RÖSSING BIODIVERSITY ASSESSMENT

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1. Introduction

1.1 Background

Rössing Uranium Limited (RUL, hereafter referred to as 'Rössing') has operated a uranium mine in the Erongo Region of Namibia, in the central Namib Desert, since 1976 (Figure 1). The mine comprises an open pit, rock dumps and tailings dam, and mine infrastructure associated with processing plants, manufacturing, maintenance and administrative operations (Figure 2), situated within the Mining Licence Area.

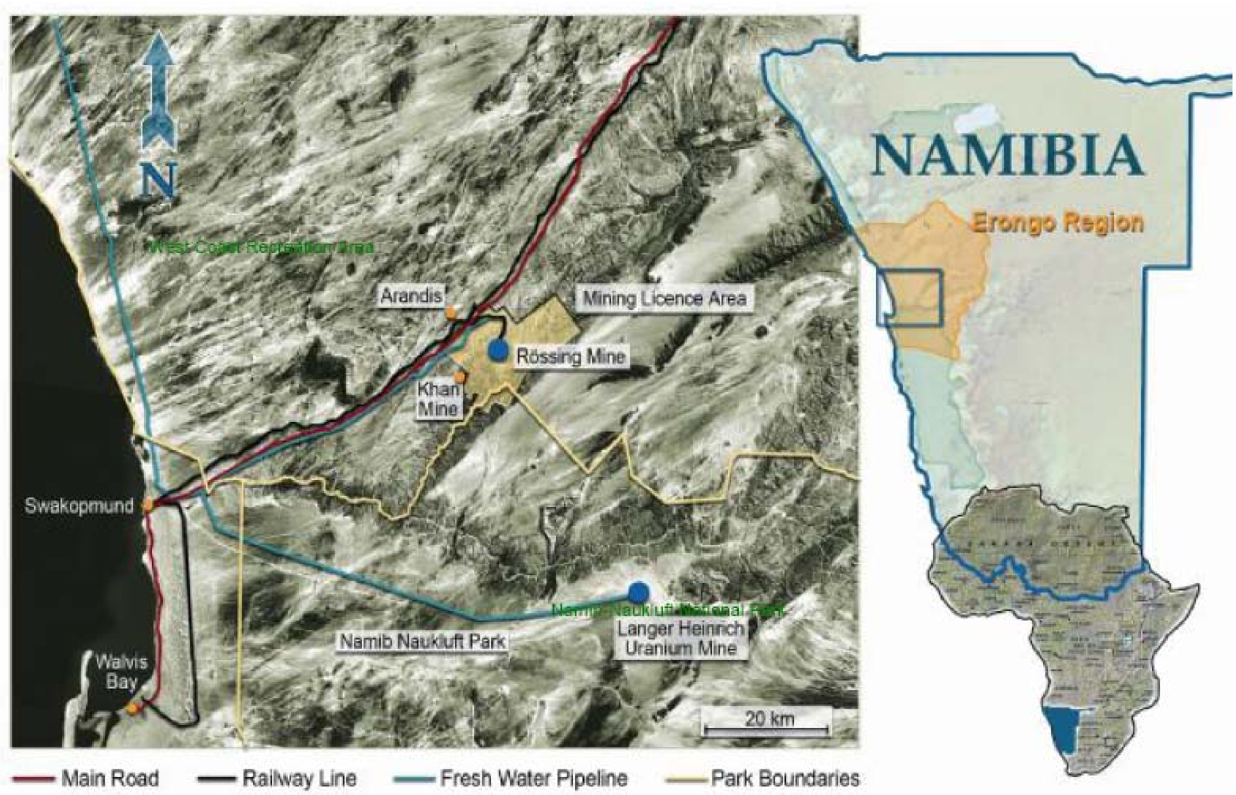

Figure 1: Location of the Rössing Uranium mine in the central Namib Desert, Erongo Region, Namibia. (Rössing Uranium Limited, August 2007).

Rössing is considering expansion of its operations that entail opening new pits with concomitant new disposal areas for waste rock, new or expanded processing plants, additional tailings dam capacity, and an increase in staff numbers and facilities. This will take place in a phased approach. Only three specific components, comprising Phase I, are being considered in the present EIA. These are:

- a sulphuric acid plant and associated storage and transport,
- a radiometric ore sorter plant and disposal of waste rock in the Dome are
- mining of an ore body known as SK4.

The acid plant and ore sorter will be situated on ground that is extensively disturbed by existing mine activities. In this phase, only the expansion into the SK4 area and Dome, and establishment of infrastructures to them, constitute activities that will newly impact on biodiversity in the Rössing area.

The scope of the current work considers biodiversity in the wider area, namely the Rössing Mining Licence Area and the surroundings (up to about 10 km away). In addition, we make recommendations with regard to the proposed expansion into SK4, where impacts on biodiversity will be felt soonest.

Figure 2: Satellite image of the Rössing Mining License Area highlighting the proposed new mining areas named SH and SK. SK4, the western-most tip of SK, is the area to be directly impacted in Phase 1. (Rössing Uranium Limited, November 2007)

1.2 Terms of Reference

The Terms of Reference for this work comprised description of a procedure, defined by Rössing, that was to be followed to implement the project. This was accepted by EEAN after review and some refinement in joint discussion with Rössing. The procedure was as follows:

Action 1: Inception meeting and site visit. The team considers that it will be valuable to meet the Rössing team that will be directing the project, and to have access to as much information as possible from Rössing at the very start. This information includes aspects such as long-term weather, hydrological and groundwater records, and any previous work of relevance such as the State Museum and other biodiversity projects. An inception meeting will facilitate exchange of information between the client and consulting teams, and will help to establish a common understanding of how this information will be used by the team.

Additionally, a preliminary visit to the project area and to the surroundings that will be included in the assessment, will be valuable. It will provide team members with a better idea of topography and habitats that will be encountered, and with at least some preliminary knowledge of the changes that would be expected, and where they would occur, from mine expansion.

This preliminary information-gathering exercise will also give a kick-start to the mapping work, as presumably some of the information is available in a GIS format that Rössing would want to build on.

Action 2: Status and distributional and ecological information pertaining to the known and expected animal species occurring in the area will be compiled into a format appropriate to the client’s needs. Follow-up of the 1980s work has already been initiated by Dr John Irish and will be brought to a conclusion.

Action 3: Field surveys of the biological soil crusts and lichens, invertebrate pit-trapping and collecting surveys and small vertebrate censuses will be conducted to work over the area for information pertaining to the distribution and occurrence of the species listed in Action 2.

While on site, habitats encountered within the mining lease area and within a radius of about 10 km will be identified, mapped and described.

Action 4:
Species lists will be compiled, including distribution and habitat information for all known and expected species.

Species will be ranked according to the criteria of vulnerability and irreplaceability, to identify those that have high conservation priority.

Action 5: Information from Action 4 will be fed in to the growing database, thereby gradually building up a model of conservation priority of the different habitats, and the spatial occurrence of the various habitats known to host high-priority species. Once the high-priority habitats are recognisable in terms of topography, vegetation and other features, it will be possible to check outlying areas for the occurrence of similar habitats.

Likewise, the botanical survey conducted by Antje Burke will be fed into the database.

Action 6: Compile multi-layered maps and reports that will be easily interpreted by decision-makers involved in planning the mine expansion, and make oral presentations to Rössing management on the conclusions and recommendations of the project.

Information collected in the entire exercise will serve as a useful baseline for future monitoring of occurrence and abundance of high-priority species.

1.3 Previous work

This report draws on biodiversity work done at Rössing over the last 23 years. Most important is the survey undertaken in 1984-1985 by State Museum staff, incorporating plants, terrestrial invertebrates and vertebrates and aquatic organisms, which is described fully in Irish 2007 (Appendix A). Different animal groups were surveyed with varying intensity and at six different sites in and around Rössing. For various reasons described in Appendix A, the work was not properly concluded. As far as is practically possible, this has now been done in the present study, although taxonomic work that progresses slowly but steadily will continue to add information to the current knowledge base in years to come.

A short spell of animal collecting was done for the current project, although it was recognized by both EEAN and Rössing management that the results from working in the hot dry season would not significantly add to the biodiversity information that existed already. A summary of the 2007 biodiveristy sampling is provided in Irish *et al*., 2007 (Appendix B). The main benefit of the work was to familiarize the team with the habitats in the Mining Licence Area and surrounds and to collectively consider the biodiversity impacts of mine expansion, with input from a range of specialists.

Rössing has, through the work of the botanist Dr Antje Burke, undertaken vegetation and biotope mapping in the area prior to this project (Burke, 2005), and as part of the current project (Burke, 2007). The results of this work are included in this report.

1.4 Project area

As described in Section 1.1, the focus of the current fieldwork was to assess biodiversity in the areas likely to be most impacted by the proposed mine expansion. We therefore selected three sampling sites within the Mining Licence Area which were directly in the areas of impact or close to them (in Phases 1 and 2) and had habitat that was typical of the areas to be directly impacted.

More broadly, the Terms of Reference required the assessment of animal biodiversity to cover the area of direct impacts as well as surrounding areas, within a radius of about 10 km. This would reveal whether species that were found in the Rössing area only also occurred in surrounding areas beyond the boundaries of Rössing's Mining Licence and Accessory Works areas. However, because it was impossible to assess distributions of all species, particularly invertebrates and those animals that are naturally rare, species occurrence had to be linked to habitats. The focus of the project therefore concentrated on habitats, largely determined by topography, occurring in and around the Rössing area. Visualisation of the project area is shown in Figure 3.

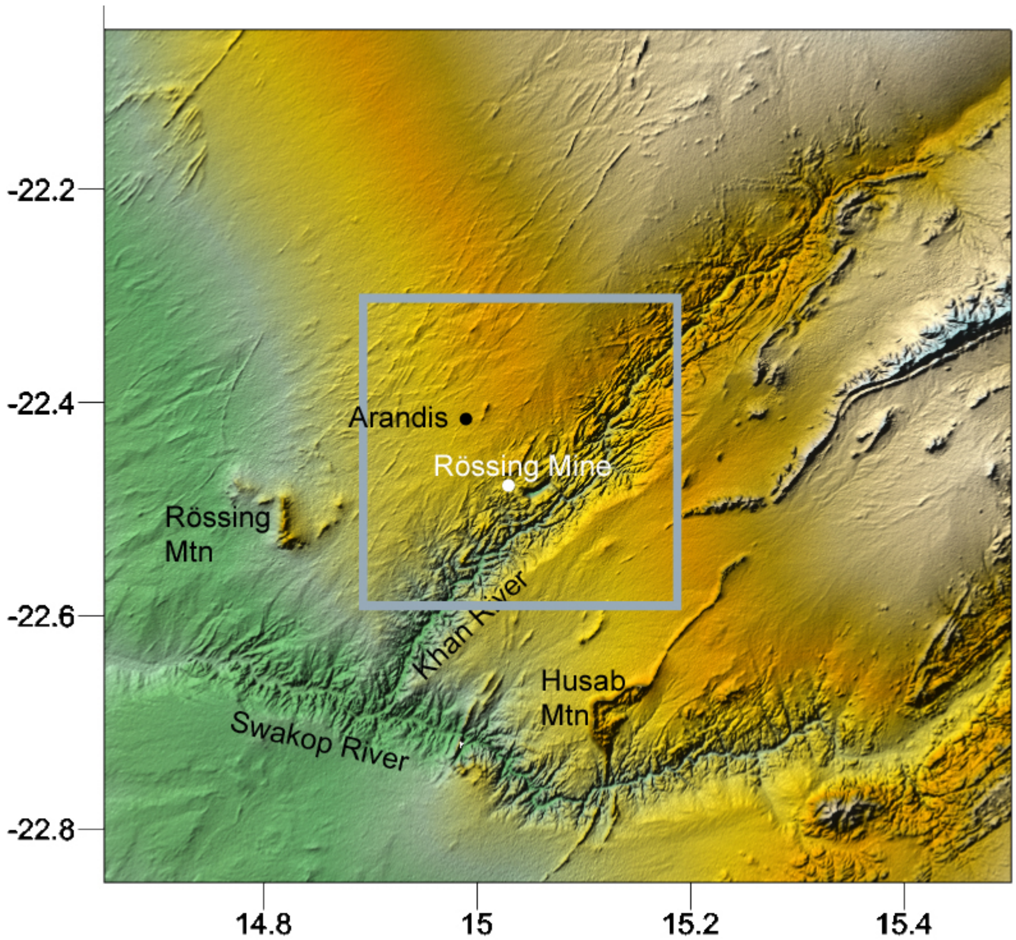

Figure 3: Rössing Uranium Mine in the context of the surrounding physical environment. The square delineates the project area.

2. Methods

2.1 Inception visit

The consulting team for the entire Social and Environmental Impact Assessment, led by Brett Lawson from Ninham Shand (Pty) Ltd., was introduced to the overall objectives of the project and the setting in which it would take place, during a two-day inception visit and mini-workshop. This took place on 17-18 September 2007, and involved only John Irish and John Pallett from EEAN. The proposed mine expansion process and desired goals were described by Rössing staff. A site visit was conducted, including a view over the SK4 area itself. All the consultants then described their individual components, information needs and expected deliverables. The schedule to have preliminary results available by early November, and final reports submitted by end November, was agreed.

2.2 Student assistance

It is DRFN and Gobabeb policy to involve students and young interns in practical work wherever possible. The Gobabeb In-Service Training programme was hosting five final-year students at the time of the project, and they were included in the implementation of the fieldwork. This was to bring more eyes and hands to the fieldwork so that it could be done more effectively in the very short time available, and to give them experience in this small component of an EIA. Three were Nature Conservation students and two were studying Land-Use Planning, all at the Polytechnic of Namibia. Mini-projects were designed for each person to undertake in the course of the ten days of fieldwork.

2.3 Area reconnaissance and study areas

Fieldwork took place from Monday 8 to Wednesday 17 October 2007, inclusive. After safety and administrative induction on the first day at Rössing, the 10-member team briefly visited the Dome study site, SK study site, and the following morning, SH study site (Figure 4, precise localities in Appendix B). This provided everyone with direct experience of what habitats they would encounter, and the opportunity to better plan their work and schedules. Three days of field collecting and habitat mapping was done at each of the SK and SH sites, while only two days were spent at Dome.

2.4 Follow-ups of State Museum work

The precise locations of four of the six invertebrate pit-trapping sites were GPS-referenced in the current fieldwork (Appendix A), since the 1980s survey predated the availability of GPSs. Two of the sites could not be confirmed this way: one is now part of the Rock Africa granite quarry adjacent to Rössing, while the other is covered by a Rössing rock dump.

Reports from the State Museum work proved difficult to track down, and not all were complete. Appendix A contains the most up-to-date information from that survey, which can now be considered finished. As taxonomists continue to work on various animal groups, such as solifuges and huntsman spiders, so it can be expected that new species will be named and described. It is impossible to force the pace at which this happens, or to predict the outcome of such ongoing studies.

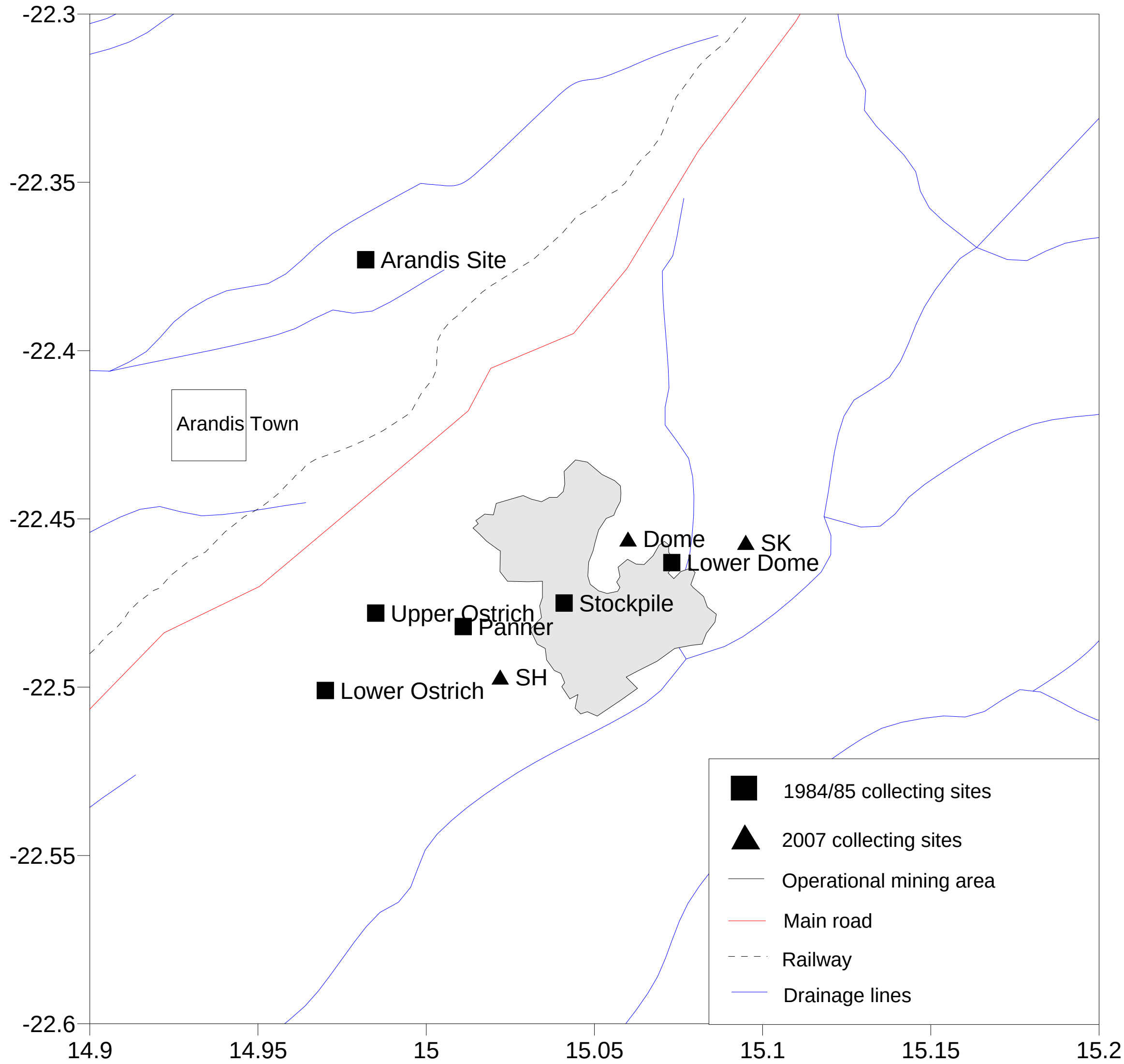

Figure 4: Location of animal biodiversity sampling sites during the 1984-1985 and 2007 fieldwork periods.

2.5 Taxa focused on

2.5.1 Biological soil crusts

Biological soil crusts (BSCs) are crucial features of desert ecosystems. Because their presence, importance and role is generally under-appreciated, or confined to lichens only, BSCs are given a short introduction here.

Biological soil crusts in the Namib comprise primarily lichens, microfungi, green algae and cyanobacteria (blue-green algae) in various proportions (Belnap & Lange 2001). Protozoans (single-celled animals), nematodes (roundworms and threadworms) and mites are often associated with them. BSCs are located on the surface to several millimeters into the ground or under translucent stones.

Figure 5: Close-up picture of a cross-section through brown biological soil crust on an open soil surface as seen on the Namib gravel plains north of Arandis.

In areas of the Namib where more conspicuous lichens do not dominate, a biological soil crust (BSC) can most easily be seen underneath stones and rocks that harbour *fensteralgen* (green diatoms) and blue-green algae (cyanobacteria, appear black in their dry state) (Rumrich *et al*. 1989, 1992; Büdel & Wessels 1991; Belnap & Lange 2001). These organisms find a home under translucent quartz and quartzite stones, and they can also grow as a near-surface ring around opaque or large stones (Warren-Rhodes *et al*. 2007). Stones trap moisture from fog or dew that condenses and runs down the sides to create a moist hypolithic (below-rock) environment, where photosynthesis is possible due to the sunlight that penetrates through them.

BSCs were assessed only in the 2007 fieldwork. We recorded the presence or absence of BSC under stones, and where present, we noted whether the colour was green or black (mixed colour was recorded as green), or whether the BSC comprised a layer of soil (brown BSC), often with fine filaments loosely binding soil and stones, possibly mycelia of micro-fungi or filamentous cyanobacteria. These three "types" of BSC each comprise micro-communities, and our casual observations indicate that the complexity increases from brown to black to green (Rumrich *et al*. 1989, 1992; Büdel & Wessels 1991; Belnap & Lange 2001).

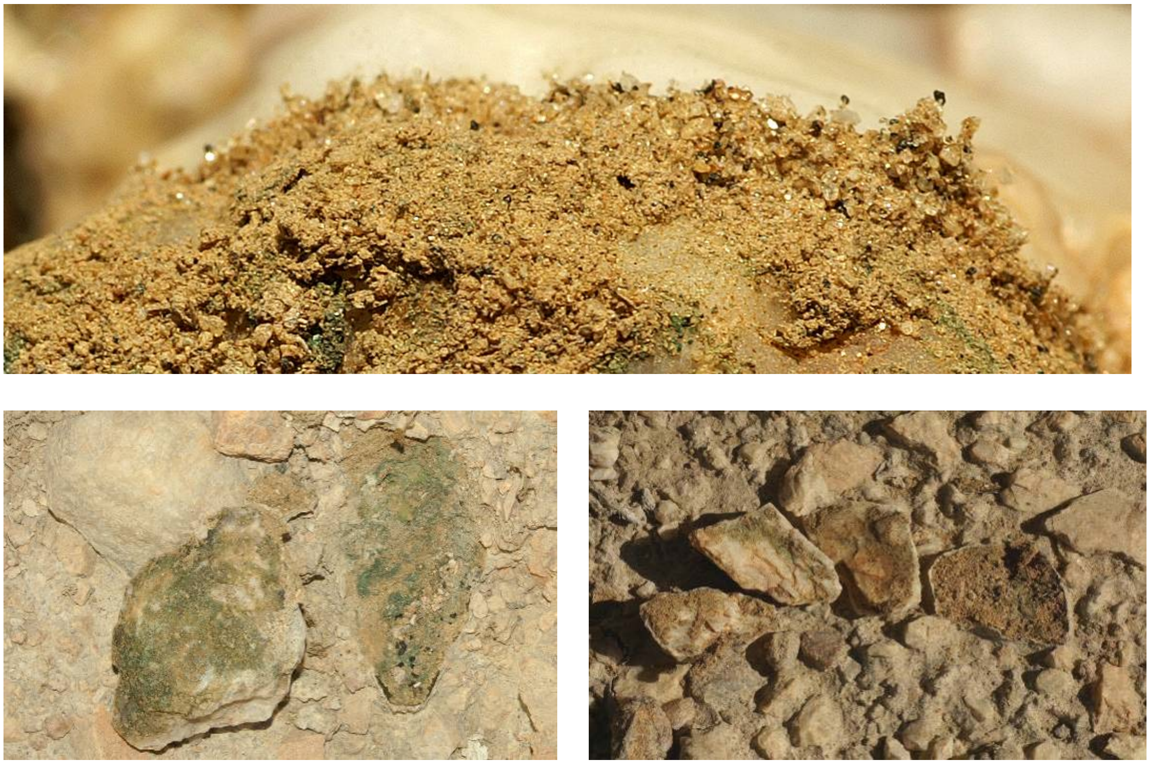

Figure 6: Top = brown BSC (with traces of green components); bottom left = green BSC; bottom right = black BSC.

BSCs are ecologically significant in stabilizing soil surfaces by protecting the soil from erosion, and in promoting water infiltration, seed germination and nitrogen and carbon fixation (Belnap & Lange 2001). They can act as biological indicators of environmental conditions. For example, lichens are sensitive to air pollution and can indicate the extent of terrestrial pollution (Hale, 1969). BSCs tend to be poorly established in areas with higher frequency of disturbance, i.e. an abundance of BSC indicates reduced disturbance (Eldridge & Greene, 1994).

2.5.2 Plants

A plant species inventory was compiled in the 1980s work. Subsequent botanical work by Burke (2005 and 2007) has concentrated on defining and describing biotopes in the Rössing area.

2.5.3 Arachnids and other non-insect invertebrates

Spiders, scorpions and sun-spiders (solifugids) were collected and recorded in both biodiversity surveys. Ticks and mites (Acari) and false scorpions (Pseudoscorpiones) were collected opportunistically, but were not focused on. Surveying the tiny pseudoscorpions and mites would have required a very careful search of rock samples and could not be combined with the more extensive, rapid survey method applied in 2007, or the pit-trapping surveys in 1984. Furthermore, pseudoscorpions are not expected to be diverse and, because they are comparatively understudied, to identify them beyond order would require drawn-out involvement of international experts of these groups.

Centipedes and millipedes were collected in the various pitfall traps set out for other terrestrial taxa in the 1984-1985 survey. None were recorded in the 2007 fieldwork.

The presence of terrestrial snails was recorded in the 2007 fieldwork, in the process of searching underneath stones while assessing arachnids and soil crusts.

2.5.4 Insects

Insects were collected in a structured pitfall-trap sampling programme in 1984-1985 and again in the brief 2007 sampling period.

2.5.5 Amphibians and reptiles

Frogs were recorded in the Rössing area from observations and calls after rain in the 1984-1985 fieldwork, and from records of a MET biologist (Griffin 2007, pers. comm.). Lizards and snakes were sampled in pitfall traps in the 1984-1985 and 2007 fieldwork periods, and records were supplemented with information from Griffin.

2.5.6 Birds

Bird fauna was assessed by two ornithologists in the 1984-1985 work, confirmed in the 2007 fieldwork, and expanded through consultation of the Southern African Bird Atlas records (Harrison *et al.* 1997). In addition, a Birdlife International ornithologist did brief bird surveys in the Rössing area in 2005, 2006 and 2007 (Stacey 2007), and there has been recent follow-up on one enigmatic species by a Swakopmund-based ornithologist (Boorman pers. comm. 2007).

2.5.7 Mammals

A small mammal trapping survey in 1984-1985 sampled rodents, sengis (elephant-shrews) and shrews. Fieldwork in 2007 and input from the MET biologist (Griffin 2007, pers. comm.) broadened the mammal inventory to include larger terrestrial mammals such as antelope and baboons, as well as bats.

2.5.8 Aquatic organisms

Organisms expected from permanent or ephemeral waterbodies include snails, freshwater crustaceans such as seed shrimps and mussel shrimps, water mites and freshwater insects such as water beetles. Seven water bodies known to exist in the Rössing area were repeatedly sampled, and other *ad hoc* waterpoints as they were encountered, in the 1984-1985 survey. Unfortunately very few specimens from this work were accessible and the written records were largely unintelligible.

3. Results

3.1 Habitat categorisation

3.1.1 Aligning biotopes with broader habitat categories

The Terms of Reference specify that species in the area should be assigned to preferred habitats or biotopes. As a first step, a biotope classification for the Rössing area by Burke (2005 and 2007) was available.

Burke identified and mapped 19 plant-based biotopes:

1. *Aloe asperifolia* plains
2. *Arthraerua luebnitziae* plains
3. Central hills
4. Eastern hills
5. *Euphorbia virosa* belt
6. Gorges
7. Khan River
8. Khan River mountains
9. Marble hill
10. Marble ridge
11. Northern dome
12. Plain drainage lines
13. South-western hills
14. Undulating granite hills
15. Western granite hills
16. *Zygophyllum stapfii* plains
17. Northern tributaries
18. Southern tributaries
19. South-eastern gneiss hills

The main sampling sites from both the 1984-1985 and 2007 biodiversity survey work can be mapped to Burke's biotopes as follows (Table 1).

Table 1: Categorisation of the 1984-1985 and 2007 fieldwork sites according to Burke's biotopes.

Sample group	Sample Site	Burke (2005) biotope
1984/85	Arandis Site	Extralimital
1984/85	Upper Ostrich Site	*Zygophyllum stapfii* plains
1984/85	Panner Site	Gorges
1984/85	Lower Ostrich Site	Extralimital
1984/85	Stockpile Site	Central hills
1984/85	Lower Dome Site	*Euphorbia virosa* belt
2007	SK Sampling Area	Eastern hills
2007	SH Sampling Area	Central hills
2007	Dome Sampling Area	*Euphorbia virosa* belt

However, we encountered difficulties in relating animal biodiversity to these plant-centric biotopes. Despite harbouring recognisably different plant communities, many of Burke's biotopes are virtually indistinguishable when factors of relevance to animal life are considered.

As an alternative, we undertook an independent habitat categorization, employing different methods (Appendix D). We ended up with a coarser categorization, distinguishing just three habitat types in the Rössing area: rocky hillsides, open plains and watercourses (Figure 7). Each of these has its own distinctive food, shelter and refuge characteristics, and each harbors a definably distinct faunal component, therefore we used only these three main habitat types in further analysis.

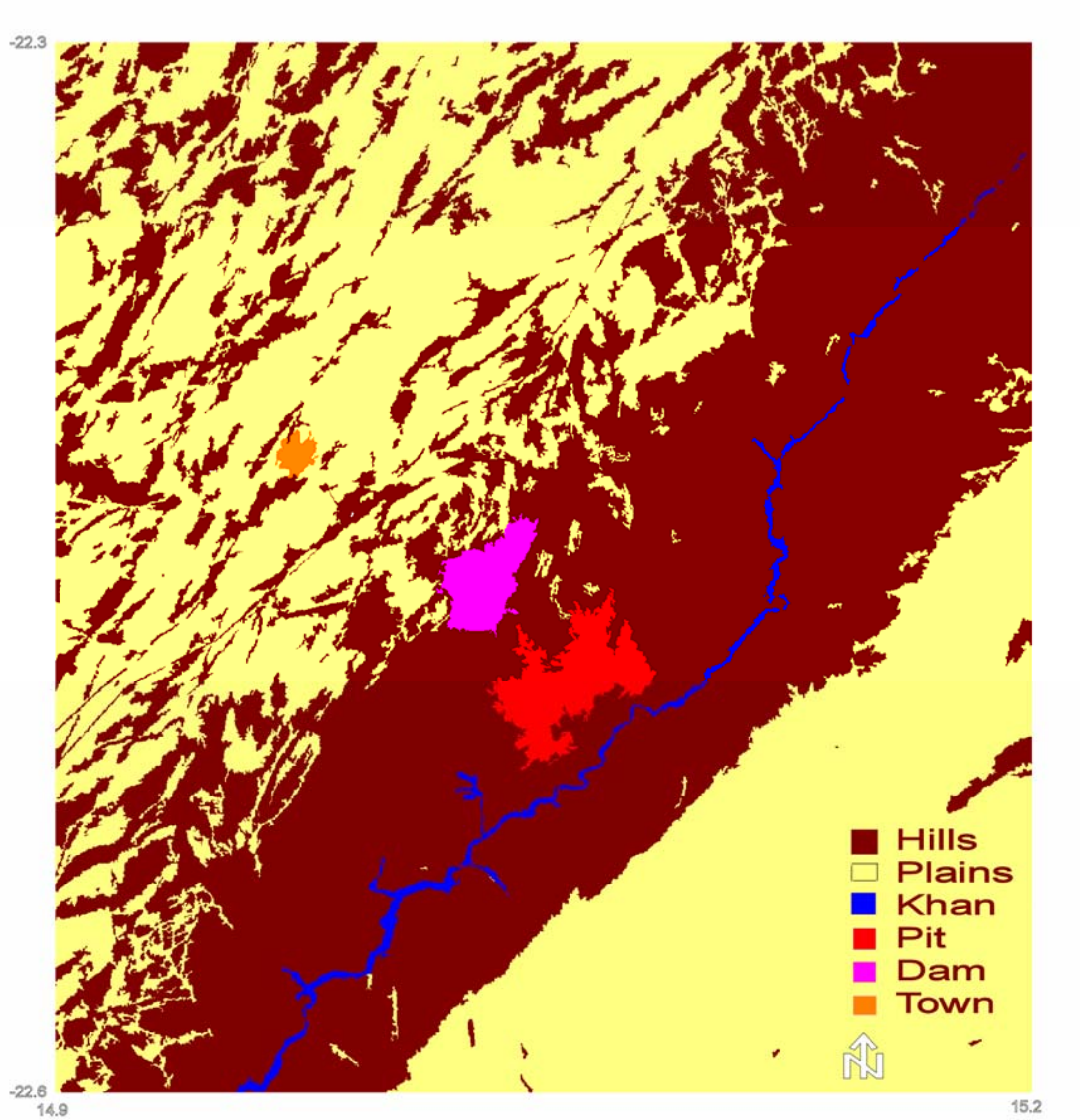

Figure 7. Habitat map of Rössing and surroundings, as used here.

Referring our habitats back to Burke's biotopes, it becomes clear that the two approaches simply categorise the environment at different scales, and the high degree of mutual correspondence increases the confidence in both (Table 2 and Figure 8).

The only significant points of difference between the two schemes are:

- Our habitat classification shows that the plains are not homogenous, but include numerous, low rocky ridges. Experience bears this out.
- Our classification does not distinguish minor watercourses from the habitat they flow through.

These differences do not impact on the conclusions drawn from habitat preferences later.

Table 2. Alignment of Burke's (2005) biotopes with the habitat types used in this assessment.

Burke (2005 and 2007) biotopes	**Current habitat types**
Aloe asperifolia plains	Plains
Arthraerua luebnitziae plains	
Zygophyllum stapfii plains	
Central hills	Hills and mountains
Eastern hills	
Euphorbia virosa belt	
Khan River mountains	
Marble hill	
Marble ridge	
Northern dome	
South-western hills	
Western granite hills	
South-eastern gneiss hills	
Gorges	Watercourses
Khan River	
Northern tributaries	
Southern tributaries	
Plain drainage lines	Plains + Watercourses
Undulating granite hills	Plains + Hills

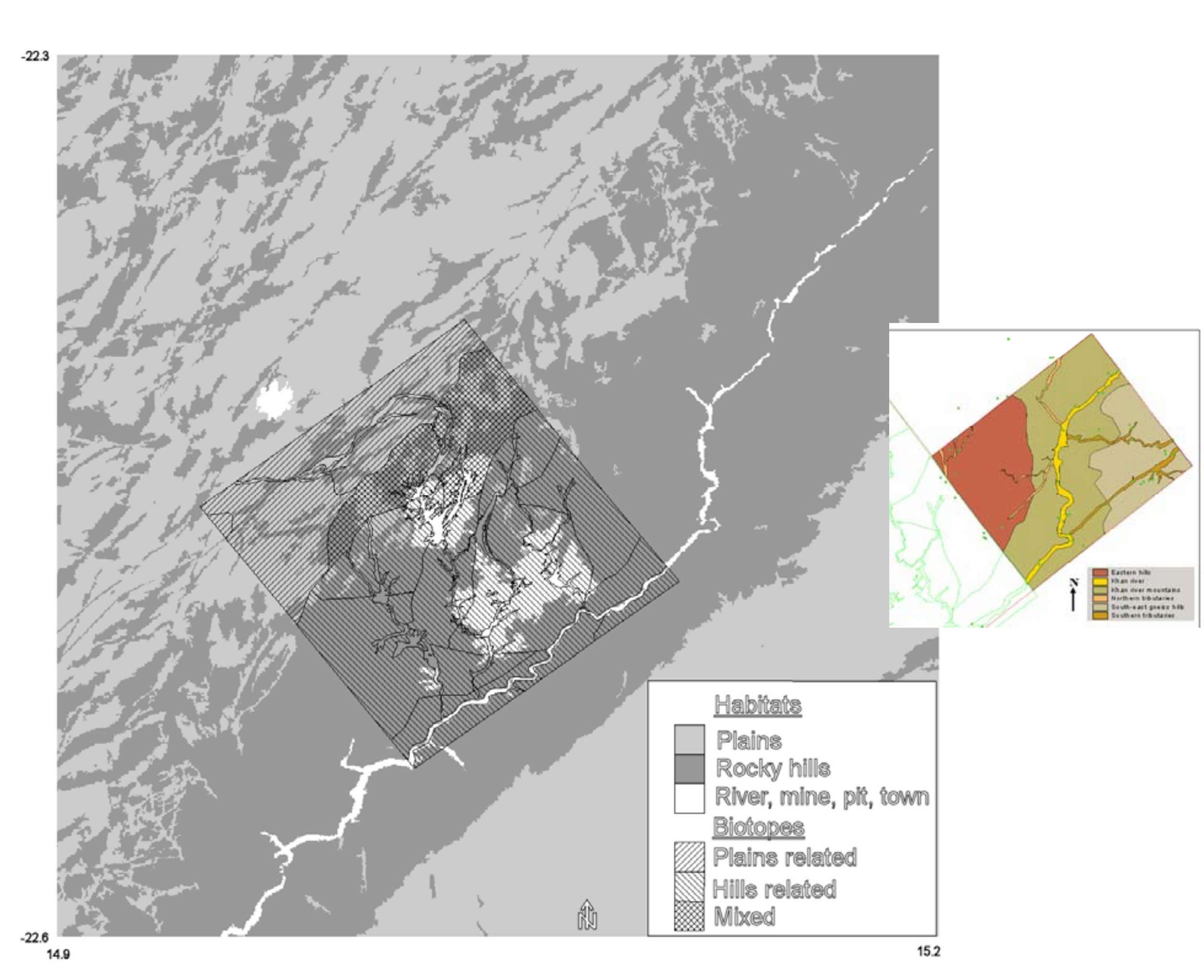

Figure 8. Comparison of habitat types used here with biotopes of Burke (2005).

The 1984-1985 and 2007 sampling sites resolve to the following main habitat types (Table 3).

Table 3: Categorisation of the 1984-1985 and 2007 fieldwork sites according to our habitat types.

Group	Sampling site	Habitat type	Notes
1984/85	Arandis Site	Plains	
1984/85	Upper Ostrich Site	Plains	
1984/85	Panner Site	Watercourse	Surrounded by hills
1984/85	Lower Ostrich Site	Watercourse	Surrounded by undulating plains, hills nearby
1984/85	Stockpile Site	Hills	
1984/85	Lower Dome Site	Hills	
2007	SK area	Hills	
2007	SH area	Hills	Adjacent to watercourse
2007	Dome area	Hills	Adjacent to watercourse

3.1.2 Categorising the habitat preference for all species

In order to determine the habitat preference of a species, the locations from where the species was recorded were considered. Each location could be assigned to a habitat, and if a species was only or most commonly found at locations that had the same main habitat, that was considered to be its habitat preference. If known from more than one different habitat type, the proportion of individuals recorded from each habitat was considered, and the significantly higher proportion was selected as the habitat preference. In ambiguous cases, practical knowledge of habitat preference as determined during fieldwork was sometimes used to select one or the other type. Still, some taxa do occur in more than one habitat type, and some are widespread over the entire area, and they were listed as such.

The resultant habitat preferences for all species are listed in the species table in Appendix C.

3.2 Biodiversity inventory

Lists of species identified from the Rössing area, and their habitat affiliations, are provided in Appendix C. Sources of information for these lists are:

- Unpublished information from the 1980's Rössing environmental survey on file at the National Museum of Namibia, on file at Rössing Uranium Limited, or received from individual scientists that were involved at the time.
- At least 45 scientific papers that have since reported on material collected during the survey.
- Relevant excerpts from the National Museum collection catalogues.
- Database query on the National Herbarium holdings.
- Query on the Namibia Biodiversity Database.
- Results of 2007 animal fieldwork and 2004-2007 plant fieldwork
- Consultation with Mike Griffin, MET expert on small mammals and reptiles.

3.2.1 Biological soil crusts

Biological soil crusts (BSCs) observed in the three study areas was exclusively hypolithic (below stones), mostly associated with quartz or quartzite stones. BSC was in general most abundant on the scree and bedrock areas (rocky hillsides) and was reduced in the watercourses. The overall occurrence of BSC was relatively infrequent compared to other undisturbed areas in the mid-zone of the Namib (e.g. north of Arandis and Aussinanis area near Gobabeb). The occurrence of BSC at the current Rössing sites was comparable to the frequency seen on gravel road banks. At Aussinanis (near Gobabeb), BSC increased with distance from a rarely-used gravel road (Aiyambo 2007), possibly correlating with a decrease in dust with distance.

The occurrence of lichen was negligible, and with our method of observation we also did not detect any epilithic BSC (on top of soil and stones) except for occasional perilithic BSC that extended for a short distance laterally from stones. Overall, the environment below stones appeared to be the only viable place for BSC to occur. BSC is therefore considered to be present in a somewhat reduced form compared to its occurrence in other nearby Namib habitats. A reduction in BSC could reduce the productivity of these desert habitats, as BSC is known to be very active in fixing and remobilising carbon and nitrogen in desert soils (Belnap 2001; Evans & Lange 2001).

Fine layers of dust caked many of the rocks and stones and sealed some of their lower extremities at the base. This would probably reduce the natural flow of condensed moisture to the hypolithic environment, resulting in drier microclimates. If this is the case, it could explain a reduction in the occurrence of hypolithic BSC. The extremely fine nature of the caked dust particles could possibly also affect the epilithic condition and explain the absence of epilithic BSC (the only lichen found occurred underneath rock overhangs without dust caking). This suggestion is offered as explanation for the reduced occurrence of BSC based on casual observations.

3.2.2 Plants

214 species of plants are identified from the Rössing area. Most have not been evaluated for IUCN status and are only categorized according to the three main habitat categories described above. Their levels of endemism are tentatively recorded in Appendix C.

3.2.3 Arachnids and other non-insect invertebrates

3.2.3.1 Arachnids

Mites and ticks (Acari)
Tentatively, four species of mites occur at Rössing, but they have been identified only to relatively high levels. Water mites, without further identification, were recorded in

ponds. Ticks, found in pitfall traps after falling from rodents inadvertently collected in the traps, have not been identified.

Spiders (Araneae)
Seventy-nine species of spiders are recorded from Rössing.

The general impression gained from the frequency of encountering spiders and observing their signs during the 2007 survey, compared to our work at other similar sites, is that overall there appear to be fewer individuals and fewer different taxa here than other comparable areas in the central Namib. This may indicate that the sites could already be somewhat depauperate. This impression is, however, qualified due to the very limited scope of the 2007 survey. Nevertheless, the array of different taxa at each location does indicate that SK and SH still have relatively good representation of this group of predators.

By comparison, the Dome area has severely reduced spider diversity and abundance. Near our Dome site, but in a different habitat, is the type locality (and only known occurrence, in 1984) of the trap-door spider *Moggridgea eremicola* (Migidae, Griswold 1987). This species is listed as Critically Endangered, and it is not known whether it still persists in this area. The general reduction of all arachnids at this site raises concern.

There is potential conservation concern of several of the observed spiders (e.g. one of the huntsmen and termite-eating spiders). Given that several other species with even higher conservation status were not recorded during the short 2007 survey, and the apparent suitability of the site for these species, it is highly recommended that further studies be conducted to confirm the status of spiders in the area.

Scorpions (Scorpionida)
Fourteen species of scorpions are recorded from Rössing. Given the limited amount of effort that has been devoted to assessing scorpions, it is not possible to make conclusions on their status.

Sun-spiders or camel-spiders (Solifugae)
Twenty-two species of solifuges are recorded from Rössing.

Solifuges are known to be diverse and fairly common in the central Namib, a world hotspot of solifuge diversity (Lawrence 1963; Wharton 1981; Griffin 1990, 1998). However, the 2007 survey revealed only one individual in the nine days of fieldwork. According to our previous experience in other nearby areas, this absence of solifuges is exceptional. This could be a seasonal effect, but solifuges were not even found below many hundreds of rocks that were examined. Further work will be required to establish the status of these predators at Rössing.

3.2.3.2 Snails (Molluscs)
Aquatic snails are only mentioned in the limnological notes, without any identifications.

During the 2007 work on soil crusts we incidentally found three shells of snails (no live animals) of different species under rocks at SK and Dome. None have been identified. Their presence indicates that these environments supported mollusks and perhaps still do, but this needs to be established with further studies. Snails are known to occur under stones in rocky habitats of the Central Namib in association with biological soil crusts (Seely 1987; Hodgson et al. 1994). The potential significance of these findings is that it indicates that populations of highly moisture-dependent organisms have the ability to survive at Rössing.

3.2.3.3 Centipedes and millipedes (Myriapods)

Three species of centipedes and one millipede represent this group at Rössing.

3.2.3.4 Crustaceans

Seed shrimps and mussel shrimps, without identifications, are recorded from Rössing waterbodies.

3.2.4 Insects

Two hundred and seventy-one species of insects are recorded from Rössing. These cover ground-living species and some winged species that were accidentally collected in pitfall traps. Certain winged groups such as moths and butterflies (Lepidoptera) and lacewings (Neuroptera) remain largely unknown for this area on account of this sampling bias, but handcollecting and the specialized treatment that specimens need, were not possible in either of the surveys.

3.2.5 Amphibians and reptiles

Three species of frogs are known to occur or are expected from the Rössing area.

Reptile diversity is high in the Namib Desert and the central Namib in particular has a surprisingly high diversity of lizards, especially geckos. The State Museum work, together with more recent literature (Griffin 2002 and Griffin 2007, pers. comm.), lists a total of 33 lizard species recorded or having a high probability of occurrence in the Rössing area. This comprises 15 Geckos, 2 Agamas, the Namaqua Chameleon, 7 Skinks, 7 Sand Lizards and one Plated Lizard. Of these 33 species, 8 are endemic to the Namib and one, the Husab Sand Lizard, has a distribution range that is restricted to the mountainous Rössing-Husab area.

During the initial phases of this assessment, concern was expressed about *Pedioplanis husabensis*, the Husab Sand Lizard, a range-restricted endemic from the Rössing area. Further investigation has shown that the species has an extent of occurrence of ca. 7800 km^2 (Griffin 2007, pers. comm.) and has been recorded from at least 47 locations in this small area (Berger-Dell'Mour & Mayer, 1989), which by itself should evaluate to a non-Threatened status. However, the official status is 'Data Deficient' (Griffin 2007, pers. comm.). The reason for this is that the potential effect of uranium mining on the species is not yet known. The currently operational Rössing and Langer Heinrich Mines, as well as the proposed Valencia, Husab and Goanikontes Mines, in combination affect the entire distribution range of the species. This is a case that strongly argues for the central Namib uranium mining industry players to confront environmental issues collectively rather than individually: while mining at any particular site (e.g. SK4) may not have a particularly severe effect on overall *Pedioplanis husabensis* populations, the same cannot be said for the combined effect of mining at an increasing number of adjacent sites.

A further species of *Meroles* is newly described from work done outside of this study, and is categorized as Not Evaluated. On the basis of the precautionary principle it is classified as Threatened – Data Deficient.

With the exception of the latter species and the Husab Sand Lizard, all the above lizard species are categorized as Least Concern (Griffin 2007, pers. comm.). Apart from lizards, one other reptile is red-listed, namely Leopard Tortoise (Vulnerable). Occurrence of Leopard Tortoise in the Rössing area is possible but very unlikely, as this species generally prefers moister habitats. It might very rarely be found in the Khan River.

3.2.6 Birds

The Rössing bird list records high diversity for an area this barren, largely due to the influence of the Khan and its tributaries as linear oases (Stacey 2007). There are no birds found in the area which are restricted to the area or threatened by the mine expansion. Two raptor species – Martial Eagle and Lesser Kestrel - carry IUCN Threatened status and another – Verreaux's Eagle – is Near-Threatened, but their populations are scattered over southern Africa, and the mine expansion will not significantly increase the factors causing their decline.

One species, Karoo Eremomela, has some taxonomic uncertainty as the central Namib population may be sufficiently genetically distinct to warrant sub-species or full species status. This is now being investigated with the assistance of local birder Mark Boorman and ornithology experts based in South Africa. Initial indications are that, even if the population is genetically distinct, it is distributed over an area exceeding 20,000 km², in which its preferred habitat of thinly vegetated watercourses is abundant.

3.2.7 Mammals

The mammals list shows medium diversity – 43 species – which is typical for the central Namib. While larger mammals such as kudu and baboon are conspicuous and quickly recognized by lay people, the mammal list includes 6 hoofed mammals, 9 carnivores, 11 bat species and 16 small terrestrial mammals including rodents and one each of shrew, sengi (elephant shrew), hare, dassie and hedgehog. Many of these, particularly the carnivores, are naturally uncommon to rare, while a few others, such as hedgehog and fruitbats, are likely to occur only very rarely as vagrants linked to the Khan River linear oasis.

Eight of the mammal species are classified as Near-Threatened, one as Vulnerable and one as Endangered. The latter, Namibian Mountain Zebra, is confined to the Namib Desert. African Wild Cat, the Vulnerable species, is threatened most by hybridization with domestic cats. The latter are likely to occur in and around the Rössing buildings, but the existence or threat posed by feral cats at Rössing has not been assessed. The threat is probably low.

3.3 Vulnerability and endemicity of taxa

3.3.1 Categorisation of taxa using IUCN guidelines

The Terms of Reference require that all species occurring in the Rössing area be ranked for vulnerability by IUCN category. The IUCN (International Union for the Conservation of Nature) maintains global Red List data. It defines Red List categories, as well as the evaluation criteria to be followed before red listing a species (IUCN 2000, 2005).

Formal IUCN categorisation is not available for most Namibian animals. Only mammals (Griffin & Coetzee 2006) and some endemic plants (not all plants, or even all endemic plants) (Loots 2005) have been formally evaluated using the latest IUCN criteria and published. Reptile categorization has been done but is not published (Griffin 2007, pers. comm.). No evaluations are available for Namibian invertebrates, or, strangely enough, birds (excepting those few species occurring in Namibia that have been evaluated on a global level).

Categorisation of the invertebrates in particular, but of all taxa, is hampered by the low level of collecting and biodiversity sampling that has been done in the study area and surrounds. As a worst-case example, some taxa are known only from one specimen that was trapped during the 1980s work. With such specimens, on the basis of the precautionary principle, their conservation status must be judged as Critically Endangered, and distribution as being limited to the Rössing area only. Taxa known from three or more specimens at least can render a polygon area of occurrence using the sites where they were sampled. These examples provide a hint of the difficulties encountered in the assessment.

Since the bulk of biodiversity at Rössing is concentrated in the invertebrates, IUCN categorisation criteria had to be newly applied to arrive at vulnerability categories for those taxa not yet formally evaluated. A full explanation of the calculation of vulnerability and endemicity using limited data is provided in Appendix E.

Table 4 shows those animal taxa categorized as Threatened (Critically Endangered, Endangered and Vulnerable), derived from the 1980s State Museum survey and the 2007 fieldwork. Information is drawn from data presented in Appendix C. No plants are sufficiently threatened to be included in the table. Only one plant species – *Adenia pechuelii* – is classified as Near-Treatened, but it has a wide range in the Namib Desert and escarpment (Curtis & Mannheimer 2005).

Table 4: Threatened taxa occurring in the Rössing area.

IUCN statuses: CR = Critically Endangered;
EN = Endangered;
VU = Vulnerable.
EOO = extent of occurrence
NOL = number of locations where collected
Habitats: RH = Rocky hillsides;
OP = open plains;
WC = watercourses
Endemism: RA = Rössing area only;
CN = Central Namib Desert (ca. Kuiseb - Ugab);
CW = Central Western Namibia;
ND = Namib Desert (Orange - Kunene);
NA = Namibia;
empty cell = Widespread (not endemic to Namibia)

Common name	**Genus, species**	**IUCN stat.**	**EOO (km^2)**	**NOL**	**Habitat**			**Ende-mism**
Tingle trapdoor spider	*Moggridgea eremicola*	CR	-	1	RH			RA
Velvet spider	*Seothyra anettae*	CR	-	1		OP		RA
Ant spider	*Cyrioctea namibiensis*	CR	-	1		OP		RA
Bee fly	*Pteraulacodes hessei*	CR	-	1		OP		RA
Sun spider	*Daesiella pluridens*	CR	-	1		OP		RA
Ant spider	*Caesetius sp. nov.*	CR	-	1			WC	RA
Flower beetle	*Hedybius irishi*	CR	-	1			WC	RA
Bee fly	*Heterotropus apertus*	CR	-	2		OP		RA
Prodidomid spider	*Namundra griffinae*	EN	-	2	RH			RA
Sun spider	*Blossia sp. Nov. A*	EN	-	2	RH			RA
Sand wasp	*Namiscophus pilosus*	EN	-	2		OP		CN
Sun spider	*Blossia sp. Nov. B*	EN	-	2			WC	RA
Flower beetle	*Metaphilehedonus swakopmundensis*	EN	5	3	RH		WC	RA
Ant spider	*Heradida griffinae*	EN	11	3	RH	OP	WC	RA
Silverfish	*Ctenolepisma sp. nov. nr. pauliani*	EN	11	3		OP	WC	RA
Sun spider	*Lawrencega sp. nov.*	EN	12	5	RH			RA
Jewel beetle	*Nothomorphoides irishi*	EN	13	3		OP		RA
Jumping plant louse	*Crastina swakopensis*	EN	27	3			WC	CN
Blister beetle	*Iselma deserticola*	EN	41	3	RH	OP		RA
Ant spider	*Diores namibia*	EN	1084	3			WC	CW
Jumping plant louse	*Colposcenia australis*	EN	1336	4			WC	CN

Common name	Genus, species	IUCN stat.	EOO (km²)	NOL	Habitat			Ende-mism
Jumping plant louse	*Colposcenia namibiensis*	EN	1336	4			WC	CN
Bee fly	*Parisus damarensis*	EN	1366	4		OP		CW
Sun spider	*Blossia planicursor*	EN	1609	5		OP		CN
Sun spider	*Hexisopus moiseli*	EN	1689	3			WC	CW
Centipede	*Cormocephalus pontifex*	EN	2127	3	RH	OP		CN
Toktokkie	*Horatoma deserticola*	EN	2347	3		OP		CN
Toktokkie	*Zophosis (Carpiella) latisterna*	EN	2776	5		OP		CN
Sun spider	*Lawrencega longitarsis*	EN	3895	5		OP		CN
Martial Eagle	*Polemaetus bellicosus*	EN						
Namibian Mountain Zebra	*Equus zebra*	EN			RH	OP		ND
Silverfish	*Ctenolepisma occidentalis*	VU	151	6		OP	WC	RA
Toktokkie	*Zophosis (Gyrosis) ornatipennis*	VU	357	9		OP	WC	CN
Sun spider	*Trichotoma michaelseni*	VU	790	6		OP		ND
Scorpion	*Uroplectes pilosus*	VU	1003	6	RH	OP	WC	CN
Sun spider	*Lawrencega solaris*	VU	2824	6		OP		CN
Sun spider	*Lawrencega minuta*	VU	4754	6		OP		CN
Toktokkie	*Pachynoteles punctipennis*	VU	6228	6		OP	WC	CW
Scorpion	*Parabuthus namibensis*	VU	7653	7		OP	WC	CN
Sun spider	*Blossia rooica*	VU	7998	5	RH	OP	WC	CW
Scorpion	*Opisthophthalmus coetzeei*	VU	8581	9	RH	OP		CW
Jewel beetle	*Acmaeodera liessnerae*	VU	9411	5		OP	WC	CW
Sand wasp	*Miscophus sabulosus*	VU	13281	5				CN
Snout beetle	*Hyomora porcella*	VU	18592	8		OP		CN
Leopard Tortoise	*Geochelone pardalis*	VU					WC	
Lesser Kestrel	*Falco naumanni*	VU						
African Wild Cat	*Felis lybica*	VU					WC	

3.3.2 Priority classification

The two criteria of endemicity (equated to irreplaceability in the Terms of Reference) and conservation status (equated to threat) can be combined to give an overall priority classication, from critical to minor, for all taxa. This is shown in Table 5, for only the taxa listed in Table 4. All other taxa are classified by this process as minor priority.

Table 5. Numbers of threatened taxa and their levels of endemicity. CR = Critically Endangered; EN = Endangered; VU = Vulnerable.

Vulnerability	CR	EN	VU	Total
Endemicity				
Endemic to Rössing area	Critical 8	Critical 9	Critical 1	18
Endemic to Central Namib	Critical 0	Essential 9	Major 7	16
Endemic to Central Western Namibia	Essential 0	Major 3	Medium 4	7
Endemic to Namib Desert within Namibia	Major 0	Medium 1	Significant 1	2
Endemic to geopolitical Namibia	Medium 0	Significant 0	Minor 0	0
Widespread	0	1	3	4
Total	8	23	16	47

Species in the upper left hand side of the matrix – those scoring critical, essential, major and medium priority – consitute our working list of key species of conservation concern for Rössing. Those taxa in the lower right hand side of the matrix, scoring significant and minor priority – there is only one species, *Trichotoma michaelseni* – are not regarded as taxa of conservation concern for Rössing.

By this scoring process, the Husab Sand Lizard and the new species of *Meroles* sand lizard do not evaluate to being priority species. However, intuition and the precautionary principle dictate that these should be included. They are listed below as high undefined priority species (Table 6), together with all the taxa of key conservation concern.

Table 6: Names and preferred habitats of high priority taxa. RH = rocky hillsides, OP = open plains, WC = watercourses.

Priority level	Taxa	Habitat		
Critical priority	*Moggridgea eremicola*	RH		
	Seothyra anettae		OP	
	Cyrioctea namibiensis		OP	
	Pteraulacodes hessei		OP	
	Daesiella pluridens		OP	
	Caesetius sp. nov.			WC
	Hedybius irishi			WC
	Heterotropus apertus		OP	
	Namundra griffinae	RH		
	Blossia sp. nov. A	RH		
	Blossia sp. nov. B			WC
	Metaphilehedonus swakopmundensis	RH		WC
	Heradida griffinae	RH	OP	WC
	Ctenolepisma sp. nov. nr. Pauliani		OP	WC
	Lawrencega sp. nov.	RH		
	Nothomorphoides irishi		OP	
	Iselma deserticola	RH	OP	
	Ctenolepisma occidentalis		OP	WC
Essential priority	*Namiscophus pilosus*		OP	
	Crastina swakopensis			WC
	Colposcenia australis			WC
	Colposcenia namibiensis			WC
	Blossia planicursor		OP	
	Cormocephalus pontifex		OP	
	Horatoma deserticola		OP	
	Zophosis (Carpiella) latisterna		OP	
	Lawrencega longitarsis		OP	
Major priority	*Zophosis (Gyrosis) ornatipennis*		OP	WC
	Uroplectes pilosus	RH	OP	WC
	Lawrencega solaris		OP	
	Lawrencega minuta		OP	
	Parabuthus namibensis		OP	WC
	Miscophus sabulosus		OP	
	Hyomora porcella		OP	
	Diores Namibia			WC
	Parisus damarensis		OP	
	Hexisopus moiseli			WC
Medium priority	*Pachynoteles punctipennis*		OP	WC
	Blossia rooica	RH	OP	WC
	Opisthophthalmus coetzeei	RH	OP	
	Acmaeodera liessnerae		OP	WC
	Equus zebra	RH	OP	
High undetermined priority	*Pedioplanis husabensis*	RH		
	Meroles sp.nov.			

Our assessment of vulnerability and endemicity carries serious implications for the decisions that must be made regarding future mining expansion. The weight of these decisions prompted much discussion and self-evaluation of the methods. A case study of one of the Critical Priority species, the spider *Moggridgea eremicola*, elaborates the logical steps and background information that justify our categorization, and makes suggestions about the next steps that follow. It is presented in full in Appendix E.

3.3.3 Habitat preferences of high priority taxa

Table 6 shows the habitat preferences of the high priority taxa. Note that the totals are more than in Table 5 because some species occur in more than one habitat.

Table 6: Habitat preferences of high priority taxa at Rössing.

Habitat	Rocky hillsides	Open Plains	Water-courses
Priority level			
Critical	7	10	7
Essential	0	6	3
Major	1	8	5
Medium	3	5	3
High (undetermined)	1	0	0
Total:	12	30	18

While this information is based on very low sample numbers and therefore carries a low confidence level, it is all that is available.

The open plains are the habitat that supports half of the high priority taxa at Rössing. This habitat extends much further beyond the Rössing area, and is considered to be less likely to hold very range-restricted taxa. Species found in open plain habitat in the central Namib might be restricted by factors such as amount and frequency of fog and or rain, which would put broad east and west limits on their occurrence. North and south limits would be less restrictive. Burke (2005 and 2007) lists only three biotopes that accord to our plains habitat (Table 2), confirming the relative homogeneity of the plains. Where habitats are homogeneous and cover a large area, the likelihood of a species being confined to a small part of that area is very low.

Watercourses support just over a quarter of the high priority taxa at Rössing. These ephemeral river beds act as linear oases, as they have more and bigger plants than the surrounding plains, and provide more plant food to organisms higher up the food chain. The fact that the watercourses are joined with each other and that vegetation in them is similar upstream and downstream indicates that this habitat is also relatively widespread and homogeneous. By the same argument used for open plains, we consider the likelihood of a species being confined to a small segment of a watercourse very low.

Rocky hillsides and steep terrain make a habitat that is relatively confined in this part of the central Namib (Figure 9). The outline of this habitat in Figure 9 encloses an area of 850 km^2. A small terrestrial animal that lives in this area and requires a rocky habitat has only so much area to spread in to.

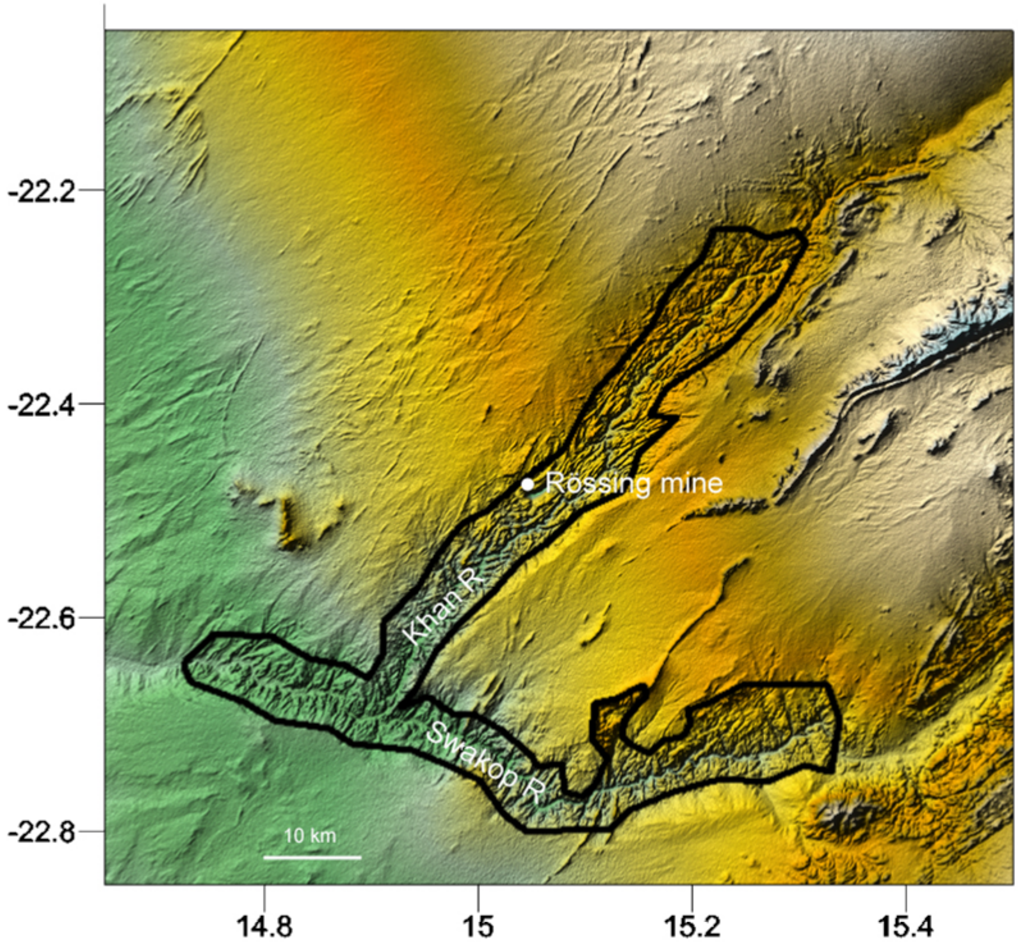

Figure 9: Satellite view of the Rössing mine area showing extent of the rocky hillside habitat associated with the dissected terrain of the Khan and Swakop Rivers.

Rocky habitats have much greater diversity of microhabitats than the plains, provided by slopes of different angles and attitudes, varying amounts of runoff from fog and rain, varying penetration of moisture, exposure to winds of different intensity and frequency, and more varied plant life. The greater number of biotopes listed by Burke (2005 and 2007) that occur on rocky and steep terrain (Table 2) reflects the diversity of habitats. Therefore distribution ranges of taxa preferring rocky habitat are more likely to be smaller and more restricted than distribution ranges of plains and watercourse species.

It must be remembered that ascribing a habitat preference to an animal on the basis of one or just a few specimens carries a very low confidence level. Recognising this, both the higher variety of microhabitats within rocky terrain and the restricted area in which these microhabitats are found, imply that the high priority taxa occurring in rocky terrain at Rössing are more likely to be range restricted. Therefore, to minimize serious negative impacts on biodiversity in the Rössing area, rocky hillsides are the habitat that should be the least disturbed.

3.3.4 Ranking of Burke's biotopes

Burke (2005 and 2007) follows a different method to arrive at a ranking of the identified biotopes that goes from critical to rare and then general. The ranking is based on the presence of selected indicator species that are red-listed (according to IUCN criteria, as shown in Appendix C) and that have designated levels of endemism. Based on the scores from the indicator plants, five biotopes emerge as critical (Table 7), four as rare and ten as general.

Table 7: Ranking of Burke's biotopes (2007) according to the scores of selected indicator plant species.

Biotope	**Assignation according to Burke**
Central hills	Critical
Eastern hills	Critical
Euphorbia virosa belt	Critical
Undulating granite hills	Critical
Western granite hills	Critical
Gorges	Rare
Khan River mountains	Rare
South-eastern gneiss hills	Rare
South-western hills	Rare
Khan River	General
Marble hill	General
Marble ridge	General
Northern dome	General
Plain drainage lines	General
Aloe asperifolia plains	General
Arthraerua luebnitziae plains	General
Zygophyllum stapfii plains	General
Northern tributaries	General
Southern tributaries	General

Significantly, all five of the critical biotopes are found in rocky habitat. This confirms our finding that rocky hillsides deserve the greatest protection from disturbance.

4. Summary and conclusions

4.1 Summary of habitat and biodiversity information

Biodiversity assessments made in 1984-1985 and in 2007, as well as other projects focusing on particular taxa, have produced a wealth of information on the plant and animal biodiversity occurring in the Rössing area. Rössing Uranium Limited deserves credit for initiating and supporting this important baseline environmental research.

This work stands out as a small focus of a lot of information in the wider area of the central Namib that is generally very poorly known in terms of biodiversity. Thus there are many species and unnamed or undescribed taxa that have been found in the Rössing surveys, and that are known only from those one or few localities. This apparent high level of endemism might be real or it might be from the sampling bias.

4.1.1 Habitats and biotopes

The habitats in the area are divided into
(i) rocky hillsides with loose surface rocks and no soil or soil that is very shallow soil, and relatively the least vegetation.
(ii) open plains with deeper soil and scattered bushes and shrubs. The plains are interrupted with rocky outcrops of varying sizes.
(iii) watercourses that are normally dry but that carry water for very short periods during the rainy season. The watercourses are marked by having more bushes and scattered trees along their length, and the substrate is usually sandy and uncompacted.

The biotopes identified and mapped by Burke (2005) form subsets of these broad habitat types. The animal biodiversity data does not carry detailed habitat descriptions for each of the specimens, thus our understanding of each species' preferred habitat is at the level of broad habitat types, not biotopes.

4.1.2 Biodiversity

The biodiversity inventory can be summarized as follows:

Biological soil crusts, comprising lichens, micro-fungi, algae and blue-green algae (cyanobacteria) are present in a somewhat reduced form compared to their occurrence in other nearby Namib habitats. Lichens are largely absent, while hypolithic organisms (the green or black coating found underneath translucent quartz stones) are more abundant but relatively reduced. This is tentatively explained as a result of fine layers of dust coating rocks and stones and reducing the natural flow of condensed moisture to the hypolithic environment, resulting in drier microclimates.

Two plant species growing in the Rössing area are of concern. The charismatic ‘elephant’s foot’ *Adenia pechuelli*, occurs in relatively high concentrations on rocky hillsides here, whereas it is found more widely scattered and as isolated individuals elsewhere. It is classified as Near-Threatened and has a wide distribution in the Namib and escarpment. *Lithops ruschiorum* is listed as ‘Least Concern’ but it has a very restricted range and is sought after by collectors. Rössing possibly has the largest population of this plant ever recorded.

Spiders, scorpions and solifuges constitute a group of predators of smaller invertebrates that can give an indication of the state of populations of their prey. Recognising the shortcomings of the 2007 biodiversity fieldwork, preliminary indications are that the abundance and diversity of spiders is relatively lower than expected, and of solifuges is exceptionally low. The latter is particularly surprising given that the central Namib is known as a world hotspot of solifuge diversity. Seven taxa of the spiders, and 11 taxa of the solifuges, are classified as Threatened. It is not possible to draw conclusions on the status of scorpions, besides the fact that 14 species are known from the area, of which three are Threatened. Further work is required to establish whether arachnid populations are indeed diminished in and near the Rössing operations, and whether mining activities are responsible.

271 species of ground-living insects are recorded from Rössing, and this excludes flying groups such moths and lacewings. 20 species are Threatened.

Three species of frogs are known to occur or are expected from the Rössing area. None are Threatened.

Reptile diversity is high in the Namib Desert and the central Namib in particular has a surprisingly high diversity of lizards, especially geckos. 33 reptile species are known or expected to occur in the Rössing area. Of these, one (a tortoise) is classified as Threatened but it prefers moister habitat and its occurrence in the area is very marginal. The Husab Sand Lizard is classified as Data Deficient as its population in the relatively small area of occurrence – rocky terrain in the area of the lower Khan and Swakop Rivers – is not well known, yet faces fragmentation and disturbance from proposed mining operations. Another recently discovered species of Sand Lizard, also known only from the area immediately inland of Swakopmund, has not yet been evaluated for its conservation status, so by the precautionary principle is also classified as Threatened.

Birdlife in the Rössing area reaches relatively high diversity for an area this barren, largely due to the influence of the Khan and other smaller linear oases. While two species are classified as Threatened, there are no birds found in the area which are restricted to the area or threatened by the mine expansion.

Mammal diversity at Rössing is not very high, as is typical in the central Namib. The list includes two Threatened species. Mine expansion will probably incrementally increase the threats that face them, namely increased habitat fragmentation and expanded area of human influence and disturbance.

4.1.3 Taxa of high priority

Combining the criteria of IUCN status and the degree of endemism of taxa provides a way to score the priority that Rössing should accord to individual taxa. By this process, 44 taxa are scored as high priority – critical, essential, major, medium and undetermined. A breakdown of these taxa using common names of animal groups is shown in Table 8. No plants are sufficiently threatened or range-restricted to warrant inclusion in this list.

Table 8: Breakdown of the taxa of high priority in the Rossing area.

Priority level	**Number of taxa**	**Taxa**
Critical	18	Spiders – 6 Solifuges – 4 Beetles – 4 Silverfish – 2 Flies – 2
Essential	9	Solifuge – 2 Centipede – 1 Beetles – 2 Plant louses – 3 Wasp – 1
Major	10	Spider – 1 Solifuges – 3 Scorpions – 2 Beetles – 2 Wasp – 1 Fly – 1
Medium	5	Solifuge – 1 Scorpion – 1 Beetles – 2 Hoofed mammal – 1
Undetermined but high	2	Lizards – 2
Significant	1	Solifuge – 1
Minor	All other taxa	

4.1.4 Habitat preferences of taxa of high priority

Five of the 19 biotopes identified in the Rössing area are ranked as critical. All five are found in rocky habitats.

The open plains are the habitat that supports half of the high priority taxa at Rössing. Watercourses support just over a quarter of the high priority taxa, and rocky hillsides just less than a quarter.

Compared to rocky hillsides, open plains and watercourse habitats are more widespread and more homogeneous. This is not the case with rocky terrain, which occupies a relatively small area - 850 km² of continuous habitat in the lower Khan and Swakop River gorges and linked with Husab Mountain. From the perspective of biodiversity, rocky hillsides are the habitat that should be the least disturbed. Avoidable disturbance in any of the three habitats should be minimized, since they all support taxa of high priority.

4.2 Conclusions regarding Rössing mine expansion

4.2.1 Impacts of mine expansion

The only component of Phase 1 expansion that has biodiversity impacts is the creation of a new open pit at SK4 and rock dumps in Dome. The new acid plant and ore sorter will be situated on ground that is already intensely disturbed, so no further biodiversity impacts are expected there.

SK4, an area of 0.2 km², makes up a small proportion – 6.7% – of the whole SK. Since the habitat of SK4 is similar to the whole SK, direct biodiversity impacts in SK4 will be proportionally reduced in extent. The direct impact of eradication of animals is dealt with under Impact 1 below.

An indirect impact on biodiversity, namely the effect of dust on invertebrates and on productivity of plants, is dealt with under Impact 2.

4.2.1.1 Eradication and/or extinction of highly endemic animals

Impact 1 Eradication and/or extinction of animals occurring in SK and proposed rock dump sites in Dome area.
Significance This impact is highly significant as it carries the possibility of the project being fatally flawed by the fact that some species may become extinct from mine expansion.
Nature of the impact

Opening a new mining pit in SK, and covering a new area in Dome with rock debri, will decrease the known area of occurrence, the quality of rocky hillside habitat and the population size of many animal species. 44 known taxa are assigned as High Priority on the basis of their conservation status and area of occurrence. Very little is known about these taxa, but 18 of them are known from the Rössing area only. Of these, seven taxa are understood to live in rocky habitat.

Extent of the impact
Direct disturbance to the animals will occur in the mined area, the rock dumps and in the road and power servitude leading from existing facilities. In these areas, habitat will be completely destroyed. We believe that effects of blasting and noise decrease very rapidly away from the sites of direct disturbance. Dispersal of dust will be more widespread, but probably confined within a radius of 5 km from the mining activity.

This EIA is concerned only with the Rössing expansion, but cumulative impacts from similar developments must also be considered. Phase 1, involving SK4 only, directly affects an area of 0.2 km^2. Further expansion of Rössing in subsequent phases will directly impact an additional 6 km^2. Establishment of mines similar to Rössing at Valencia and Goanikontes within the next 5 – 10 years, will destroy greater areas and further fragment the rocky hillside habitat.

Duration of the impact
Permanent.

Intensity of the impact
The severity of the impact is difficult to assess. Seven species are listed in Table 4 as Threatened and occurring on rocky habitat in the Rössing area only. They are:

Tingle trapdoor spider	*Moggridgea eremicola*
Prodidomid spider	*Namundra griffinae*
Sun spider 1	*Blossia sp*
Sun spider 2	*Lawrencega sp*
Blister beetle	*Iselma deserticola*
Ant spider	*Heredida griffinae* (also on plains and watercourses)
Flower beetle	*Metaphilehedonus swakopmundensis* (also in watercourses)

So little is known about these animals that their role in the ecosystem is not known. The case study of the spider *Moggridgea* (Appendix E) indicates that, because of its rarity, it is not likely to be a ‘keystone’ species i.e. not one on which many others depend or which fills a critical niche in the ecosystem. (Animals which are vital to pollination of certain plants [e.g. wasps, bees], or which play a big role in cycling nutrients back into the soil [e.g. termites], are considered as keystone species.) While we cannot be certain, it is likely that the other six taxa, also known to be very rare, are not key components in the ecosystem. Caution in this prediction is deserved as examples are known of species whose importance has been realized after their extinction (e.g. the case of the seeds of a certain tree eaten by dodos, and no longer establishing young plants as the seeds no

longer pass through dodo guts. Refer S.J.Gould ….). As an educated guess, eradication of a few species which are naturally rare in an arid ecosystem that naturally has very low productivity, will have a low to medium impact i.e. the environment will be altered but the ecosystem will continue to function, possibly in a modified manner. While our prediction is a low to medium impact, the combination of Rössing expansion with other mines in the area will exacerbate the impact. It is impossible to predict how much it will be exacerbated.
Probability of the impact SK and Dome constitute rocky hillside habitat. By our assessment, the total extent of this habitat in and around Rössing is 850 km². The total area of direct disturbance to this habitat is 6 km². As a direct proportion, the disturbed area is therefore less than 1% of this habitat. Open plains and watercourse habitats cover a larger area in and around Rössing, so if there is any direct disturbance in them, it will be a smaller proportion than that of rocky hillsides. The likelihood of causing any extinction from mining in SK and expanding rock dumps in Dome, is therefore very low.
Degree of confidence in predictions The severe shortage of information leaves us with very little confidence in our predictions. This translates to the need for greater caution in our recommendations, as our judgements become based on worst case scenarios.
Possibilities for mitigation Nothing can be done to reduce the severity of destroying an area by open pit mining or smothering it in rock debri. Infrastructures associated with the mining should be sited on lower-priority habitat, namely plains.

4.2.1.2 Dust accumulation

Indications from the 2007 fieldwork were that biological soil crust activity was reduced, and spider and solifuge populations were less than expected. While still inconclusive, these results might be early indications of habitat deterioration caused by Rössing mining activities, outside of the area of direct disturbance.

Impact 2 Increased area of accumulation of dust around the mining operations, which may reduce the productivity of plants, and reduce the abundance and diversity of soil crust organisms

and small invertebrates.
Significance Medium to low significance. This impact has the potential to lower productivity of the ecosystem by reducing plant growth, reducing the cycling of nutrients through soil crust organisms, and reducing the ability of animals such as spiders and solifuges to survive in the area.
Nature of the impact It is suggested that dust, originating from blasting and earth-moving operations, is blanketing rocks and stones on the soil surface, then during fog events being washed down the sides of stones and sealing the cracks and crevices around the base of stones. The mechanism by which this affects soil crust organisms is not known. For invertebrates such as spiders and solifuges, it possibly reduces their shelter and refuge places.
Extent of the impact Dispersal of dust was not assessed in this study. Sites within 2 km from the present open pit and rock dumps showed this feature. It is estimated that the impact could extend about 5 km away from dust-creating operations.
Duration of the impact During mining operations and for a few years (until the next intense rain event) after the end of dust-creating operations.
Intensity of the impact This impact is indirect and probably low to medium severity. Further work is required to understand whether this is responsible for the low arachnid abundance recorded in 2007.
Probability of the impact Possible. At the present state of understanding, it is impossible to predict whether this impact is likely or unlikely.
Degree of confidence in predictions Dust accumulation is certain, yet its role in influencing invertebrate abundance and diversity is very uncertain. Our confidence in stating this impact is very low, hence the need for further work to assess its validity and importance.
Possibilities for mitigation Greater emphasis on dust suppression.

4.2.2 Confidence of our predictions

4.2.2.1 Quantifying risks with statistically perilous data

This whole biodiversity assessment is bedeviled by inadequate information. Most importantly, the very small sample sizes for some taxa, due to their inherent rarity, make our understanding of their extent of occurrence and habitat preference extremely limited.

The very significant consequence of this shortcoming is that our recommendations must err on the side of caution. As explained in Appendix E, the worst case scenario for the spider *Moggridgea* and the 17 other taxa known only from Rössing, is that the small area centred on the Rössing mine is their only area of occurrence, and their populations are severely threatened by mining operations. The best case scenario is that they occupy similar habitats within a radius of 20 – 40 km and, though they are rare, Rössing's impact on their populations is low. The truth probably lies somewhere between the two.

We have tried to quantify the risks to biodiversity according to areas of occurrence and preferred habitats, both of which are based on sample sizes that are statistically worthless. Practicality demands that our biodiversity and ecological expertise should inform our recommendations in the interest of doing least harm to the natural environment. Using this as a basis, the emphasis changes from concentrating on individual taxa, to the functioning of the ecosystem as a whole.

The information from the 1984-1985 and 2007 studies, scanty as it is, does show which taxa are common and which are rare. In terms of ecosystem functioning, the ones that are very rare are less likely to be 'keystone species'. Thus we can be reasonably confident that ecosystem functioning will be maintained even if slightly altered or deteriorated by the proposed Rössing expansions.

4.2.2.2 Strengths and weaknesses of preliminary field observations

The tight schedule for this biodiversity assessment did not allow the second round of animal collecting in 2007 to be done in an appropriate season or over a more productive length of time. Yet observations were made and possible causes of worrying signs have been suggested. How worthy are they?

Preliminary indications from the 2007 fieldwork are exactly that – only preliminary, not well verified, and only indications, not proof. Yet the observations were made conscientiously and with scientific rigour, so deserve proper consideration. The suggestions for further biodiversity and ecological work at Rössing will help to assess whether the indications are borne out, and whether possibly unexpected impacts will be identified. If they are, they can contribute to improved environmental management of the mining activities.

4.2.3 Options for mitigation

Options for mitigation of the proposed mine expansion activities are severely limited.

4.2.3.1 Minimise the new footprint

As a critical biotope will be directly affected by the planned mine extension, reducing the footprint of the expansion to a minimum is mandatory. This will require clearly demarcated access routes and stringently enforced track discipline. All work areas need to be clearly demarcated and sign-posted. Any movements outside these marked areas will require special permission involving Rössing's environmental staff. Further, waste and pollution management, water and energy usage will need to follow established procedures.

4.2.3.2 Translocation

The area ear-marked for mining harbours several large *Adenia pechuelii* plants, some of which may be directly affected by the future mine extension. As these are charismatic species of high conservation importance, transplanting trials would be a very valuable exercise enabling Rössing to demonstrate its commitment to biodiversity conservation. Once the site lay-outs for the extension area are available, affected specimens should be marked and a suitable site selected for a transplant trial. Involvement of the National Botanical Research Institute would be essential to obtain permits and relevant expertise.

While translocation or rescue operations can be worthwhile for plants and some large animals, this option is not practical for small animals such as scorpions or solifuges, especially rare ones. Firstly, capturing small fast moving or very cryptic or very scattered animals is impractical. Once caught, they have to be moved to another area of suitable habitat. Such habitat will already be occupied by other individuals of those species, and the new arrivals will face problems such as territoriality from the residents, inability to find or make adequate shelter, and consequent predation or death from being exposed. A high proportion of the newcomers are likely to die. Even if they do survive immediately, the final population size is closely related to the area of appropriate habitat, and the fact will remain that some of the appropriate habitat has been destroyed, so total population size will decrease proportionally. These are just a few of the obstacles that make translocation of very small animals an impossible or ineffective solution.

4.3 Recommendations for further work

4.3.1 Improve biodiversity data collection

Although more intensive plant collecting over the past growing seasons have greatly improved overall plant data coverage, most parts of the Rössing extension area have only been surveyed once. Repeated sampling will be necessary, particularly in those mapping units that were only accessed along their margins, such as the Khan River mountains and south-east gneiss hills.

Long-term collecting of animals, especially invertebrates, in particular biotopes will shed more light on the habitat requirements of those species that exist in the Rössing area. As mentioned in Section 3.2.3.1 (arachnid results), questions have been raised about the status of arachnids, particularly solifuges, in the Rössing area. Fieldwork on an ongoing basis, to include rainy seasons and the periods of activity that follow rains, will be beneficial here. This will enable Rössing to better understand and possibly mitigate its negative impacts on arachnids as well as other animals.

The approach to biotope monitoring by Burke (2005 and 2007) is to monitor selected indicator plants. This approach could usefully by applied to animals too. Appropriate animal indicator species, such as solifuges which are readily trappable and hold relatively high positions in the food chain, should be identified and monitored.

At the same time, it must be recognized that more collecting is very likely going to reveal more new species, so the process is likely to answer some questions and open up some more. This is not a reason to avoid doing such work, as all of the information contributes to improved understanding of the central Namib ecosystem, for the benefit of sustainable management.

4.3.2 Evaluate restoration and rehabilitation methods

Special measures to facilitate the recovery of critical biotopes are required. Rehabilitation practices such as preserving and re-spreading topsoil, seeding and replanting with indigenous species will need to be tested and site-specific protocols developed for particular habitats. Presently very little is known about appropriate practices in this arid environment and setting up trials will be an essential part of Rössing's biodiversity strategy.

With regard to biological soil crusts, it will be useful to retain surface soil layers in areas to be newly disturbed. Experiments could reveal whether this assists restoration rehabilitation of disturbed areas, and could provide practical guidelines on how to most effectively maintain biological soil crusts. As a first lesson, always return BSC-bearing stones to their original place and orientation, so that the organisms are not killed by being dried out.

4.3.3 Specifically evaluate impacts of dust on micro-habitats

We suggest that dust could have a more profound effect on ecological processes than has been previously recognized. In this regard, it would be useful to monitor physical quantities of dust and its deposition in areas surrounding the mining areas, and associated features such as biological soil crusts, moisture below stones and rocks, and processes associated with them.

4.4 Conclusions regarding Phase I expansion

Opening up and mining of the SK4 area, expanding rock dumps in Dome and establishment of road and power infrastructure to the new pit, are the components of expansion in Phase I involving extension onto undisturbed land. It is possible, but unlikely, that any of the species recorded at Rössing will be eradicated by these expansions. Since the individuals of the taxa categorized as High Priority are naturally rare, it is unlikely that any of them can be considered ‘keystone species’, therefore functioning of the ecosystem will continue with little change.

Phase 2 expansion into the remainder of SK and into SH will slightly increase the likelihood of causing any extinctions, and will add to the cumulative impacts of habitat fragmentation and disturbance caused by other quarries and uranium mines in the surroundings. For this reason, further biodiversity sampling work and ecological investigations are urgently needed to improve our understanding of the species that are highlighted as High Priority, and of their ecological roles. Additionally, work on biological soil crusts and apparent scarcity of arachnids will reveal whether there are other features of mining activities at Rössing that require management.

5. Glossary

biological soil crust (BSC)	association in different proportions between soil particles and cyanobacteria, actinomycetes, microalgae, microfungi, lichens, mosses and liverworts in the top millimeters of soil surfaces or under translucent stones
black BSC	biological soil crust without active diatoms and green algae, this assumed to be dominated by cyanobacteria
brown BSC	soil-coloured crust adhering to stones/rocks and sometimes lightly bound with filaments that could be microfungal mycelia or filamentous cyanobacteria
green BSC	biological soil crust assumed to be dominated by diatoms / microalgae
cyanobacteria	blue-green algae that grow in crusts, filamentous aggregations or mats
epilithic	on top of stones/rocks
fensteralgen	hypolithic green algae and diatoms found under translucent stones
hypolithic	under stones/rocks
morphospecies	organisms that look alike and are probably the same species
perilithic	near-surface soil area around the base of stones/rocks
voucher specimen	a specimen collected for identification, and representing many other individuals of the same species that are not collected.

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