species can be transplanted and help to create realistic restoration goals, but will also highlight potential problems that may have to be addressed to ensure the continued survival of these plants.

Topsoil storage
It may not be feasible to store topsoil of all areas mined. Priority should however go to the sandy soils from the Gawib River itself. These are an accumulation over hundreds of years of weathered material from the surrounding mountains, and there is no additional source of these soils. The vegetation on these alluvial deposits depends on this portion of their habitat able to be re-establish. It will also be desirable not to dump such topsoil in small heaps, but rather to flatten it out to create an interim surface, on which seeds can germinate and such plants help to strengthen the seed bank in these soils.

Acquisition of suitable remote sensing material to facilitate future studies
The Remote Sensing Unit of the CSIR in Pretoria is currently investigating and acquiring several formats of satellite imagery, from which mapping of sparse desert vegetation may be done more accurately. Such satellite imagery may further be useful to produce a 3D image of the terrain, as well as assist in groundwater studies. More accurate vegetation mapping for the remainder of the mining licence area will depend on the type and quality of such remote-sensing data. From high resolution aerial photographs the distribution of larger trees and shrubs may be deducted, but such photos give no information as to the delineation of other vegetation or communities. For this actual reflectance data is necessary, which measures the types and intensities of chlorophyll, heat reflectance as well as turgor (water content) of plants, which is characteristic for different types of vegetation. It is recommended that CSIR specialists be contacted for the best satellite imagery to be attempted.

Recording rooting depth

Poor data exists on the depth of roots of the riverine vegetation, which will become an important issue when tailings or waste rock are filled into pit areas. One opportunity to solve this would be to try and do root counts where a pit wall is extended into still existing vegetation. For this, a rectangular area of about 50 cm is marked onto a freshly cut pit wall, and extended from top to bottom. For every 50 x 50 cm square, the number of roots can be counted without too much effort. Ideally roots should be divided into woody and non-woody roots, as this is an indication of their parent plant – trees and larger shrubs or smaller shrubs, forbs and grasses.

Obtaining soil data

Currently there are no data available on the soil characteristics of the areas where different plant communities occur. Data that is needed includes soil conductivity, acidity, texture and nutrient status. Materials excavated from the pit area will most likely have very different characteristics than current topsoils. To enable proper planning and realistic expectation for restoration practices after mine closure, the difference between existing topsoils and soils that may later be used as topsoils needs to be known.

Planning with the environment

Allow sufficient time for identifying and excavating plants that need to be removed. The environmental section must be involved and fully informed of all plans for new dumping sites right from the start. The environmental section will need sufficient time to survey the area to make sure they remove and transplant all suitable plant specimens. The National Botanical Research Institute will also welcome some of these specimens for the Botanical Garden.

Discussion and Conclusion

The Gawib River is one of the larger and more diverse river systems within the Central Namib. The section of the Gawib River that bisects the Langer Heinrich Mountains and the Schieferberg is potentially the most diverse and unique habitat within this river system, due to the enhanced runoff from the adjacent mountains. This is reflected in the relatively high species diversity compared to the surrounding areas of the Central Namib. On a larger scale, this section of the Gawib River is an important link and passage from higher lying plains on the east, up to the Tinkas watershed, and the plains and larger river systems to the west and north. The Langer Heinrich Mine is situated exactly in the centre of this link, potentially blocking off resource flows. This has already become evident during a rare but significant rainfall event early in 2008.

Approximately 25% of the species recorded are endemic; some of these, like *Aloe namibensis*, have a very narrow distribution, and parts of the study area provide an ideal habitat for these plants. The latter statement is supported by observations on the size-distribution of some of the plant species. For all *Commiphora* species, *Aloe namibensis, Euphorbia guerichiana, E. virosa*, which have their prime habitat in the Central Namib, size-classes of individuals ranged from recent seedlings, to juveniles (established plants but too young to flower), to very large plants. This shows that these species are reproducing well and the populations are currently stable. For the larger trees – i.e. *Acacia erioloba*, *Boscia* species, *Euclea pseudebenus*, *Ficus cordata, Maerua schinzii, Parkinsonia africana* and *Sterculia africana* the only seedlings found were for *Acacia erioloba*. Juvenile plants were even scarcer, and only included specimens of *Acacia erioloba* and *Parkinsonia africana*. This phenomenon is probably due to two factors: either the plants become very old and can persist readily in an undisturbed habitat, thus the necessity of large seed-production is small (as is the case with *Welwitschia mirabilis*), or these species are only able to become established during successive years of sufficient rainfall, and take very long to reach their present size because of the harsh environment. As these species are also restricted to specific habitats, the second scenario is more likely. This, of course, has major implications for the impact of the mine. Whilst *Sterculia*, *Ficus* and some *Boscia* species occur on habitats where no ore has yet been identified and can be protected from disturbance, the same does not apply to the Gawib channel itself. It is envisaged that the majority of the large specimens of *Acacia erioloba, Euclea pseudebenus* and *Maerua schinzii* will disappear as mining activities progress. As these trees provide important habitat to other plant species as well as fauna, whilst also contributing to the overall functioning of the ecosystem, planning of mine activities will have to consider mitigating activities in these areas (shown in Figure 5) from the start.

Figure 5: *Areas where mitigation measures will become necessary are indicated in green. Of these, possible key seeding areas, indicated in blue, should be treated as NO GO areas. The approximate position of current stock piles, tailings facility, and mine dumps are indicated in brown.*

The following will be necessary:
- Identify key patches of preferably denser stands of these trees that fall outside the ore body, and demarcate them as seeding areas for future regeneration purposes. Disturbance of these key areas (possible sites indicated in Figure 5) must be prevented.
- Store topsoil from the sites that will be excavated in future.
- Monitor seedling establishment and growth in seeding areas, and establish nurseries if seedlings succumb early.

Within the current core area of the Langer Heinrich Mining Lease, there are areas where, due to harsh environmental conditions, plant species diversity is relatively low. These areas are mostly to the south of the mine, on the lower schist outcrops of the Schieferberg, as well as adjacent low footslopes. Other areas with low plant biodiversity are the relatively instable conglomerates, north and north-east of the current mine. In all of these areas, perennial shrubs, dominated by *Commiphora saxicola* and *C. virgata*, are concentrated along runoff channels or steeper slopes that are partly shaded. Despite the lower plant species diversity here, most of the lower parts of the tributaries coming from the Schieferberg are frequented by larger mammals. The same applies to the conglomerates, which, despite their low vegetation cover, support grazing that will be available during times of very poor precipitation, when no other grasses may have foliage. This means that even low plant diversity areas also need to be protected to some degree.

On the conglomerates and the Schieferberg, four areas have been identified where mining activities are expected to have minimal impact on the vegetation. Of these, the schist outcrops between the current water reservoirs and telephone line, as well as the gravelly footslopes and plains north-west of these outcrops, appear to be the most suitable for permanent dumping sites, provided that no undesirable material can be re-distributed into lower-lying tributaries (See sites 1 and 2 – Figure 6). However, many remnants of bulbous plants were found on the gravelly footslopes and plains (site 2), which could not be identified. Collecting bulb specimens for identification is thus imperative. Furthermore, as bulbous plants are in general poorly known in Namibia, but may be an important food source for some animals, topsoil will have to be removed and bulbs salvaged. These bulbs can easily be kept in a nursery, and transplanted again at a later stage.

The low foothills south-east of the new low grade ore stockpile could be used to extend the stockpile (See site 3 – Figure 6). However, care should be taken not to block off the tributaries from the Schieferberg, whilst also minimising the disturbance of the Gawib channel itself.

A smaller site that may be suitable for storing topsoils, are the relatively eroded conglomerate ridges and blind valleys west of the current explosives store and the north-east of current tailings dam (See site 4 – Figure 6, area indicated in Figure 7).

Waste Rock Dump 1 should be filled up right to the end of the blind valley against the conglomerates. Waste Rock Dump 2 already infringes on very sensitive habitat on the western channel it uses, and should rather be extended to the east.

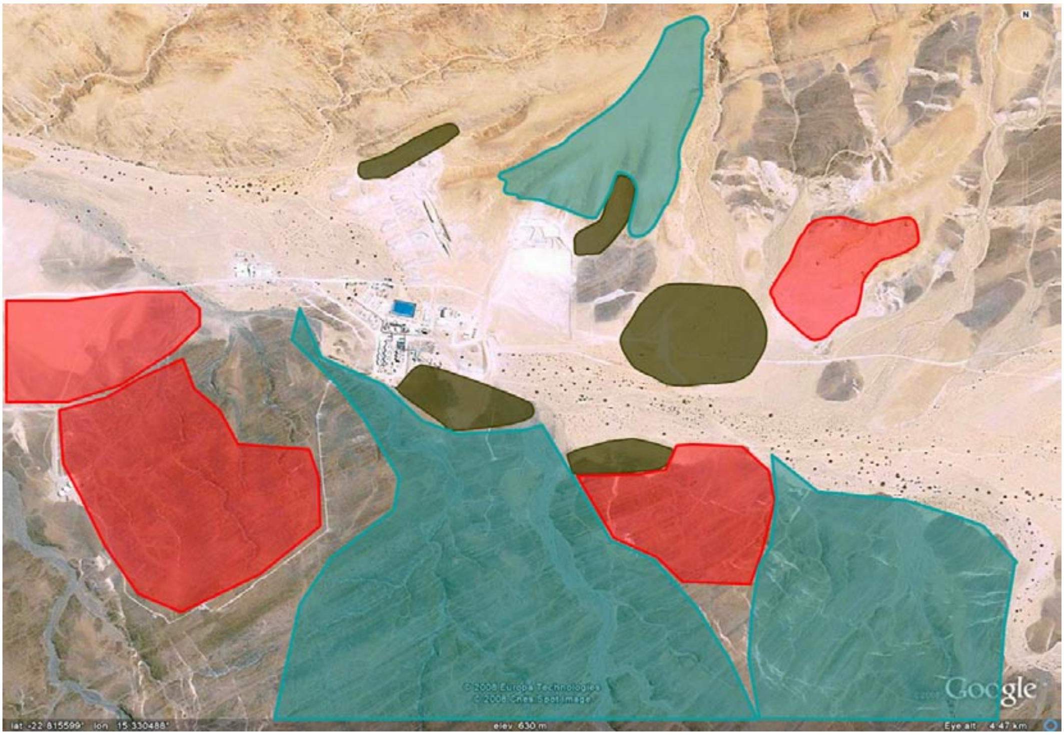

Figure 6: *Possible sacrificial areas are indicated in red. Areas with lower sensitivity that should be retained due to more niche availability and animal presence are indicated in green. The approximate position of current stock piles, tailings facility, and mine dumps are indicated in brown.*

Figure 7: *Two blind conglomerate valleys northeast of the current tailings dam that could be used to store topsoil.*

The quartzite slopes, ravines and boulder washes spanning the northern portion of the mining lease support the highest diversity of plants within the core mining area with 92% of all plants that could be identified during the survey represented here. As this area lies outside the ore body, there is no justification for any disturbance of these areas (Figure 8).

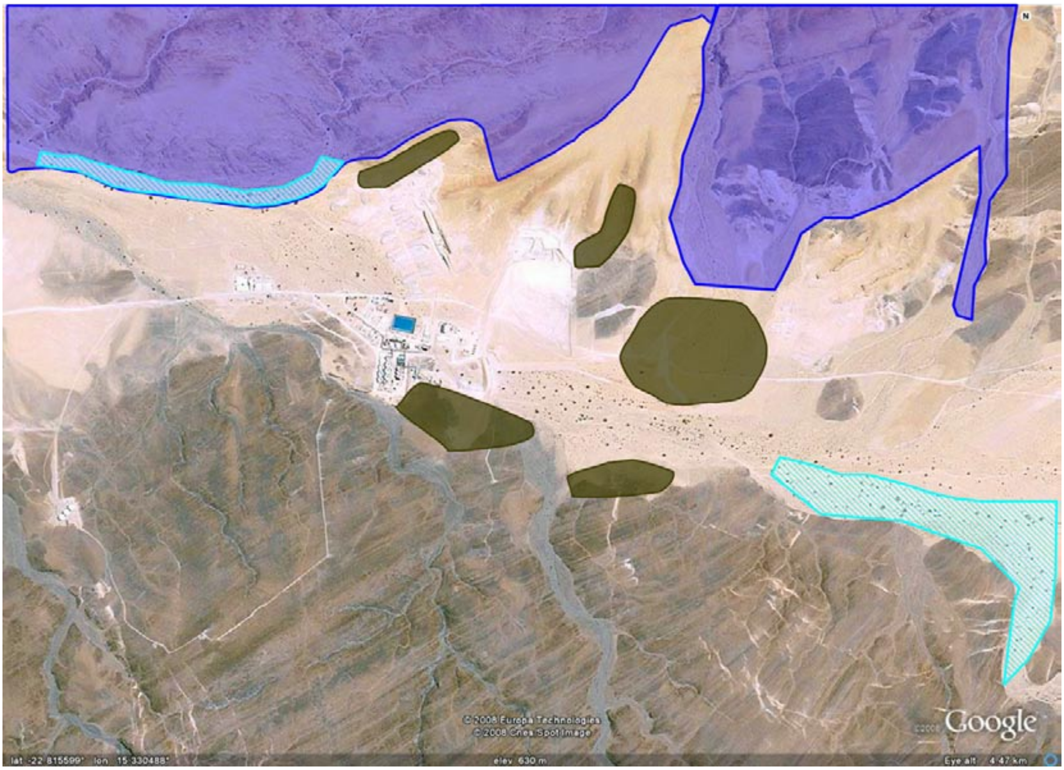

Figure 8: *NO GO areas with high biodiversity and niche availability are indicated in dark blue. Also indicated are the possible key seeding areas, representative of the Gawib River vegetation that should be treated as NO GO areas as well. The approximate position of current stock piles, tailings facility, and mine dumps are indicated in brown.*

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Appendix 1 - Overview of the plant associations and communities:

1. The *Commiphora glaucescens – Aloe namibensis* association

Communities:	Habitat	Most important species
1.1 Commiphora virgata – Zygophyllum cylindrifolium sparse shrublands Community statistics: 2 restricted endemics 10 narrow endemics 11 widespread endemics 1 Red Data species 4 protected species 4 keystone species 93 observed species 115 expected species Sensitivity score: 538 **Irreplaceable community and habitat**	Found on quartzite slopes, outcrops and upper runoff channels. These are part of the larger Langer Heinrich Mountain, thus relatively limited within the study area and it is expected that the habitat may be limited beyond the study area as well **Management implications:** This community and habitat should be disturbed as little as possible. The relatively high incidence of the red-listed *Aloe namibensis*, as well as the high number of observed and expected species indicates that this area should, as far as possible, be treated as a non-disturbable conservation area.	**Constant species:** *Antephora pubsecens (Wool grass), Aristida parvula,* *Commiphora glaucescens (Blue-leaved Commiphora),* *Commiphora virgata (Slender corkwood)* *Enneapogon desvauxii* *(Eragrostis nindensis (Eight-day love grass)* *Hermannia helianthemum* *Indigofera auricoma* *Monechma cleomoides (Namib perdebos)* *Pegolettia senegalensis* *Petalidium variabile (variable Petalidium)* *Stipagrostis ciliata (tall bushman grass)* *Stipagrostis hirtigluma* *Stipagrostis uniplumis* *Tephrosia monophylla (single-leaf Tephrosia)* *Zygophyllum cylindrifolium* *Zygophyllum stapfii (dollarbush)* **Unique species:** *Aloe namibensis (Namib aloe)* *Boscia foetida (Noeniebos)* *Euphorbia guerichiana (Paper-bark Euphorbia)* *Euphorbia virosa (Candelabra Euphorbia)* *Helichrysum tomentosulum* *Sesamum marlothii* *Sterculia africana (Ticke tree)*

1.2 Petalidium variabile – Aloe dichotoma sparse shrublands

Community statistics:
5 restricted endemics
16 narrow endemics
18 widespread endemics
2 Red Data species
9 protected species

7 keystone species
138 observed species
164 expected species

Sensitivity score:
786

Irreplaceable community and habitat

Granitic boulders, flats and outcrops as found in localised areas in the eastern portion of ML140, where the overlying schists have eroded away. The granites closest to the present mine are just south of the prospectors camp. This habitat does occur extensively around the study area, especially towards the Swakop River and Tinkas Mountains. However, due to their position within the study site and its landscapes, these granites are expected to be significantly different in species composition compared to granites found elsewhere in the country, e.g. Erongo.

Management implications:

This community and habitat should be disturbed as little as possible, it will be impossible to reacreate it. The high number and diversity of niches available are responsible for the high plant diversity found here.

Constant species:

Asparagus pearsonii
Calicorema capitata
Calostephane divaricata
Chamaesyce glanduligera
Commiphora glaucescens
Commiphora virgata
Enneapogon desvauxii
Enneapogon scoparius
Eragrostis nindensis
Hermannia helianthemum
Indigofera auricoma
Monechma cleomoides
Petalidium variabile
Stipagrostis ciliata
Stipagrostis hirtigluma
Stipagrostis uniplumis
Tephrosia dregeana
Tephrosia monophylla
Zygophyllum stapffii

Unique species:

Aloe dichotoma (Quiver tree)
Aloe namibensis (Namib aloe)
Amphiasma divaricatum
Aptosimum angustifolium
Boscia albitrunca (Witgat)
Engleria africana
Euphorbia virosa (Candelabra Euphorbia
Grewia tenax
Hoodia currorii
Jamesbrittenia hereroensis
Maerua schinzii

1.3 Sterculia africana – Enneapogon sparse shrublands

Community statistics:
2 restricted endemics
9 narrow endemics
10 widespread endemics
1 Red Data species
3 protected species

2 keystone species
73 observed species
91 expected species

Sensitivity score:
500

Irreplaceable community and habitat

Quartzite ravines

Constant species:

Abutilon pycnodon
Anthephora pubescens
Anticharis imbricata
Barleria merxmuelleri
Commiphora glaucescens
Cucumella aspera
Dyerophytum africanum
Enneapogon scaber
Enneapogon scoparius
Forsskaolea candida
Hermannia helianthemum
Monechma cleomoides
Ruellia diversifolia
Stipagrostis hirtiglum
Trichodesma africanum

Unique species:
Barleria merxmuelleri
Ficus cordata
Forsskaolea candida
Helichrysum tomentosulum
Marcelliopsis splendens

1.4 Petalidium variabile – Stipagrostis hochstetteriana sparse shrublands Community statistics: 4 restricted endemics 16 narrow endemics 14 widespread endemics 1 Red Data species 3 protected species 6 keystone species 118 observed species 138 expected species Sensitivity score: 656 **Irreplaceable community and habitat**	Quartzite boulder washes	**Constant species:** Adenolobus pechuelii Barleria lanceolata Blepharis grossa Calicorema capitata Chamaesyce glanduligera Cleome foliosa Forsskaolea candida Geigeria alata Hermannia helianthemum Indigofera auricoma Kohautia ramosissima Monechma cleomoides Petalidium variabile Sesamum marlothii Stipagrostis ciliata Stipagrostis hochstetteriana Stipagrostis uniplumis Tephrosia monophylla Trichodesma africanum Tripteris microcarpa **Unique species:** Boscia foetida Euphorbia guerichiana Fagonia sinaica v. minutistipula Heliotropium hereroense Jamesbrittenia hereroensis Polygala guerichiana Sesamum marlothii Sterculia africana Stipagrostis damarensis Stipagrostis schaeferi

2. *Trianthema triquetra – Stipagrostis hirtigluma* association

Communities:	Habitat	Most important species
2.1 Eragrostis nindensis – Trianthema triquetra sparse grasslands Community statistics: 1 restricted endemics 7 narrow endemics 3 widespread endemics 0 Red Data species 1protected species 2 keystone species 50 observed species 63 expected species Sensitivity score: 242 **Sensitive community and habitat**	Conglomerate flats and upper slopes **Management implications:**	**Constant species:** **Unique species:**
2.2 Adenolobus pechuelii – Zygophyllum cylindrifolium sparse grasslands Community statistics: 3 restricted endemics 11 narrow endemics 9 widespread endemics 1 Red Data species 3 protected species 4 keystone species 83 observed species 108 expected species Sensitivity score: 450 **Irreplaceable community and habitat**	Pegmatite intrusions on schist ridges **Management implications:**	**Constant species:** **Unique species:**

2.3 Enneapogon desvauxii – Pegolettia senegalensis sparse grasslands Community statistics: 1 restricted endemics 6 narrow endemics 3 widespread endemics 0 Red Data species 3 protected species 2 keystone species 55 observed species 71 expected species Sensitivity score: 200 **Least sensitive community and habitat**	Schist ridges	**Constant species:** **Unique species:**
2.4 Petalidium canescens – Commiphora saxicola sparse grasslands Community statistics: 0 restricted endemics 8 narrow endemics 2 widespread endemics 0 Red Data species 0 protected species 2 keystone species 52 observed species 69 expected species Sensitivity score: 224 **Sensitive community and habitat**	Steeper schist slopes and runoff channels	**Constant species:** **Unique species:**

3. *Zygophyllum stapffii – Sesamum marlothii* association

Communities:	Habitat	Most important species
3.1 Zygophyllum stapffii – Sesamum marlothii riverine shrublands Community statistics: 1 restricted endemics 6 narrow endemics 4 widespread endemics 0 Red Data species 1 protected species 3 keystone species 56 observed species 78 expected species Sensitivity score: 322 **Highly sensitive community and habitat**	Narrow flood channels between schist outcrops and mountains, with schist gravel and / or boulders **Management implications:**	**Constant species:** **Unique species:**

4. *Calicorema capitata – Stipagrostis schaeferi* association

Communities:	Habitat	Most important species
4.1 Acacia erioloba – Stipagrostis damarensis sparse shrublands with low trees Community statistics: 2 restricted endemics 16 narrow endemics 14 widespread endemics 0 Red Data species 5 protected species 7 keystone species 127 observed species 148 expected species Sensitivity score: 662 **Irreplaceable community and habitat**	Sandy washes and rivers	**Constant species:** **Unique species:**

4.2 Acacia erioloba – Stipagrostis ciliata sparse shrublands with low trees Community statistics: 2 restricted endemics 9 narrow endemics 9 widespread endemics 0 Red Data species 4 protected species 7 keystone species 87 observed species 110 expected species Sensitivity score: 432 **Highly sensitive community and habitat**	Sandy or gravelly river terraces	**Constant species:** **Unique species:**
4.3 Adenolobus pechuelii – Stipagrostis ciliata sparse shrublands with low trees Community statistics: 3 restricted endemics 10 narrow endemics 11 widespread endemics 0 Red Data species 2 protected species 4 keystone species 96 observed species 115 expected species Sensitivity score: 400 **Highly sensitive community and habitat**	Small shallow washes	**Constant species:** **Unique species:**

5. *Stipagrostis obtusa – Zygophyllum simplex* association

Communities:	Habitat	Most important species
5.1 Aizoanthemum rehmannii – Monechma desertorum sparse grasslands Community statistics: 1 restricted endemics 6 narrow endemics 4 widespread endemics 0 Red Data species 0 protected species 1 keystone species 59 observed species 76 expected species Sensitivity score: 138 **Least sensitive community and habitat**	Schist and calcrete plains and footslopes	**Constant species:** **Unique species:**
5.2 Salsola tuberculata – Jamesbrittenia barbata sparse grasslands Community statistics: 2 restricted endemics 7 narrow endemics 2 widespread endemics 0 Red Data species 0 protected species 1 keystone species 40 observed species 46 expected species Sensitivity score: 160 **Least sensitive community and habitat**	Quartz gravel plains and erosion slopes	**Constant species:** **Unique species:**

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Soil and vegetation changes under livestock production in the northern Kalahari, Namibia

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Abstract
The spatial scale and intensity of rangeland degradation under continuous grazing around water points in arid and semi-arid environments depend on the population density of livestock, the duration of water point use and the distance livestock travel from water points. We visually established a broadscale pattern of vegetation zonation along a grazing gradient on 28 settlements in the Kalahari to place five sampling points from artificial water points. We selected four settlements for a more intense study of vegetation and soil changes under livestock production. We tested the effect of livestock on species diversity of herbaceous and woody plants, structural parameters of woody plants, and soil moisture and nutrient contents. We found that the marked effect of livestock on vegetation was confined to the vicinity of the artificial water points. The diversity of herbaceous and woody species decreased under high livestock pressure, but the abundance of herbaceous species present near water points increased significantly. Soil parameters were not influenced significantly by livestock activities along the grazing gradient, however the upper soil layer had significantly higher organic carbon and total nitrogen, but lower soil moisture content. It appeared that marked livestock impact around artificial water points in the Kalahari was confined to the immediate areas of the water points. Alternatively, livestock impact may have resulted in relatively uniform vegetation and soil changes beyond the 200 m distance from the water points.

Key Words: arid environments, bush encroachment, dryland pastoralism, land degradation, soil hydrochemistry, range management.

Introduction
Arid and semi-arid environments are inherently variable, and largely driven by rainfall events (Ellis & Swift 1988, Ward *et al*. 1998, Illius & O'Connor 1999). To cope with this natural variability, pastoralists have been able to: 1) migrate to ephemeral water sources where forage

could be utilised during the wet seasons, while resting forage resources in areas with perennial water sources; 2) keep a variety of livestock to utilise both browse and grazing resources; and 3) utilise a wide land area to minimise localised negative impacts on resources (Ellis & Swift 1988). Much of Namibia is semi-arid to extremely arid (Van der Merwe 1983, Aharoni & Ward 1997), thus Namibian pastoralists have traditionally used the abovementioned flexible grazing system described by Ellis and Swift (1988) for the arid Turkana region of Kenya. However, this system of range and livestock management has changed in Namibia because current land tenure systems have confined pastoralists to specified land areas, and the provision of artificial permanent water sources has created permanent settlements. Elsewhere in arid and semi-arid Sub-Saharan Africa, the creation of permanent pastoral settlements, the high proportion of domestic grazers (cattle) to browsers (goats) and the decline of wild ungulate browsers in agricultural lands have tilted the balance between woody species and grasses into woody plant-dominated rangelands (Coppock 1993, Moleele 1998, Moleele *et al*. 2002). In addition, livestock pressure in the vicinity of water points reduces species diversity, increases the prevalence of invasive herbaceous species, reduces the abundance of palatable grass species, but favours unpalatable species (Tolsma *et al*. 1987, Strohbach 1992). The impacts on soils are multiple, but depend mainly on the soil type and the topography of the affected landscape (Behnke & Scoones 1993, Stafford-Smith & Pickup 1993). Excessive trampling and overgrazing can lead to soil erosion, compaction and reduced moisture infiltration on slopes (De Klerk 2004). However, sandy Kalahari soils are less affected (Dougill *et al*. 1999). Nonetheless, irrespective of soil type, the concentration of livestock around water points leads to increased nutrient accumulation in the soil as a result of urine and dung deposition (Tolsma *et al*. 1987).

A distinctive pattern of vegetation and soil changes develops around artificial water points under continuous grazing (Lange 1969, Jeltsch *et al*. 1997), of which the extent is determined by the age of the water point, livestock densities and the capacity of animals to forage away from the water points (Andrew 1988). Lange (1969) termed this unique ecological system centred around artificial permanent water points, 'piosphere' (derived from a Greek word: '*pios*', meaning 'to drink'). The area closest to the water points experience severe pressures such that only few herbaceous plants can survive. This area is referred as the "sacrifice" zone (Graetz & Ludwig 1978). The sacrifice zone is characterised by extensive bare ground, particularly during the dry season, and is dominated by annual invasive herbs (Thrash 1998, Brits *et al*. 2002) that are mostly unpalatable to livestock (James *et al*. 1999, Ward 2004). Beyond the sacrifice area, is the second zone where the impact of large herbivores tapers off, until an upper asymptote is approximated (Thrash *et al*. 1993). The second zone is characterised by a rapidly-increasing total woody biomass, while the third has a relatively constant woody biomass (Thrash 1998). Thus, the impact of large herbivores on vegetation and soil parameters forms a sigmoid relationship with distance from water points (Thrash 1998, Britz et al. 2000). Thrash (1998) used a 2000 m transect to arrive at this sigmoid curve. Tolsma *et al*. (1987) reported thickets of *Acacia* spp. and *Dichrostachys cinerea* from 800 - 1 500 m of water points in a semi-arid district of eastern Botswana, and that these thickets were transitional to a tree savannah at 3 000 m from the water points. Cattle in our study area were occasionally observed at about 7 000 m from water points (personal observations). Pickup (1994), using a model based on the Australian semi-arid rangelands, demonstrated that the effect of cattle on vegetation might extend beyond 7 000 m from water points.

The objective of this study was to investigate the extent of vegetation and soil changes in relatively homogenous flat landscapes of the northern Kalahari communal rangelands dominated by *Terminalia sericea*. We specifically tested the effects of livestock on species diversity, the structural parameters of woody plants, soil moisture and nutrients.

Materials and Methods

Site selection

We drove through 28 pastoral settlements and observed the pattern of vegetation distribution and abundance with increasing distance from artificial water points. We combined our observation with 30-year-old and current aerial photographs (1:60 000) to select four settlements with homogenous landscapes in all directions from the water points. All settlements located on calcrete outcrops and those dominated by *Acacia* species were excluded because of their limited distribution, and unusual vegetation composition to most of the northern Kalahari (Makhabu *et al*. 2002). All selected settlements had a flat landscape and were situated away from low-lying areas. The selection criteria met the requirement of our assumption that the impact of livestock on vegetation and soil is radial in relation to the locations of artificial water points in homogenous flat landscapes and that the impact is most intense at water points. This assumption is consistent with that adopted in related studies in arid and semi-arid environments (Lange 1969, Thrash 1998, Ward *et al*. 1998, Makhabu *et al*. 2002). In this study the distance between the selected and nearest neighbouring settlements ranged between 8 000 and 9 000 m. This distance was selected to minimize overlaps in livestock home ranges between the settlements and to allow for a maximum possible distance between settlements such that the full extent of livestock impacts could be determined around the water points. The age of the selected settlements ranged from 32-51 y, and with cattle production as the main form of land use (Table 1). The study sites were located between the Epukiro Omuramba (omuramba means dry drainage line) and Eiseb Omuramba in the Otjinene communal area (S21^{o}E19^{o}) (see Figure 1).

Table 1. *Location of and date that water points were drilled and livestock numbers at the selected settlements. Figures of livestock numbers were obtained from village water point committees.*

Settlement	Geographical coordinates	Borehole drilled (year)	Cattle no. (2002)	Goats no. (2002)	Sheep no. (2002)
Oukango	S21°16.509'; E19°04.904	1950	561	237	73
Otjirarua	S21°12.714'; E19°13.871'	(±1960)	916	356	135
Okatjana	S21°02.402'; E19°04.958'	1970	480	202	31
Ombujonjama	S21°00.421'; E19°08.987'	1970	734	157	48

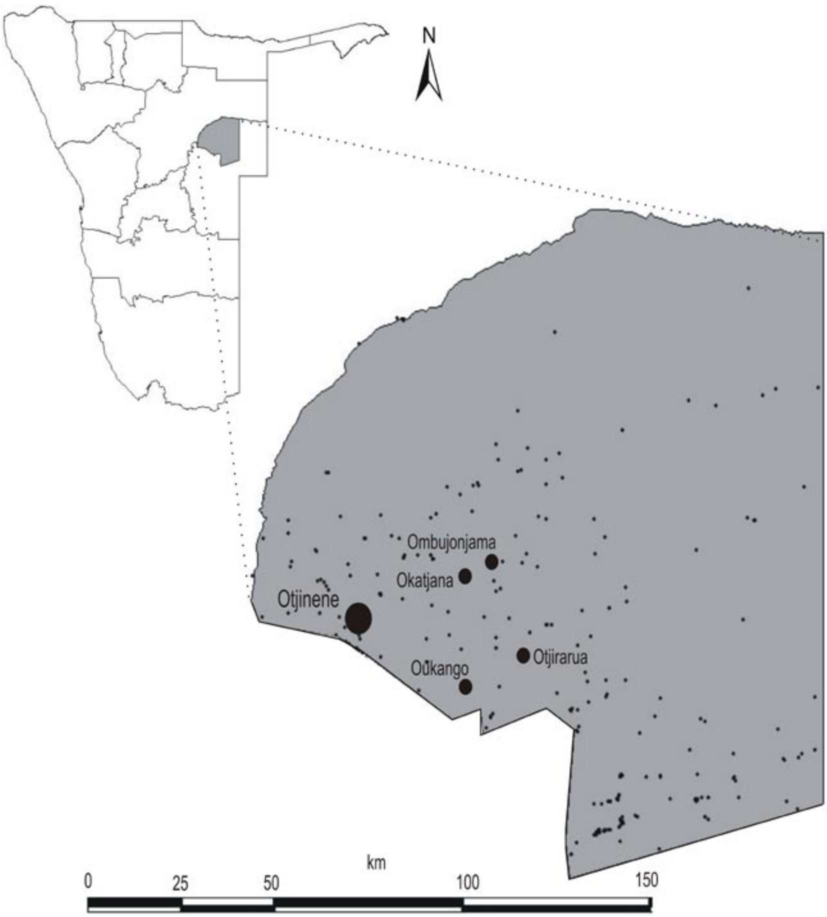

Figure 1: *Otjinene constituency in the Omaheke region, indicating the Otjinene settlement, the four study sites and numerous artificial water points scattered in the constituency. The constituency falls within the northern Kalahari vegetation type.*

Site Description

The long-term mean rainfall in the study area ranges from 250 - 400 mm per annum (Dealie *et al*. 1993). The coefficient of variation of the annual rainfall varies between 30 - 40% of the long-term mean rainfall (Mendelsohn *et al*. 2002). The general area consists of a large undulating landscape covered with sand dunes traversed by low-lying inter-dunal valleys (Köhler 1959). The sandy soils have low phosphorus and nitrogen contents (Mendelsohn *et al*. 2002). The vegetation of the area is classified as northern Kalahari bush savannah (Mendelsohn *et al*. 2002) and is characterised by dense stands of edible bush covering the dunes, of which *Croton gratissimus*, *Combretum apiculatum*, *Terminalia sericea* and *Philenoptera nelsii*, and shrubs such as *Bauhinia petersiana* and *Grewia* species are the most common (Rawlinson 1994). *Terminalia sericea* is regarded as the main bush encroaching species in the study area (De Klerk 2004).

Oukango and Otjirarua were the oldest of the four settlements (Table 1, Figure 1). According to Mr. Naftalie Mukungu, one of the first permanent residents of Oukango, the settlement water point was sunk at the end of 1951. The borehole at Otjirarua was drilled in 1960 (Mr. Alfeus Kauta, pers. comm. 2002). The water points at Okatjana and Ombujonjama were both drilled at the end of 1969. Prior to this date, only a few Khoi San families roamed the area (settlement elder, Chief Ben Hembapu, pers. comm. 2002). Free ranging cattle production was the main form of land use in all the settlements.

Data Collection

Observation of vegetation away from water points

A consistent vegetation zonation away from the artificial water points was observed during field reconnaissance and site selection exercise, across 28 settlements in June of 2001. We subdivided the observed vegetation pattern into five zones, on the basis of the abundance of *Sida cordifolia* (Malvaceae) which is a local invasive herb on degraded rangelands, clarity of browse line, shrub and bush density, and the proportion of tree and grass abundance (Table 2). Plant community structure differed across the distances from the water points. Nothing grew within about 30 m radius around the water points. Areas closest to the water points, but beyond 30 m, had the most sparse vegetation cover particularly woody plants, and the dominant tree *Terminalia sericea* rarely occurred in this zone. This zone (Zone I) extended to about 850 m from the water points. It was dominated by *Sida cordifolia*, and few scattered tall trees (mainly *Acacia erioloba* and *Combretum collium* subsp. *gazenze*) with a clear browse line. Homesteads and livestock pens were located in this zone - ranging from 300 - 600 m from the water points. A disappearing browse line and declining herbaceous-layer, but increasing shrub-layer characterized Zone II. This zone stretched from approximately 850 - 2 000 m from the water points. Beyond Zone II, the woody vegetation became denser and dominated by woody species such as *Terminalia sericea*, *Grewia flava*, *Bauhinia petersiana*, *Acacia fleckii* and *Acacia mellifera*. This we classified as Zone III, which extended approximately

3 000 m from the water points. This appeared to be the bush proliferation zone. Zone IV, 3 000 - 4 000 m was more of a transitional zone showing varying features of Zone III at some sites, and also becoming more of a savannah vegetation type (sparse trees interspersed with herbage) at other sites. Zone V, from 4 000-5 000 m from water points, was more open with shrubs, trees and a grassy layer. Overgrazing by livestock made identification of the grass component difficult at the time of the field reconnaissance.

Table 2. *Observed vegetation zonation along a livestock pressure gradient. Zone I experienced the greatest pressure at the water point, while Zone V suffered the least pressure on soils and vegetation. This pattern is based on field observations of 28 settlements in the northern Kalahari.*

Zone	**I**	**II**	**III**	**IV**	**V**
Distance	30 - 850 m from water points (WPs).	± 850 - 2 000 m from WPs.	± 2 000 - 3 000 m from WPs.	± 3 000 - 4 000 m from WPs.	+ 4000-5000 m from WPs.
Vegetation	Mainly invasive herbs – i.e. *Sida cordifolia* and *Acanthospermum hispidium*; few big trees: *A. erioloba*, *Combretum collium subsp. gazenze*, and shrubby *A. hebaclada.*	Increasing shrub layer; greater tree abundance and lesser invasive herbs compared to Zone I.	Dense woody plants dominated by *T. sericea; A. flecki*, *A. mellifera, G. flava* and *Bauhinia petersiana* seemed to occur frequently.	This seem to be a transitional zone between zone III and V, at some sites it was becoming less dense, while at others is was more of a savannah dominated by *T. sericea* and tall perennial grass cover.	Woody species interspersed with grass layer.

Other observations	Clear browse line. *Combretum collium subsp. gazenze* was more abundant than *A. erioloba.*	Diminishing browse line. *Terminalia sericea* started to be more abundant in this zone.	Bush proliferation zone.	It is possible that the age of the water points and cattle density may play a defining role in this zone. (older sites = more dense woody plants in this zone, meaning expansion of piosphere on older WPs).	This zone could not clearly be established as only few villages had inter-village distance exceeding 10 km.

Quantitative analysis of vegetation and soil parameters along a grazing gradient
We sampled woody vegetation, herbs and soil parameters at 200, 600, 1 200, 2 500 and 4 000 m along two random transects from the artificial water points. These sampling distances were selected as such to match and test the observed vegetation zonation. No sampling was done in the sacrificial zone.

Woody Vegetation Sampling
We recorded woody species richness, basal circumference, height and canopy diameter in 50 m x 10 m plots at each sampling point along the two grazing gradients from water points. Canopy diameters were measured in two perpendicular directions, that is the longest and the shortest diameters of the canopy. Average canopy diameter was then obtained for each tree measured and then the area of the canopy cover was calculated, assuming a circular spread. Basal area was measured above the buttress swelling, and in the case of multi-stemmed trees, where the stems are separated at the ground level; each was measured separately, but summed to give the total stem basal for the tree. In the majority of cases, plant height was measured directly with a tape, but in a limited number of cases where trees were too high, a clinometer was used to calculate tree height (Brower and Zar 1984). Only one observer was consistently used throughout this exercise. The density of woody species was estimated by the *T*-**s**quare method (Greenwood 1996). The T-square sampling method is based on the point-to-object and

nearest neighbour methods. Twenty (20) random points at each sampling distance were sampled. These random points were more than the 10 recommended by Greenwood (1996).

Herbaceous-layer Sampling

Herbaceous species were recorded in 24 restricted random quadrats (1 m^2) along a 50 m tape at 0, 10, 20, 30, 40 and 50 m intervals at each sampling distance away from water points (Figure 2). Species abundance by counts was recorded. Sampling was carried out at the beginning of April 2002 during the growing season when herbaceous species were easily identifiable. Species that could not be identified in the field were identified at the National Botanical Research Institute in Windhoek.

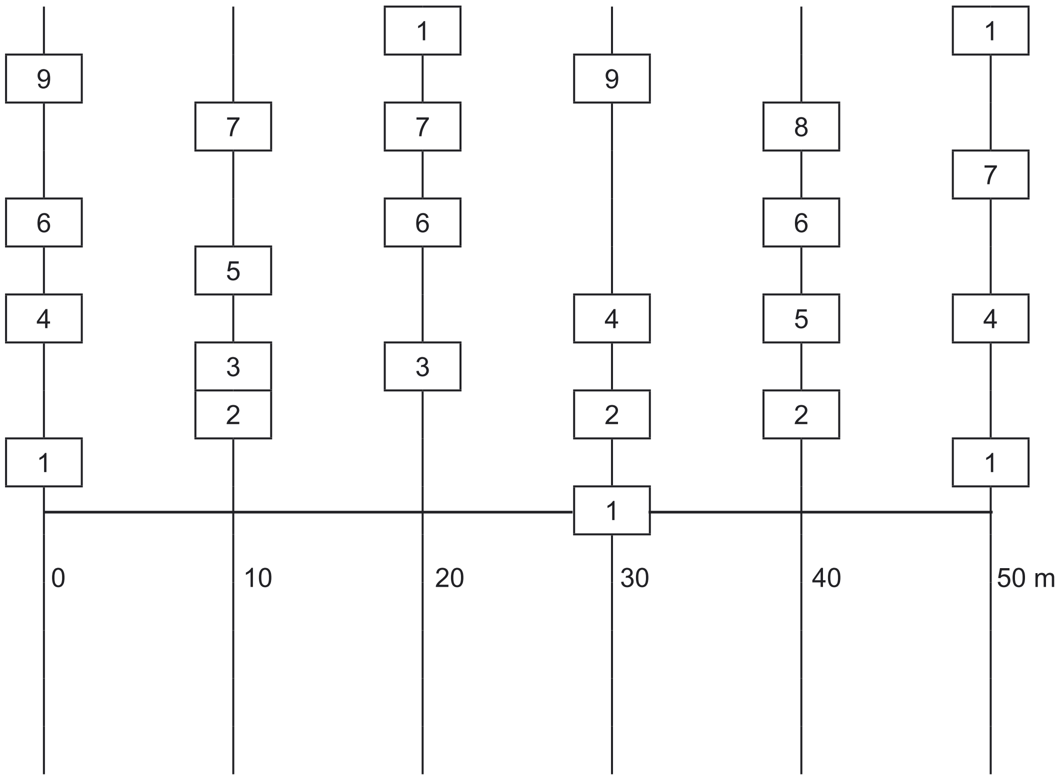

Figure 2: *General layout of 24 restricted random sampling quadrats, for herbaceous species abundance, placed at 10 m interval along a 50 m tape. At each interval four samples were collected at any random distance from 1 to 10 m perpendicular from the tape.*

Soil Parameters

The top loose-sandy soil containing litter was removed and samples were taken from three depths: 10-20, 50-60 and 90-100 cm during May 2002. A total of 120 samples were collected, air-dried and delivered to the Agricultural Laboratories of the Ministry of Agriculture, Water and Forestry (Government of Namibia) in Windhoek. The samples were further dried at 65^{o}C for 48 hours and passed through 2 mm sieve. Available phosphorus was extracted following the Olsen method– measured with a UV/VIS spectrophotometer (Olsen *et al*. 1954), organic carbon by the Walkley-Black method (Walkley 1947) and total nitrogen by the Kjeldahl digestion method (Cohen 1910).

Data Analyses

Vegetation community analyses

We used detrended correspondence analysis (DECORANA) for the analysis of differences in woody and herbaceous plant communities, using total counts of each species encountered at the 40 sampling localities along a decreasing livestock pressure gradient from the water points. DECORANA group's vegetation into one or more composite dimensions (axes) on the basis of floristic similarities that generally correspond to major influencing factors in the environment (Ward & Olsvig-Whittaker 1993). It is an improved multivariate eigenvector technique based on reciprocal averaging (also called correspondence analyses) but correcting its main faults (Hill & Gauch 1980). The ordination was performed on the 40 sampling localities and 31 woody or 65 herbaceous species. The data were log transformed and rare species were downweighted. Pearson product-moment correlations were used to determine correlations between Shannon-species diversity index values and eigenvalues of species abundance for axis 1 (DC1) and axis 2 (DC2) across the distance from water points.

Furthermore, a two-factorial mixed model ANOVA was performed to compare differences in woody plant species diversity, basal area, density, height and canopy area, using distance from water points as a fixed factor and sites as a random factor. Basal area, canopy area and height data were log-transformed. A three-factorial mixed model ANOVA was used to compare soil parameters (organic carbon, total nitrogen, available phosphorus and soil moisture), using soil depth and distance from water points as fixed factors and site as a random factor. Best-fit arcsine and square-root transformation equations were fitted to organic carbon and total nitrogen data respectively to normalize the data. Soil moisture was also arcsine-transformed, while available phosphorous remained untransformed. Degrees of freedom and mean square errors were computed using Satterthwaite method. Transects from water points were treated as replicates. A Scheffe *post hoc* test ($\alpha = 0.05$) was carried out to determine where significant differences occurred when the treatment effects were significant in ANOVA; means were listed with standard errors in tables, but 95% confidence limits were plotted in Figure 3.

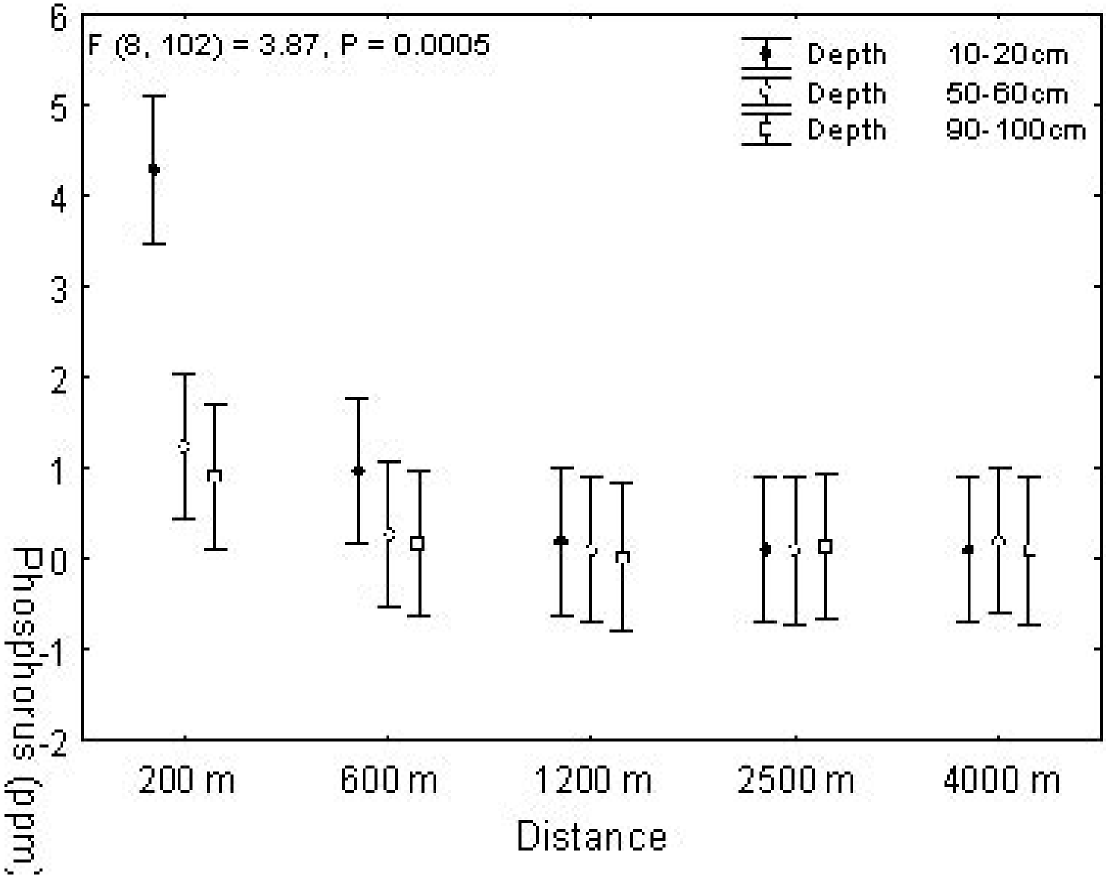

Figure 3. *Interaction effect of distance and soil depth on available phosphorus content. Error bars denote 95 % confidence limits.*

Results

Quantitative analysis of vegetation structure at distances from water points

Species composition

Distance from water points affected woody species diversity significantly (F = 13.46, P < 0.001, d.f. = 4, 12). Scheffe *post hoc* test showed that mean woody species diversity was significantly lower at 200 m (P < 0.05), compared to further away from the water points (Table 3). There were no significant differences among woody species diversity further away from water points (P > 0.05). The pattern of herbaceous species diversity resembled that of woody plants (F = 7.61, P < 0.05, d.f. = 4, 12). Mean herbaceous species diversity was significantly lower at 200 m than further away from the water points (P < 0.05, Table 3). No significant differences existed in herbaceous species diversity at the remaining distance from water points (Table 3).

Table 3. *Mean±SE woody and herbaceous species diversity at distances from water points. The Shannon-Wiener index was used to express species diversity. Different letters indicate significant differences in mean values at P < 0.05.*

Distance (m)	Woody species diversity (H')	Herbaceous species diversity (H')	Woody plants DC 1 values	Herbaceous plants DC 1 values
200	0.219 ± 0.0805 a	0.448 ± 0.4844 a	0.375 ± 0.4678 a	4.079 ± 0.3643 a
600	0.726 ± 0.1022 b	0.758 ± 0.0576 b	2.073 ± 0.5723 b	2.678 ± 0.1443 b
1200	0.813 ± 0.0496 b	0.858 ± 0.0731 b	2.814 ± 0.2849 bc	0.824 ± 0.5013 c
2500	0.723 ± 0.0428 b	0.839 ± 0.0596 b	3.441 ± 0.2722 bc	0.244 ± 0.2624 c
4000	0.731 ± 0.0426 b	0.785 ± 0.0346 b	3.644 ± 0.3357 c	0.655 ± 0.1729 c

We used DECORANA to compare woody vegetation parameters sampled at 40 localities from water points. The percentage of variance in woody plant species abundance explained by the first two axes in the DECORANA was low (DC1 = 20.6%, DC2 = 10.5%). There was a positive significant correlation between DC1 values of species abundance and woody species diversity along the livestock pressure gradient ($r = 0.42$, $P = 0.0068$, $n = 40$), the correlation between DC2 values and woody species diversity was non-significant ($r = 0.05$, $P = 0.7646$, $n = 40$). We found a highly significant difference in DC1 values between sampling distances from the water points ($F = 17.65$, $P < 0.0001$, d.f. = 4, 12). DC1 values at 200 were significantly lower than at any other distance from the water points, but generally increased with distance from the water points ($P < 0.05$, Table 3). There were no significant differences in DC2 values ($F = 0.53$, $P = 0.7160$, d.f. = 4, 12). These results indicate that the most important axis in the ordination of woody species was the livestock pressure gradient around the artificial water points.

The percentage of variance in herbaceous plant species abundance explained by the first two axes in the DECORANA was low (DC1 = 21.3%, DC2 = 7.5%). There was a negative significant correlation between DC1 values and herbaceous species diversity along the grazing gradient ($r = -0.66$, $P < 0.0001$, $n = 40$), however, the correlation between DC2 values and herbaceous species diversity was non-significant ($r = 0.002$, $P = 0.9882$, $n = 40$). We found highly significant differences in DC1 values between sampling distances from the water points ($F = 35.06$, $P < 0.0001$, d.f. = 4, 12). DC1 values at 200 and 600 m were significantly higher than those at the remaining distances ($P < 0.05$, Table 3), while values at 200 m were significantly higher than at 600 m. There was no significant difference in DC2 values between sampling points from water points ($F = 0.60$, $P = 0.6666$, d.f. = 4, 12). Again, these results indicate that the most important axis in the ordination of herbs (DC1) is primarily a grazing intensity axis, and that herbaceous abundance increased with declining diversity towards the water points. The secondary and tertiary axes indicated significant differences that existed in herbaceous abundance between the settlements.

Basal area

Basal area of woody plants varied significantly along a distance from water points ($F = 13.89$, $P < 0.001$, d.f. = 4, 12). Mean basal area declined with distance from water points (Table 4). Trees at 200 m had the biggest mean basal area, while there were no further significant differences among the remaining distances from the water points (Scheffe test, $P > 0.05$).

Woody Plant height

Plant heights differed significantly with distance from water points ($F = 5.88$, $P < 0.05$, d.f. = 4, 12). Trees at 200 m were significantly taller (mean±SE, 2.43 ± 0.107 cm), while those further away from water points did not differ significantly in height (Scheffe test, $P > 0.05$) (Table 4).

Canopy area

Mean canopy area differed significantly along the grazing gradient ($F = 25.38$, $P < 0.0001$, d.f. = 4, 12). Trees in the vicinity of water points (200 m) had significantly the biggest canopy area (Table 4). Canopy area at 600 m and further away did not differ significantly (Scheffe test, $P > 0.05$).

Table 4. *Mean±SE woody plant basal area, height, canopy area and density at distances from water points. Different letters indicate significant differences in mean values at $P < 0.05$. Data were log-transformed.*

Distance (m)	Basal area (cm^2)	Plant height (cm)	Canopy area (cm^2)	Woody density (m^{-2})
200	2.59 ± 0.125 a	2.43 ± 0.107 a	5.1 ± 0.16 a	0.01 ± 0.005 a
600	1.90 ± 0.141 b	2.08 ± 0.053 b	4.5 ± 0.11 b	0.06 ± 0.017 ab
1200	1.65 ± 0.075 b	2.07 ± 0.043 b	4.2 ± 0.05 b	0.11 ± 0.014 b
2500	1.64 ± 0.121 b	2.09 ± 0.030 b	4.2 ± 0.07 b	0.15 ± 0.033 b
4000	1.75 ± 0.126 b	0.02 ± 0.046 b	4.2 ± 0.07 b	0.15 ± 0.024 b

Woody plant density

Livestock activities around water points affected plant density significantly ($F = 10.92$, $P < 0.001$, d.f. = 4, 12). Plants were sparsely distributed around 200 to 600 m off the water points, but increased gradually in density with increasing distance. Mean tree densities at 200 and 600 m (Table 4) did not differ significantly ($P > 0.05$), however only woody density at 200 m was significantly lower than at 1200, 2500 and 4000 m ($P < 0.05$). Thus mean tree density did not differ significantly at 600, 1200, 2500 and 4000 m from water points.

Soil organic carbon

Soil organic carbon did not differed significantly across the distance from water points (F = 1.98, P = 0.1621, d.f. = 4, 12). Mean organic carbon differed significantly across the soil profile (F = 42.97, P < 0.001, d.f. = 2, 6). Organic carbon content was significantly higher in the 10-20 cm depth (Scheffe test, P < 0.05), while no significant differences existed between the 50-60 cm and 90-100 cm depth (Table 5) (Scheffe test, P > 0.05).

Total nitrogen

Total nitrogen in the soil did not differ across the distance from water points (F = 1.041, P = 0.4264, d.f. = 4, 12). However, mean total nitrogen differed significantly across the soil profile (F = 29.66, P < 0.001, d.f. = 2, 6). Mean total nitrogen was significantly higher in the 10-20 cm layer than down the soil profile (Table 5). No significant differences existed between the 50 – 60 cm and 90 – 100 cm soil depths (Scheffe test, P > 0.05).

Available phosphorus

The individual effects of distance and depth on soil phosphorus content were not significant (P > 0.05). However, their interaction effect was significant (F = 4.80, P = 0.0013, d.f. = 8, 24). A Scheffe *post hoc* test revealed that the 10-20 cm layer at 200 m from the water points contained significantly higher phosphorus content, than at any other depth and distance from water points (Figure 3). Phosphorus content away from the water points and at 50-60 cm and 90-100 cm depths at 200 m did not differ significantly (Scheffe test, P > 0.05).

Soil moisture

Soil moisture did not differ significantly across the distance from water points (F = 1.84, P = 0.1859, d.f. = 4, 12). However, it differed significantly across the soil profile (F = 11.65, P = 0.0086, d.f. = 2, 6). The 10-20 cm soil layer contained significantly lower moisture content than at 50-60 cm and 90-100 cm depths (Scheffe test, P < 0.05), and no significant differences existed between the latter depths (Table 5).

Table 5. *Mean±SE soil organic carbon, total nitrogen and soil moisture across the soil profile. Different letters indicate significant difference in mean values at p < 0.05.*

Distance (cm)	Soil organic carbon (%)	Total nitrogen (ppm)	Soil moisture (%)
10-20	0.228±0.0197 a	13.177±0.5281 a	0.308±0.0094 a
50-60	0.146±0.0093 b	10.708±0.6235 b	0.400±0.0238 b
90-100	0.112±0.0070 b	9.406±0.6091 b	0.436±0.0332 b

Discussion

Vegetation and soil changes along a grazing gradient

Sinking boreholes to tap groundwater resources facilitated all-year round livestock production in the semi-arid Kalahari, and high livestock pressure around artificial water points often leads to undesirable vegetation and soil changes (Andrew 1988, Thrash 1998). We found that livestock activities near the water points had significant impacts on vegetation and soils. The status of vegetation and soil around the water points reflected the situation of continuous livestock pressure on relatively homogenous dune fields of the northern Kalahari after 32 to 51 years of livestock production.

Fewer, but taller trees with broader canopy areas grew near the water points. Tree density declined with 91 %, while their height and canopy area increased with about 96 % and 16 % respectively around 200 m from the water points in comparison with farther distances (Table 4). It appears that reduced competition for soil nutrients and moisture among the sparsely distributed trees, and increased phosphorous fertilisation from dung may have been responsible for increased plant growth. Soil moisture, organic carbon and nitrogen did not differ across the distance from water points, but because of fewer trees near water points more resources could have been available for the individual trees. Livestock trampling may have reduced soil moisture in the upper layer of the soil, whilst scattered woody distribution in the vicinity of water points may reduce evapotranspiration resulting in the higher moisture down the profile (Dougill & Cox 1995). The predominant matrix flow of water movement in the Kalahari allows nutrient adsorption onto soil particles (Dougill *et al*. 1998). Hence, Dougill *et al*. (1998) suggested that high nitrogen and phosphorus would remain in the upper soil layer because of the low mineralization and adsorption onto soil particles. We found higher organic carbon and nitrogen content at 10 – 20 cm depth than at lower depths despite higher soil moisture down the soil profile. Available phosphorus in the upper soil layer was only high at 200 m from water points, and may have resulted from dung deposition by cattle supplemented with phosphorous licks. Phosphorus is generally very low in the Kalahari environment (Mendelsohn *et al*. 2002).

Herbaceous abundance increased with proximity to the water points. These results suggest that disturbance decreased species diversity, but increased the population size of herb species in the vicinity of water points. Graminoid species such as *Setaria verticillata*, *Cynodon dactylon* and herb species such as *Sida cordifolia*, *Acanthospermum hispidium*, *Tribulus terrestris*, *Amaranthus thunbergii* and *Indigofera* species were most abundant (Katjiua & Ward, unpublished data) and may be indicators of land degradation. The combination of high soil fertility, especially phosphorous out of those measured in the upper soil layer and reduced tree density may have increased the intensity of the above-ground herb interspecific competition which resulted in fewer species, but with high abundances (Wilson & Tilman 1991). In this system, selective herbivory may have altered community structure by enhancing the abundance of unpalatable species. Disturbance and low tree density favours the production of herbaceous species (Barker *et al*. 1990, James *et al*. 1999), while livestock activities may reduce the establishment of perennial species (Britz *et al*. 2002).

Spatial and temporal vegetation change under grazing

This study showed that the current pattern of vegetation was significantly altered near the water points. However this result does not confirm with certainty that livestock impact is only confined to the areas near the water points. Livestock in the study area had unrestricted movement on the rangeland and normally returned to the water point every other day. The non-significant differences away from water points may be a reflection of small sample size, given the clear differences observed during field reconnaissance and elaborated on in the descriptions of the different zones. The absence of long-term data is a limitation; hence we cannot ascertain the nature of change. However, long-term observations by pastoralists revealed that the structure of plant community has changed substantially from an open savannah to a more closed savannah ecosystem all over the rangelands since the commencement of sedentary settlements around the artificial permanent water points some 32 to 51 years ago (Katjiua & Ward unpublished data). The effects of grazing on the structure of plant communities depend on the distance livestock travel from water points (Jeltsch *et al*. 1997) and temporal scale (Ward *et al.* 1998). Simulation data for the arid and semi-arid environments, southern Kalahari (Jeltsch *et al.* 1997) and northern Australia (Pickup 1994), showed that the effects of cattle grazing on vegetation can indeed extend beyond 7 000 m from artificial water points, which is further than what this study could possibly assess given the high density of pastoral settlements in the study area. Historically livestock production has significant impact on the structure of plant communities in Namibia, even if current local-scale data suggest that the impact is confined to the areas near water points. Grass production in Namibia has decreased by approximately 100% between 1939 and 1997 (Ward *et al*. 2004), while woody plants have increased in density over much of Namibia's rangelands over the past 40 to 50 years (De Klerk 2004).

However, a distance of more than 10 000 m between water points would potentially minimise the expansion of negative impacts on range resources under continuous grazing production systems, and ensure grazing reserves mid-way between settlements (Walker *et al*. 1987). Thus such distance may prevent starvation-induced mortality during droughts (Owen-Smith 1996). The 7 000 m distance applied by the Ministry of Agriculture, Water and Forestry for spacing water points between pastoral settlements may intensify land degradation and increase drought vulnerability under continuous grazing production systems. In addition, the current uncontrolled fencing and subdivisions of communal rangelands by some pastoralists may confine livestock foraging activities, thereby causing excessive livestock pressure which may lead to potentially undesirable vegetation change. The development of community-based rangeland management institutions is a potential avenue for introducing controlled stocking density and rotational grazing at village level.

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Determining carrying capacities in highly variable and unpredictable environments - A Namibian perspective

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Abstract
Based on available national-level information, this paper proposes an approach to livestock status assessment in Namibia. Although there is no consensus on the appropriateness of equilibrium versus non-equilibrium models in arid rangeland science, planning tools are badly needed in developing countries where the majority of the population rely on livestock farming. The proposed map of stocking status in Namibia incorporates elements of both, conventional (equilibrium) concepts of range science in the form of carrying capacity, but also includes a measure of unpredictability of the environment (risk of farming), thus an element of non-equilibrium models. This map provides a planning tool for directing further field assessments and rangeland research in Namibia.

Key words: desertification, equilibrium, livestock, rangeland, resource management, Southern Africa

Introduction
Adapting livestock numbers to what the land can support sustainably is of pivotal importance in arid and semi-arid rangelands. This is particularly so where livestock farming is often the only means for the rural population to make a living, such as in many parts of Namibia. Rangeland degradation is evident in Namibia (Seely *et al.* 1995; Zimmermann 2010) and there is debate on whether or not equilibrium or non-equilibrium models apply to Namibian rangelands, as elsewhere in arid rangelands (e.g. Ellis & Swift 1988; Mentis *et al.* 1989; Westoby & Noy-Mei, 1989; Gillson & Hoffman 2007).
While there is no consensus on the appropriateness of either concept (Cowling 2000), planning tools are badly needed as an important step towards reversing rangeland degrading processes and to guide national initiatives such as the government's resettlement programme (Falk *et al.* 2010). One such planning tool has been compiled on a national level in Namibia in a comprehensive publication of environmental data (Mendelsohn *et al.* 2002). The "Atlas of Namibia" includes a suggestion for determining the status of stocking rates by combining a map of carrying capacity with stocking density. Carrying capacity was based on the assessment of the Agro-Ecological Zoning project of the Ministry of Agriculture in Namibia and a UNDP

report (1998). The resulting composite map illustrates areas that are overstocked and those that have potential for more stock (Mendelsohn *et al.* 2002, p. 151). Although the explanatory text makes reference to the debate on determining carrying capacity, the composite map carries the risk that, if used in isolation, it may convey misleading information for development planning. However, the authors also provide a nation-wide assessment of risk of farming, based on average and variation in rainfall and plant productivity (Mendelsohn *et al.* 2002, p. 152). The purpose of this paper is (1) to suggest a transparent method for combing these two maps, and (2) to review the resulting "stocking status" against published information from the field. The resulting map would provide a planning tool for rangeland management which also incorporates a measure of environmental variability, thereby incorporating elements of equilibrium and non-equilibrium rangeland theory.

Materials and Methods

A transparent process to combine the quantitative data of the livestock density minus carrying capacity map (referred to as "composite map") (Figure 1) with the qualitative data of the "risk of farming map" (Figure 2) is required. In order to align the values of the composite map with the seven qualitative classes of the risk map, intervals of 10 were used and values were assigned to seven classes in the risk map in a reverse order (i.e. high = 60, low = 0). The reverse order would match the range of values on the positive (understocked) side of the composite map scale (Table 1). The values of the risk map were then subtracted from those of the composite map for each resulting mapping unit. The same class interpretations as in the composite map were used in the resulting map of stocking status (Table 1). However, while the composite map is based on real values (kg livestock weight / unit area), the livestock status map generated relative values, as it was not possible to convert the risk of farming to livestock-related field data.

Table 1. *Class intervals and median of composite (livestock density minus carrying capacity; values reversed from classification of Atlas of Namibia to indicate positive for potential for more stock) and risk of farming map; and class intervals for stocking status map (there were no polygons in the class ranges -80 to -60 and -100 to -80, and these have thus been omitted from the map).*

Livestock density minus carrying capacity (kg/hectare)		**Risk of farming**		**Stocking status**	**Interpretation**
Existing class	**Median**	**Existing class**	**Median**	**Class**	
More than 60	70	1 (high)	60	More than 60	potential for more stock
40 to 60	50	2	50	40 to 60	
20 to 40	30	3	40	20 to 40	
-20 to 20	0	4	30	-20 to 20	near carrying capacity
-20 to -40	-30	5	20	-20 to -40	overstocked
-40 to -60	-50	6	10	-40 to-–60	
-60 to -80	-70	7 (low)	0	Less than -100	
-80 to -100	-90				
Less than -100	-110				

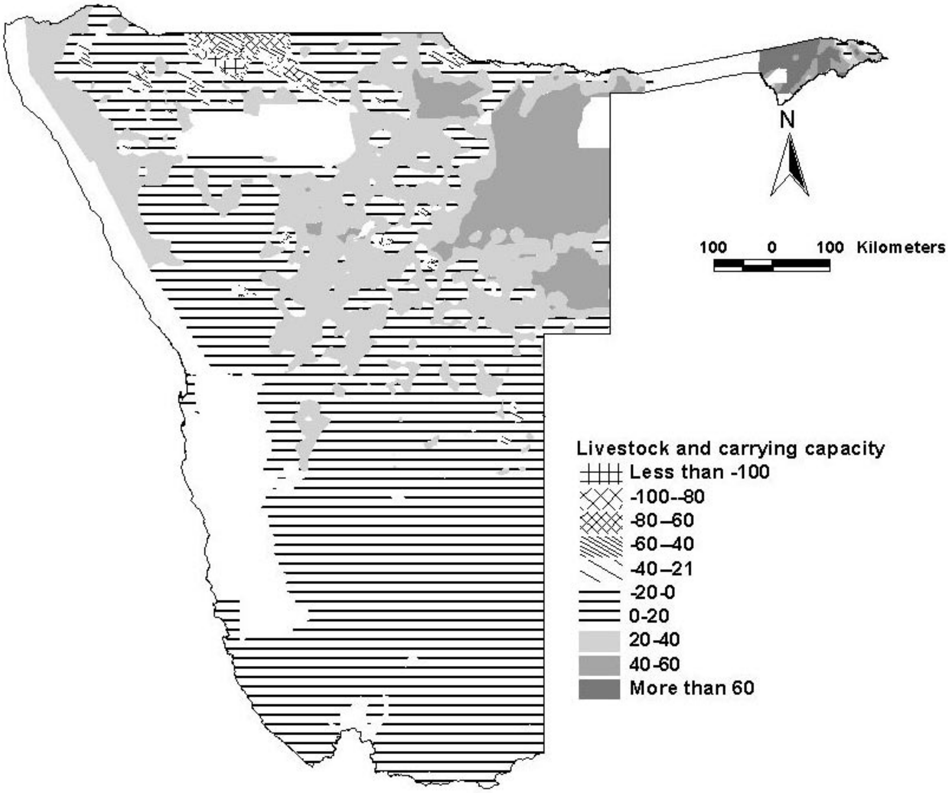

Figure 1: *Composite of stocking rates minus carrying capacity (kg/ha) (white = protected areas) (after Mendelsohn et al., 2002; values are reversed to indicate positive for potential for more stock).*

Results and Discussion

The resulting map of stocking status (Figure 3) showed a similar pattern to the composite map (Figure 1), but areas showing potential for additional stock are approximately 50 % reduced due to the high risk of farming in half of the country. This is particular evident in the western, arid regions, which also experience the highest variability in rainfall and resulting plant production. Areas with potential for more stock (all shaded areas in Figure 3) are now only found in the higher rainfall areas in the north-east of the country with extensions into the central area. The inclusion of "risk of farming" has eliminated all areas in the arid west that were depicted on the composite map as having potential for more stock (Figure 1).
Does the resulting map of livestock status provide a better reflection of areas that may have potential for more stock than the composite map? Although field assessments in all resulting mapping units are required to verify these maps, assessments available in the literature give

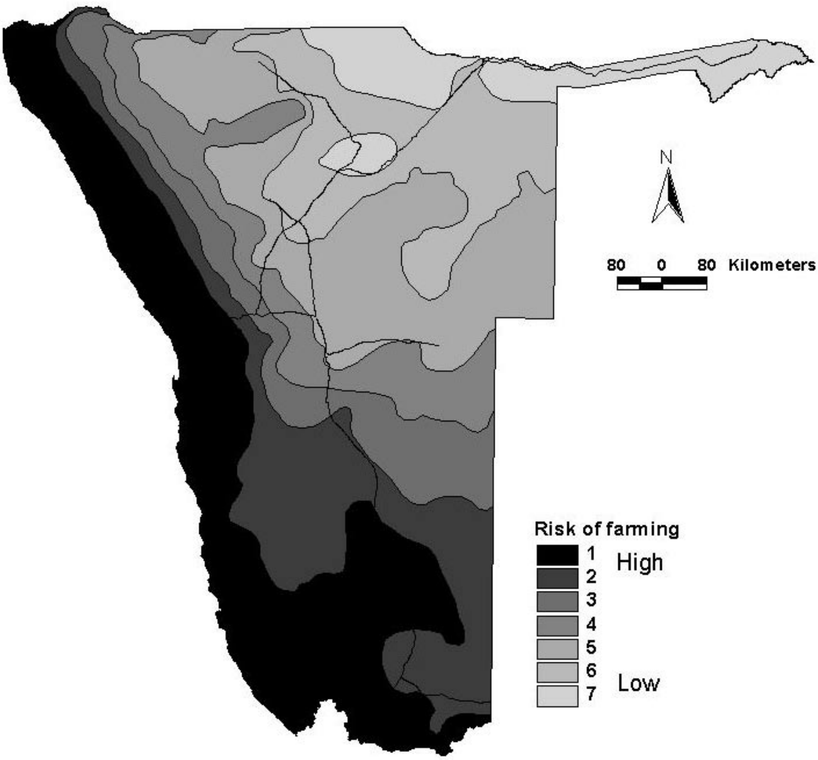

Figure 2: *Risk of farming (after Mendelsohn et al., 2002).*

some indication. Some of the areas depicted on both maps as suitable for more livestock, for example in parts of the Caprivi and Kavango Regions, have indeed been evaluated in field assessment to be able to absorb more livestock (Hines & Burke 1997; Burke 1998; Directorate of Rural Water Supply 2000). However, similar assessments for the Kunene Region in areas depicted on the composite map with potential for more livestock (Figure 1), but now with no further potential for additional livestock once risk of farming was incorporated (Figure 3), report degradation in many of these areas (Schulte 2002) and a reduction in livestock numbers has been called for (Directorate of Rural Water Supply 2001). Similarly rangelands in the central west of Namibia (Erongo Region) are stocked under the nationally recommended carrying capacity due to a shortage of available grazing, despite an abundance of water points (Burke 2004). Many areas in the south of Namibia, depicted as stocked to capacity on the composite map (Figure 1), are degraded, particularly in the communal areas (e.g. Dreber & Falk 2010). The stocking status map shows these now as negative, thus no more potential for absorbing more livestock (Figure 3).

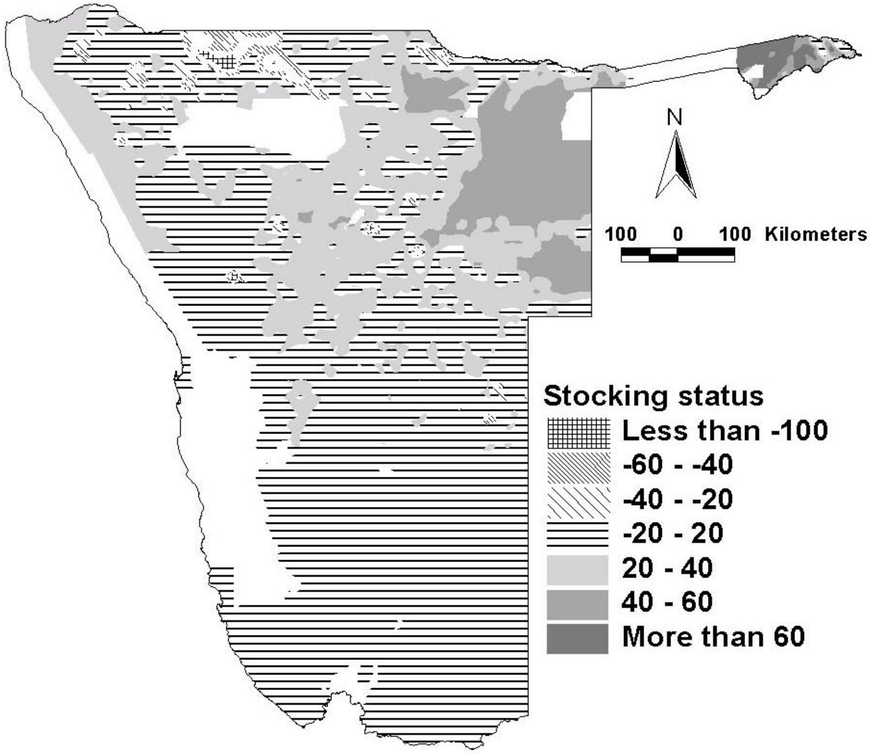

Figure 3: *Stocking status based on composite map incorporating risk of farming (white = protected areas; shaded areas indicate potential for more livestock).*

Although the new map of stocking status provides a tool at the national level, and appears to provide a more realistic reflection of the status of Namibian rangelands, some aspects have to be kept in mind when using this map. (1) The level of detail in the underlying base data determines the final outcome of the composite and stocking status maps. Maps of carrying capacity in Namibia vary widely (van der Merwe 1983; Sweet 1998; Ministry of Agriculture 1998), and the choice of map integrated in this process will determine the outcome of the synthesised maps. (2) Although the stocking status map was based on a mathematical procedure and long-term data, there are different ways to combine these data. The values in the stocking status map have no direct correlation to livestock-related field data and this map only provides a relative measure. In a field situation, for example, a high risk of farming does not necessarily require the subtraction of 60 kg/hectare from established carrying capacities. (3) A national level assessment cannot incorporate the detail expressed in topography and resulting vegetation types on the ground. Large mapping units show variation in usage, particularly where topography is varied (Directorate of Rural Water Supply 2001). Animals do not graze or browse homogeneously over vast areas (DeSimone & Zedler 1999), and as elsewhere in arid rangelands (Milchunas & Noy-Meir 2002), grazing impacts in Namibia are higher in level areas than on slopes (Joubert 1997), and in certain vegetation types (Burke 1997; Strohbach 2000). Forage quality differs significantly between vegetation types. For example, *Burkea* savannah in the north-east of Namibia (Burke 2002) which is depicted as understocked (Figures 1 & 3), is a very nutrient poor vegetation type with many unpalatable species, slow regrowth and thus poor resources for herbivores (Byrant *et al.* 1989). Carrying capacity, numbers of livestock and farming risk cannot provide an indication of the condition of the rangeland. Hence all areas depicted with potential for more stock (Figure 3) will require detailed field assessments prior to development (e.g. water points or resettlement), particularly with regard to status of the rangeland and grazing management. This map provides guidance at the national level, but the status of the rangeland needs to be determined in the field and at the scale of the proposed development.

Conclusion

The developed map of stocking status in Namibia provides a planning tool for rangeland research and management and appears to indicate a realistic assessment of stocking status in areas where information from the field has been published.

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Thanks are due to the Namibian Atlas team (John Mendelsohn, Alice Jarvis, Carole Roberts and Tony Robertson) and many rangeland researchers who contributed to compiling the background data. The Government of Finland is acknowledged for providing financial support to the atlas project and the Ministry of Environment and Tourism for providing access to these data. Valuable comments from a reviewer improved the manuscript.

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Short Communications

A Simple Aid to Assessing Cryptic Succulents in the Field

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By virtue of their very nature, cryptic succulents present a challenge to workers trying to assess populations in the field. They are difficult to spot (e.g. Figure 1) and, once spotted, are easily missed again if you take your eyes off of them. They may also be counted or assessed more than once by mistake, particularly if several people are involved in the work. Regularly faced by this challenge, we came up with a cheap and simple tool that we have generally found to be useful, as well as easy to carry and use.

Figure 1: *Lithops ruschiorum in situ.*

We obtained several hundred brightly coloured plastic balls of the type used in children's playground equipment. These are the kind that children "swim in". We cut them in half and now use them to temporarily mark the location of plants in the field (Figure 2).

These markers are light and easy to carry. They are not excessively bulky because they slot into one another. Although they tend to be blown around in high winds, due to their "cup" shape they can easily be weighted down using sand or pebbles. They are easy to see (Figure 3) and can be numbered or counted beforehand if this is considered necessary. In very undulating terrain pre-counting can be useful so as to know at the end whether all the markers have been found and the plants they are marking assessed. To reduce the time spent calculating how many markers have been set out, ziplock bags each containing a given number can be pre-packed, or the markers can be threaded onto a loop of wire with separators such as large beads or plastic discs at given intervals.

Figure 2: Once individuals have been spotted the markers make it easy to move from one individual to the next for assessment, preventing duplication and unnecessary damage. They can be weighed down if necessary.

Figure 3: *The extent of a population of Lithops ruschiorum made visible by temporary markers.*

Besides making it easier to know whether or not an individual has already been assessed, we find that marking in this way reduces trampling of the area and thus damage to the plants. It is also easy to establish the periphery of the population, walking from one marker to another with a GPS, easily seeing which plants are the outermost. The lightweight and temporary nature of these markers ensures minimal disturbance to the habitat.

One risk of using this method is that substrate important for the plants, such as pebbles, may be disturbed. The necessity to avoid this must be impressed upon all workers involved in the assessment. Obviously, to avoid pollution, all the markers must also be found and removed once the work is finished.

We have found this tool to be less useful where grass cover is dense as well on very steep slopes or in areas where there are numerous large boulders. However, once plants on a steep segment have been counted the requisite number of markers can be slotted together and placed at the slope base to obviate any unnecessary recounting.

The balls are sold in bags of mixed colours. In our work in Namibia we find the most visible colours are red, royal blue, bright purple and bright pink. Yellow and pale colours are less easy to spot, especially on quartz fields and as distance increases. These latter colours can, however, still be used in small areas, in the very first part of a population, or in dense populations in a small area.

These markers are extremely durable, although some are better quality than others. We have used them to increase speed and accuracy in assessments of genera such as *Avonia*, *Dinteranthus, Lapidaria* and *Lithops,* and they would probably work just as well for many more, including *Anacampseros* and *Conophytum.* We think other workers may find them equally useful.

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Opinion Notes

Beyond species lists - Endemics and their use in environmental management in Namibia

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Abstract
Endemics are used as indicators of conservation importance because of their limited distribution ranges and thus risk of extinction. Environmental impact assessments therefore often use endemics to identify environmentally sensitive areas and to guide development decisions. However, endemic-rich countries such as Namibia will need to go beyond national level endemism to develop appropriate criteria for the protection and management of endemics in the course of development projects. With the aim to achieve greater transparency in environmental assessments, a tool is introduced which uses level of endemism appropriate to the impact area and a selection of red list criteria to determine appropriate management actions.

Keywords: biodiversity and environmental impact assessment, indicators, mitigation, Namib endemics, risks, scale, target species

Introduction
Because of their limited ranges endemics are often used as indicators of conservation importance. Conservation planning, for example, relies on information about their distribution to determine conservation priorities (e.g. Lovett *et al.* 2000; Cavieres *et al.* 2002; Allen 2007). Nowadays biodiversity assessments form an important part of the environmental assessments process and endemics are often used to identify and delineate environmentally sensitive areas and to guide development decisions (Koziell & Omosa 2003; Slootweg & Kolhoff 2003; Wegner *et al.* 2005). However, in developing countries the information on endemics is often only available at a national level, as field work has not been sufficient to obtain a good understanding of the distribution and abundance of endemics in the area in question (e.g. Barnard 1998; Simmons *et al.* 1998). While coarse resolution data may be adequate to undertake regional assessments and investigate broad patterns (e.g. Cowling & Lombard 1998; Taplin & Lovett 2003); it poses challenges when trying to use endemics to influence management decisions at a local level. The question for environmental practitioners arises

regarding management actions to prescribe when endemics are affected by proposed developments. Unlike some countries (e.g. EPA Western Australia 2009), there are no guidelines in Namibia how to define “species of conservation importance”, definitions vary widely and different approaches are used. Does the mere occurrence of an endemic plant or animal at the site to be developed warrant to stop the development, for example (Business and Biodiversity Offsets Programme 2009)? Or can mitigation measures be developed and implemented for all endemic species? Can all impacts on endemics be managed to assure minimal damage? Only few environmental assessments in developing countries which incorporate biodiversity aspects have successfully implemented mitigation measures, because the technical, ecological and economic feasibility of the suggested measures are not sufficiently evaluated (UNDP, UNEP & GEF 2001). Prioritising target species for interventions is one way of ensuring that appropriate measures are developed.

Besides maintaining ecologically functioning ecosystems, the ultimate purpose of environmental management actions related to biodiversity, is to avoid losing entire species, and to minimise the impact on species of conservation importance (Matsuda 2003; BBOP 2009). The likelihood of this to happen, increases as the distribution range of a species becomes smaller. Small distribution ranges occur naturally (Magurran & Henderson 2003), or are often created by human activities encroaching on habitats that contain many species associated with a certain type of habitat (Millennium Ecosystem Assessment 2005). Sessile endemic species, such as endemic plants in the terrestrial- or benthic organisms in the marine context are thus always candidates for special protection or management actions during environmental assessments (Tyler-Walters *et al.* 2008). Typically, endemics are used during environmental assessments (1) to identify sensitive habitats, often delineated as “no-go” conservation areas to be kept out of bounds during the development of a site, (2) to develop special species management - (e.g. translocation and restoration) and monitoring plans for the affected endemics, or (3) to develop suggestions for more detailed study, if available information is believed to be too fragmentary.

In endemic-rich areas, such as the Namib Desert (Robinson 1978; Werger 1978), endemics always occur in the area to be assessed (e.g. Burke 1997; Mannheimer 2006) and developing management actions for all of these is neither feasible, nor warranted, unless there is a risk of extinction of certain species. Prioritising these will help to develop feasible management actions. This study with examples from the Namib Desert illustrates how using different levels of endemism can facilitate identifying priority species and provides a practical tool for using level of endemism in biodiversity assessments.

Materials and Methods

Study area

The Namib Desert on southern Africa’s west coast stretches for just over 1,000 km from south of the Orange River in South Africa to southern Angola. Two contrasting climate regimes reign in the Namib Desert. The southern hemisphere’s temperate cyclone system influences the south and this area receives winter rains regularly. The vegetation there is typical of southern Africa's Succulent Karoo Biome (Burke *et al.* 2002). The central and northern part of the Namib Desert, however, falls within southern Africa's summer-rainfall regime and the vegetation is characterised by ephemeral grassland and localised patches of shrubland (Jürgens *et al.* 1997). The high level of endemism typical of the Succulent Karoo Biome (Cowling & Hilton-Taylor 1999) is also reflected in the southern Namib, particularly amongst plants. The central and northern Namib on the other hand, harbour lower numbers of endemic species, but endemics are often very abundant, forming the dominant vegetation (Burke 2007).

Data analysis

Plant species lists from environmental assessments for mining developments across the Namib Desert were analysed with regard to occurrence of Namibian, Namib and local endemics as well as near-endemic plant species. The sites ear-marked for mining developments were, from south to north: Sendelingsdrif, Skorpion and Pocket Beaches (all three southern Namib) and Rössing and Trekkopje (both central Namib). Based on the investigation of distribution records from published sources (Craven 2002), the National Herbarium's plant specimens database and own observations, different levels of endemism were assigned to the recorded plant species. Namibian endemics were defined as occurring within Namibia's political borders and near-endemics as occurring in the Gariep Centre and Kaokoveld centres of endemism as described by van Wyk & Smith (2001), but within the borders of the Namib Desert. Namib endemics were defined as occurring in the Namibian part of the Namib Desert and local endemics as occurring within the central or southern Namib respectively, following Giess' (1971) definition of subdivisions of the Namib Desert. Comparisons between different levels of endemism were made.

Development of assessment tool

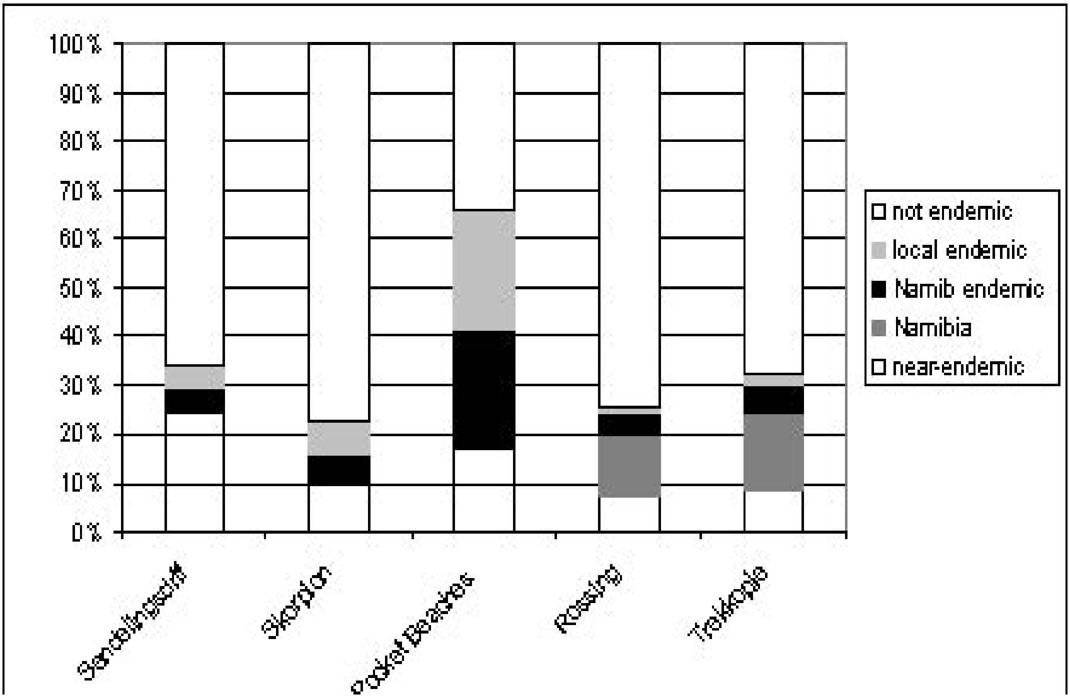
An assessment tool to link level of plant endemism with management actions was developed, using the guidelines of the South African National Biodiversity Institute (Driver *et al.* 2009) as a basis, but adapted to the Namibian situation. This takes the status of biodiversity knowledge as well as the nature of Namibia's flora into account. In the Namibian context level of endemism is considered the base criterion, because (1) endemism is one of the key aspects of Namibia's flora, and (2) Namibia's red list for plants (Loots 2005) would require some further refinement to make it useful for this purpose. For example, many "rare" species (IUCN 2001) have presently not been assessed. Therefore endemics provide a more robust indicator.

Prioritisation using endemics

A total of 624 plant species were included in the analysis. Overall, 36 local endemics, 13 Namib endemics, 45 Namibian endemics and 66 near-endemics were counted. The southern Namib sites (Sendelingsdrif, Skorpion and Pocket Beaches) harboured by far the most local endemics, including coastal endemics such as *Eremothamnus marlothianus* and *Marlothiella gummifera* as well as inland endemics such as *Bulbine namaensis* and *Pteronia pomonae*. Only five local endemics were present at the central Namib sites, including the succulents *Aloe namibensis* and *Hoodia pedicellata*.

As expected, the percentage of endemic plant species at different levels of endemism varied across sites (Figure 1). At the three southern Namib sites (Sendelingsdrif, Skorpion and Pocket Beaches) only local endemics and near-endemics were recorded. The two central Namib sites, however, show marked differences between levels of endemism (Figure 1). With regard to risk of extinction only local, and under certain circumstances Namib- and near-endemics would possibly be threatened by developments, and these are therefore important indicators for environmental assessments.

Figure 1: *Percentage plant endemics at different sites across the Namib Desert (local endemics = occurring in southern Namib or central Namib only; total species included in analysis: Sendelingsdrif: 41, Skorpion: 192, Pocket Beaches: 70, Rössing: 138 and Trekkopje: 183).*



Endemics and management actions in Namibia

Environmental assessments, particularly in the developing world, suffer from lack of transparency when it comes to assessing impacts on biodiversity (e.g. Ortega-Rubio *et al.* 2001; Mandelik *et al.* 2005). There is much debate regarding suitable indicators for biodiversity assessments (e.g. Lunt 2003; Cabeza *et al.* 2007) and how best to integrate these in the environmental assessment process (Wegner *et al.* 2005; Business and Biodiversity Offsets

Programme 2009). Avoiding the risk of extinction is the overarching goal and therefore endemics are good indicators during the environmental assessment process, provided that the level of endemism is appropriate to the impact area. A standard process of categorisation achieves greater transparency and, at a broad level, comparisons can be made across sites. One example of such a standard process is the biotope method, which arose out of the necessity to incorporate a measure of impacts on biodiversity in life-cycle assessments across different operations (Kyläkorpi *et al.* 2005), and which was then further developed with emphasis on a framework approach which takes site-specific conditions into account (Burke *et al.* 2008). In this approach levels of plant endemism constituted one important criterion in the biodiversity evaluation process at the landscape level.

Systematic approaches to the environmental assessment process are thus crucial to achieve greater transparency. With the purpose to introduce more transparency in environmental and biodiversity assessments in Namibia, recommended management actions related to level of endemism, and incorporating selected red-list criteria, are introduced (Table 1). The tool provides a 2-step process, whereby the level of endemism facilitates the narrowing down of species lists to those requiring more in-depth study. For those, the "additional criteria" require information on subpopulation, number of known sites and number of individuals. Good distribution records are the basis for undertaking such assessments with a reasonable level of confidence (e.g. Fraser *et al.* 2003), and this often poses a challenge in poorly collected areas. However, where such information is available, such as in the Namib Desert where information on distribution of plant species can be obtained from national databases, incorporating greater levels of detail regarding endemics is feasible.

Table 1: *Guidelines for developing management actions based on a 2-step process using level of endemism in Namibia and additional criteria commonly used in red list assessments.*

Level of endemism	Additional criteria	Recommendation
Local	Species range < 2000 km^2	No further loss of natural habitat
Namib	(1) Subpopulation affected not within threatened ecosystem or (2) not known from less than 10 sites or (3) not less than 1000 individuals of this species exist.	Limited habitat loss permitted, but restoration of viable population or offset required (e.g. effective protection of adequate number of subpopulations)
	If the antonym of one of the above applies	No further loss of natural habitat
Namibia	Subpopulation affected not within threatened ecosystem	Limited habitat loss permitted
	If the antonym of above applies	No further loss of natural habitat

Near-endemic	Species range < 2000 km^2	No further loss of natural habitat
	Species range > 2000 km^2 and (1) Subpopulation affected not within threatened ecosystem or (2) more than 1000 individuals of this species exist or (3) known from more than 10 sites	Limited habitat loss permitted
	If the antonym of (1), (2) or (3) apply	No further loss of natural habitat

Applying the tool to the case studies presented, no loss of habitat would be permitted for 2 plant species at Sendelingsdrif, 12 at Skorpion, 17 at Pocket Beaches, 1 at Rössing and 4 at Trekkopje, if a species range of less than 2,000 km^2 is assumed for all these species. This would, however, need to be determined for all these species and is considered feasible for the numbers affected. An additional Namib- and near-endemic 10 plant species at Sendelingsdrif, 18 at Skorpion, 12 at Pocket Beaches, 16 at Rössing and 23 at Trekkopje, would require further investigation with regard to the type of ecosystem affected, the number of sites recorded elsewhere, the position of subpopulations and a statement whether the number of individuals per species can reasonably be assumed to exceed 1,000. The number of species requiring such further information is not excessive in any of the study areas. At Rössing a further 17 and at Trekkopje 28 Namibian endemics affected by the development would have to be evaluated with regard to their position in a threatened ecosystem.

Current practice

In the central Namib prioritising management actions for species with the most limited ranges has, for example at Rössing Uranium, resulted in a field-based, detailed red-list assessments and species management plans for the most critical species (Loots 2009). A transboundary red-list assessment for a very rare, near-endemic was also initiated and supported by Namdeb at Sendelingsdrif. However, this did not follow a process of prioritisation based on level of endemism, but was based on the fact that limited distribution records existed for one species that would be affected by the proposed mine and thus, following the precautionary principle, a significant threat to the plant had to be assumed (Burke 2004). In this case eliminating near-endemics from further prioritisation for management actions would have been risky, as the threat of extinction of a species existed before further field work indicated a wider distribution of the near-endemic plant. However, the guidelines in this paper would have identified these species for further investigation.

Conclusion

More transparency in biodiversity assessments can be achieved, if clear criteria are used for selecting appropriate indicators and prioritising target species for intervention. Because of their limited range and thus greater risk of extinction, plant endemics are useful indicators, and a combination of level of endemism and selected criteria used in red list assessments, is proposed as a practical tool to prioritise.

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