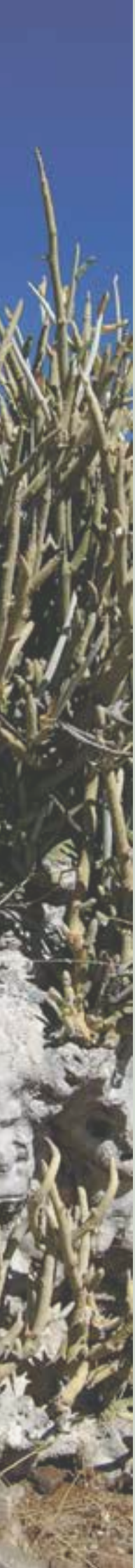


National conservation assessment and management of two Namibian succulents

with specific reference to the Rössing Uranium Mine



Report on a partnership project
between the National Botanical Research Institute of Namibia,
Rössing Uranium Limited, the Rio Tinto Group and the Royal Botanic Gardens, Kew.



Project details

AUTHORS	Sonja Loots: National Botanical Research Institute
CONTRIBUTORS	H. Kolberg: Millennium Seed Bank Project
	Steve Bachman: Royal Botanic Gardens, Kew

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Rio Tinto Rössing Uranium Limited

Kew PLANTS PEOPLE POSSIBILITIES

MILLENNIUM SEED BANK PROJECT Kew

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List of Acronyms and Abbreviations

ETM	Enhanced Thematic Mapper
ICRAF	International Centre for Research in Agro-forestry
IUCN	World Conservation Union
LC	IUCN Red List category: Least Concern
MAWF	Ministry of Agriculture, Water and Forestry
MET	Ministry of Environment and Tourism
MSB	Millennium Seed Bank
MSBP	Millennium Seed Bank Project
NBRI	National Botanical Research Institute
NNP	Namib Naukluft Park
NPGRC	National Plant Genetic Resources Centre
NT	IUCN Red List category: Near Threatened
pers. obs.	personal observation
RBG	Royal Botanic Gardens (Kew)
RUL	Rössing Uranium Limited
SCP	Skeleton Coast Park
WIND	National Herbarium of Namibia

SUMMARY

Rössing Uranium Limited's (RUL) biodiversity strategy recognised the importance of managing plant species of conservation importance occurring within the licence area of the mine. Based on their conservation importance, two species from the mine were selected to be assessed in order to answer two main questions:

1) What percentage of the global population of each of the target species occur within the licence area?

2) How important are these populations compared to the rest of the populations across the distribution range of the target species?

A partnership was formed between RUL, NBRI, Rio Tinto Group and RBG Kew to carry out field assessments on 35 sites of *Adenia pechuelii* (Engl.) Harms and 19 sites of *L. ruschiorum* (Dinter & Schwantes) N.E.Br., across their distribution ranges in Namibia.

Of the 2,671 *A. pechuelii* individuals recorded over its distribution range, some 226 are located at RUL. This accounts for approximately 8 percent of the total number of plants recorded. In terms of the number of plants recorded, the RUL population is the third-most important. In terms of density, however, this population is rated as one of the lowest, as the plants are widely scattered over a large area.

Some 8,367 *L. ruschiorum* individuals were recorded over its distribution range. Of these, 2,011 were recorded at RUL, making it the second-largest population in the study area. This accounts for approximately 24 percent of the total number of plants recorded.

Most of the sampling sites at RUL, which are regarded as important for the conservation of *L. ruschiorum*, are located directly north of the tailings facility.

The data collected suggest that the original tailings facility was constructed over a large part of the *L. ruschiorum* population at RUL, and consequently a part of this population was destroyed. It is therefore crucial to conserve the remainder of this habitat with over 1,000 plants in the "no-go area", which was established by RUL.

The Red List status for *L. ruschiorum* remains unchanged at Least Concern. The status for *A. pechuelii* is down-listed from Near Threatened to Least Concern. This updated national assessment will be published in a local publication in due course.

It was found that conducting a national assessment on a species with a wide distribution range is a significant undertaking and it is therefore recommended that in future only one species should be investigated at a time.

Future work on *Lithops* as a genus should focus on the distribution of species at various scales, which should include the investigation, testing and development of abundance estimators that will be applicable to a wider range of small succulents.

Molecular studies on *Lithops* populations could provide further insight with respect to determining population boundaries. A critical review should be conducted on the conservation status of all *Lithops* species in Namibia.

Recruitment in populations of *A. pechuelii* should be monitored and a study to investigate the reasons for the poor seed setting in most populations should also be carried out.

INTRODUCTION

As part of RUL's Biodiversity Action Plan and its commitment to having a positive impact on biodiversity, and consistent with specific recommendations made by Burke (2005), the company undertook to identify and assess plant species of conservation concern within its licence area. RUL, as part of the Rio Tinto Group, is committed to the conservation of threatened and endemic species and to the protection of high priority conservation areas. They also support local, national and global conservation initiatives.

Conducting Red List field assessments is a mandate of the NBRI [MAWF], but its resources are limited. The number of staff available to do the work is inadequate, as is the operational budget, given the significant distances that needed to be covered in the course of carrying out the field assessments.

With this in mind, a partnership was formed between the National Botanical Research Institute (NBRI), Rössing Uranium Limited (RUL), the Rio Tinto Group and the Royal Botanic Gardens, Kew, incorporating the Millennium Seed Bank Project (MSBP). These partners developed a concept note for a project to conduct Red List assessments on selected target species and to devise management and monitoring plans for these species within the RUL licence area. Each partner had a different, but equally important, role to play.

The NBRI, which resides under the Ministry of Agriculture, Water and Forestry, was mandated to conduct the field work (staff time), provide office space and equipment, transport, Daily Subsistence Allowance and genebank storage facilities. Rio Tinto provided the funds to obtain additional equipment and consumables necessary for conducting field work, to facilitate data capture and analysis, and to pay for mileage, Daily Subsistence Allowances for collaborators outside the NBRI and consultancy fees.

RUL provided additional funds for accommodating NBRI staff during their work in the licence area, as well as technical support, staff time to assist with Red List assessments, training in health and safety, and maps. RUL also set aside funds which will be used for monitoring the target species after the project has ended. Kew provided staff time for the overall management of the project and a consultancy for targeting species localities. The MSBP provided staff time for identifying species suitable for seed collecting, conducting seed collecting, processing, production of data for the species management plan, as well as long term seed storage and a report on seed collecting activities.

The anticipated short-term outcome of the project was "increased knowledge and improved management of priority plant species found in the RUL mine licence area". The long-term goal was "improved long-term conservation, management and restoration of plant diversity, plant communities, and the associated habitats and ecosystems, *in situ* (both in natural and in managed environments), and where necessary to complement *in situ* measures, *ex situ*, preferably in the country of origin".

The project is in line with the following wider initiatives:

- the Global Strategy for Plant Conservation (GSPC)
- the Millennium Seed Bank Project
- the Threatened Plants Project of the NBRI
- the National Biodiversity Strategy and Action Plan (NBSAP)
- the National Development Plan 2 (NDP 2)
- the National Development Plan 3 (NDP3)
- the MAWF Strategic Plan
- the Rio Tinto Biodiversity Action Plan.

The project also had the following Target Conservation Outcomes:

- Improved awareness of the conservation status and national population distribution of target species and relevant importance of populations found at RUL
- Species management plans for target species developed for RUL and under implementation
- Raising the capacity of MET and mine staff to undertake Red List field assessments, seed collections and monitoring
- Seed of target species (endemic and Red List species found at RUL) in *ex situ* collections at the MSB, UK and the NPGRC, Namibia
- Long-term monitoring strategy developed and implemented for target species.

The following purpose indicators were listed for the project:

- IUCN ratings for species are reviewed, based on more detailed knowledge/information acquired and, if necessary, amended by the end of 2009, leading to more accurate assessments
- Rio Tinto's biodiversity partners recognise that RUL is making active management decisions (indirect or direct) that take into account NBRI's recommendations for target species
- No loss of target species populations on the RUL concession area recorded from the time when the project is completed until mine closure (figures to be specified and specific indicators defined following field research)
- Management recommendations for long-term species conservation included in the mine's closure plan.

The outcome of this project has enabled RUL to make a valuable contribution to the conservation and management of some important Namibian plant species, especially in terms of new information gained on the distribution and abundance of the target species. Management of these species within RUL's boundaries is the responsibility of the company.

Chapter 1

CHAPTER 1: ASSESSMENTS ON *LITHOPS RUSCHIORUM* AND *ADENIA PECHUELII* IN THE RUL LICENCE AREA

Background

Among Namibia's wealth of plant diversity a significant number of species are of conservation importance. Over 1,000 species have been evaluated against the IUCN Red List criteria, and of these, some 600 are rare, endemic or threatened with extinction (Loots, 2005).

Undertaking field assessments on populations of species that are of conservation concern adds invaluable knowledge, thereby contributing to their conservation and management. Field assessments are the most reliable way of monitoring numbers of plants in a population and enable scientists to detect decline in population size over time, which is one of the criteria for Red List assessments (IUCN, 2001).

Initial research was carried out on botanical diversity within and around the RUL licence area (Burke, 2005), but without focusing on any species in detail. Some 140 plant species were recorded, with 68 appearing in Namibia's Red Data Book (Loots, 2005). Twenty-four species from this list, which are of conservation concern and/or endemic to Namibia, were identified as priority species and used to rate biotopes in the mine's licence area (Burke, 2005).

This list includes *A. pechuelii* (Conservation status: NT) and *L. ruschiorum* (Conservation status: LC; protected under Nature Conservation Ordinance 4 of 1975). Given their desirability to succulent collectors and vulnerability to potential habitat destruction, both species are of conservation concern. These reasons provided the motivation for choosing the two species on which the survey focused. The proportion of the global populations of *A. pechuelii* and *L. ruschiorum* that occur within RUL's licence area was not known.

Existing records show that both species are endemic to Namibia, but unconfirmed reports claim that *A. pechuelii* occurs in the south-west of Angola. This is entirely possible since records show that the northernmost occurrence of *A. pechuelii* is at the border between Namibia and Angola. It is also possible that *L. ruschiorum* occurs in Angola. If these reports are confirmed with herbarium specimens, it would mean that neither species is endemic to Namibia.

In addition to *A. pechuelii* and *L. ruschiorum* there are other species of conservation concern in and around the RUL concession area, for example *Commiphora oblanceolata* (Schinz) and several species of *Hoodia*.

Increasing the knowledge of the distribution and conservation status of these species is a priority for their conservation and management. However, given the time constraint and the detailed nature of the study that was undertaken on *L. ruschiorum* and *A. pechuelii*, it was not possible to focus on these other species as well.

Therefore, a partnership was formed between RUL, NBRI, Kew and Rio Tinto Group to undertake field work from 2006 to 2008 for the purpose of assessing populations of *Lithops ruschiorum* (Dinter & Schwantes) N.E.Br. and *Adenia pechuelii* (Engl. Harms) throughout their distribution ranges in Namibia. As a result, clarity was gained about where the densest populations are and how the populations at RUL compare to the rest of the populations across the distribution ranges of the two species.

Although some taxonomists, such as D. Cole, an international expert on the genus *Lithops*, divide *Lithops ruschiorum* into two varieties (Cole, 1988), The National Herbarium of Namibia (WIND) follows Germishuizen and Meyer (2003), who do not recognise any infra-specific taxa for this species.

In this report, *Adenia pechuelii* will hereafter be referred to as *A. pechuelii* and *Lithops ruschiorum* will be referred to as *L. ruschiorum*.

Methods

The work done by Burke (2005) indicated in which biotopes *L. ruschiorum* and *A. pechuelii* are present, and was used as a guide for sampling the licence area. The area was divided into 1 km grid squares, and some 68 corresponding waypoints at the grid nodes, hereafter referred to as "sampling sites", were entered into a GPS (Figure 1.1).

These 68 sites were then systematically surveyed, as described below, in order to find sites with *L. ruschiorum* and *A. pechuelii*. In addition to the sampling sites, *A. pechuelii* specimens were recorded whenever they were encountered within the licence area.

In addition to the 68 predetermined sampling sites, five more sites were selected to the north of the tailings dam to cover an area of *L. ruschiorum* that was previously known, as well as a site in the marble hills biotope and another one east of the tailings dam near the office buildings.

This brought the total number of sampling sites to 75. A data sheet, on which all relevant data for each site were recorded, was designed for the two species (Appendix 1). At every sampling site, the presence or absence of *L. ruschiorum* and *A. pechuelii* was recorded, as well as a site description and relevant habitat information.

If *L. ruschiorum* was observed at or near a particular sampling site, each plant was temporarily marked with coloured markers in order to count the plants and determine the boundary of the site (see photographs Appendix 2). Then the number of mature plants (plants that are capable of reproduction), the number of juveniles (plants not yet capable of reproduction) and the number of damaged plants were recorded.

A plant was considered damaged when insect or other damage was extensive enough to affect the plant's growth or ability to reproduce. Minor damage was therefore not recorded.

The distinction between mature plants and juvenile plants is rather subjective as there is no recorded procedure to determine at what size a plant starts to flower.

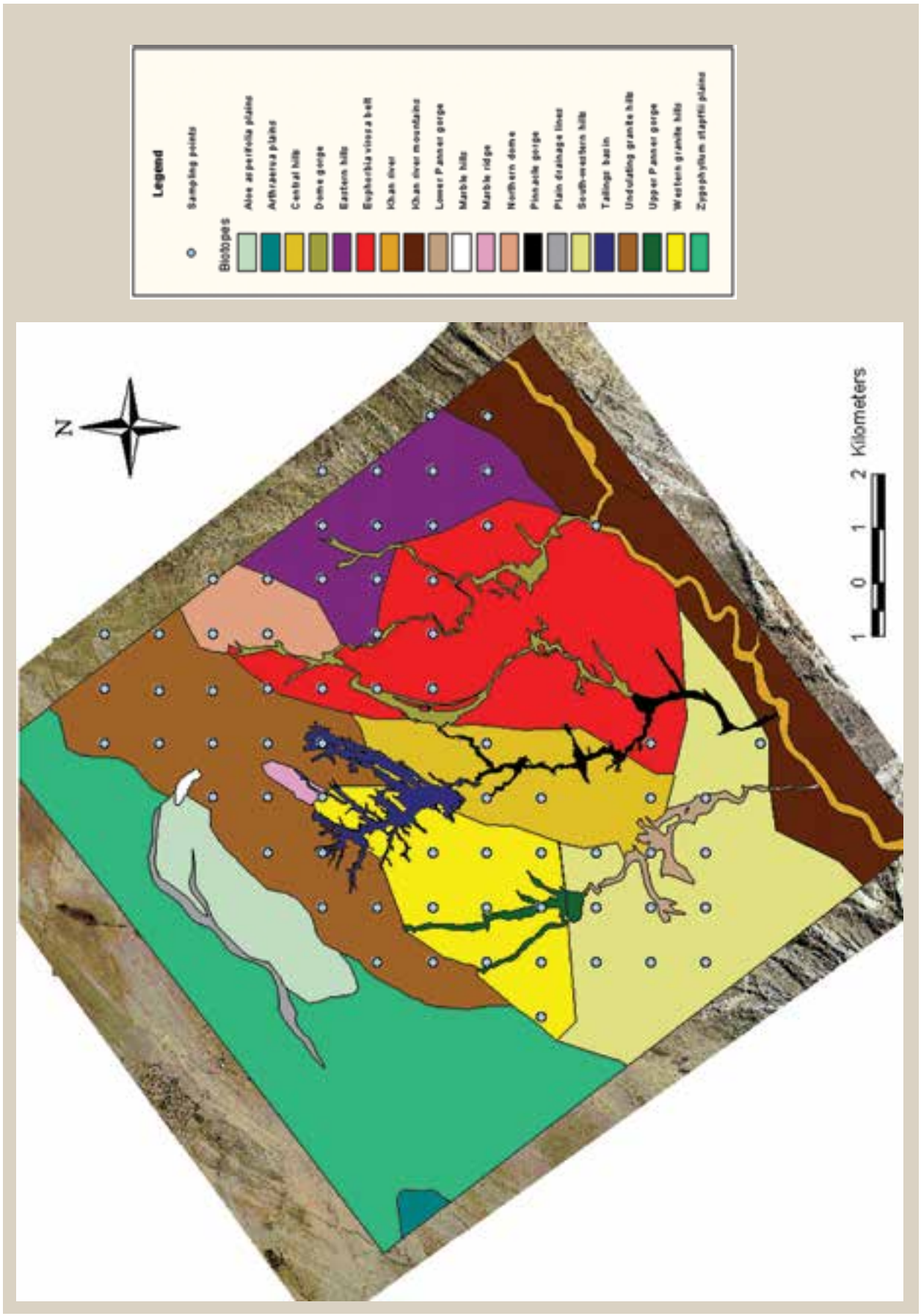

Figure 1.1: Biotopes (Burke, 2005) and sampling sites in the RUL licence area

For the purpose of the survey, a plant was regarded as juvenile if it was smaller than 1 cm in diameter, did not yet have the distinctive heart-shaped body, but rather a flat top, and the two lobes of the body were not yet partially separated. See Appendix 2 for a photograph of a juvenile plant.

At each sampling site the area in which the *L. ruschiorum* occurred, was measured using the track log function of the GPS. The track log was set up to record one set of coordinates every second. In this way, the GPS recorded between 85 and 800 points for each population, making the outline of the site as accurate as possible. The tracks were then regularly downloaded onto the Garmin Trip and Waypoint Manager, from where they were imported into Arc View version 3.29 to produce maps.

A 10m x 10m (100m²) square was established over one of the densest parts of selected sites to serve as a long-term monitoring plot. Each corner of the square was marked with a red iron dropper, and the GPS reading taken in the centre of the square to mark its location. No monitoring square was established at sites where there were few plants, so that each monitoring square contained at least eight plants at the time of establishment. The red iron droppers were later replaced with yellow metal poles, which were fixed with cement to make them permanent.

The number of plants in the monitoring squares was recorded separately from the number of plants in the rest of the site, and the two figures were then added to get a total number of plants in a site. The density of the site was calculated as follows:

$$\frac{\text{Number of plants in monitoring square + number of plants in the rest of the site}}{\text{Area of the site (m}^2\text{)}}$$

At every sampling site the GPS coordinates were taken in the centre of the site for both target species, with altitude, soil type, soil colour, lithology, aspect and gradient also recorded. Soil samples were taken at 52 sampling sites and brought back to the NPGRC where they were analysed for colour, texture and pH.

Soil texture was determined via a manual process based on a standard procedure used by ICRAF. Soil pH was determined using a Hannah microprocessor pH meter. These data were used to determine the habitat preference of the target species at RUL.

Photographs were taken of the habitat, monitoring squares and some plants from close-up (Appendix 2 and 5). Associated vegetation was recorded and where the plants could not be identified, specimens were collected according to standard practice.

A. pechuelii plants were recorded individually, unless more than one plant occurred at the same coordinates, in which case only one set of coordinates was recorded, indicating the number of plants present there. As these plants are usually far apart, monitoring squares were not established and the area around the plants was not measured.

The same habitat data as for *A. pechuelii* were recorded for *L. ruschiorum*. The density of the *A. pechuelii* population at RUL was calculated using the "Nearest Neighbour Method" (Cottam and Curtis, 1956), a plot-less sampling method, and "Density from Distances" (Henderson and Seaby, 1999), a software programme that calculates density using plot-less density estimators upon entering of the data.

The data recorded on the data sheets were entered into the MS Access database that was developed in collaboration with RBG Kew. This allowed the data to be queried for mapping and to be analysed for producing results. Field work and data analysis undertaken at RUL were conducted from 2006 to 2007.

Results

L. ruschiorum were recorded at 19 of the 75 sampling sites surveyed at RUL, *A. pechuelii* at 16, and both species at 14 of the sampling sites. At 26 of the sampling sites, neither species could be found. Figure 1.2 presents these results as percentages.

Soil and lithology in the RUL licence area

The pH recorded at various sampling sites ranged between 7.9 and 9.8. The soil at the sampling sites in the RUL licence area is therefore slightly to moderately alkaline. Figure 1.3 shows the soil textures recorded at the sampling sites, indicating that clay-loam is the preferred soil type with which both *L. ruschiorum* and *A. pechuelii* at RUL are associated.

Where *L. ruschiorum* and *A. pechuelii* occurred, the soil predominantly had a light brown colour. The lithology was dominated by quartz, granite and pegmatite, but marble, dolerite and schist were also occasionally recorded.

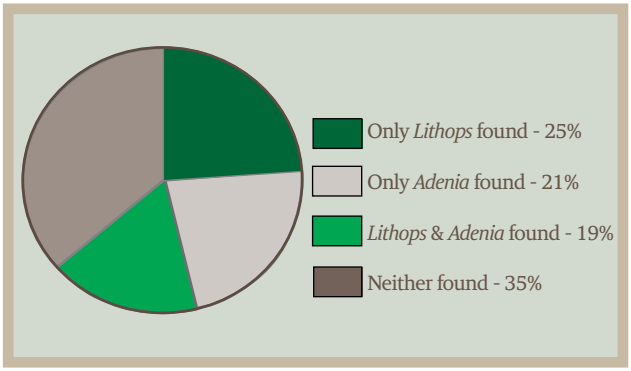

Figure 1.2: Summary of sampling sites surveyed in the RUL licence area

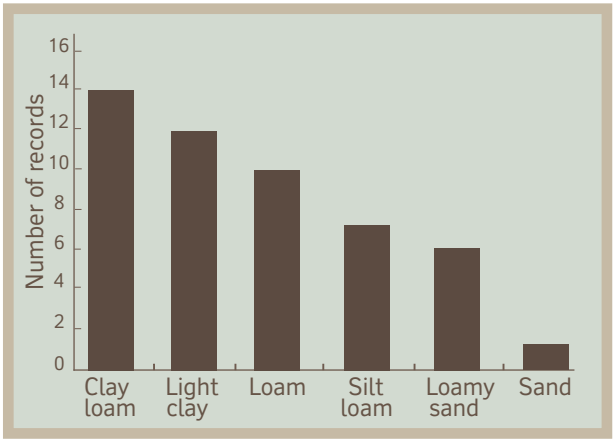

Figure 1.3: Soil texture recorded in the RUL licence area

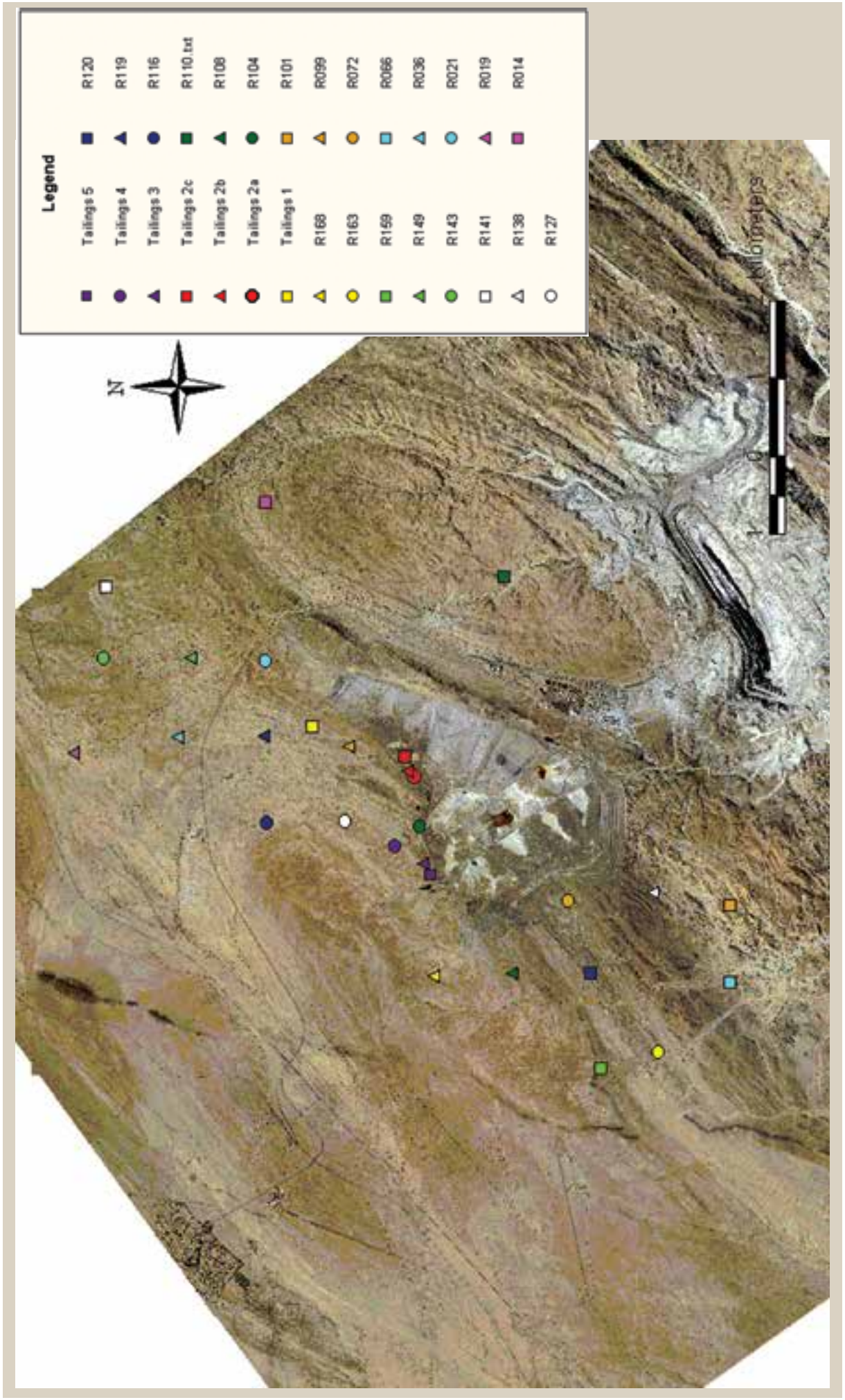

Figure 1.4: Distribution of *L. ruschiorum* in the RUL licence area

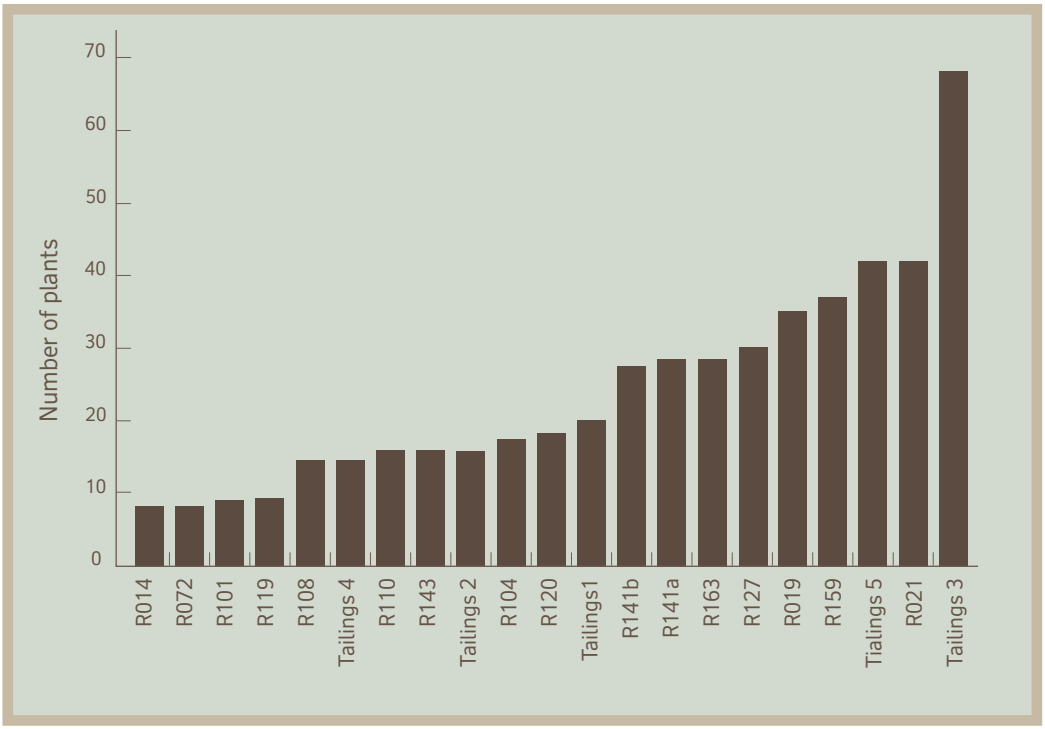

Figure 1.5a: Number of *L. ruschiorum* plants in each monitoring square

Distribution and density of L. ruschiorum *in the RUL licence area*

Field work revealed that *L. ruschiorum* occurs as individual plants or in clusters of varying densities at RUL. Figure 1.4 (on the previous page) maps the distribution of the sites at which *L. ruschiorum* was recorded in the RUL licence area.

A total of 2,011 *L. ruschiorum* individuals was recorded in 33 sampling sites across the licence area, including 520 in the 21 monitoring squares. Thus the *L. ruschiorum* in the monitoring squares constitute approximately 26 percent of the *L. ruschiorum* recorded in the licence area. Appendix 2 includes photographs of *L. ruschiorum* and their habitats taken at some of the sampling sites. Appendix 4 depicts the individual outline of each *L. ruschiorum* site recorded at RUL, as it was mapped on the Orthophoto.

Figure 1.5a shows the number of *L. ruschiorum* plants in each monitoring square. The three monitoring squares with the most plants are all very close to the tailings dam (Figure 1.5c).

Figure 1.5b shows the number of plants in the monitoring squares as a frequency distribution, demonstrating that squares with a low number of plants occur at a high frequency and those with a higher number of plants occur at a lower frequency.

Figure 1.5c maps the distribution and number of plants in each of the monitoring squares that were established for *L. ruschiorum*.

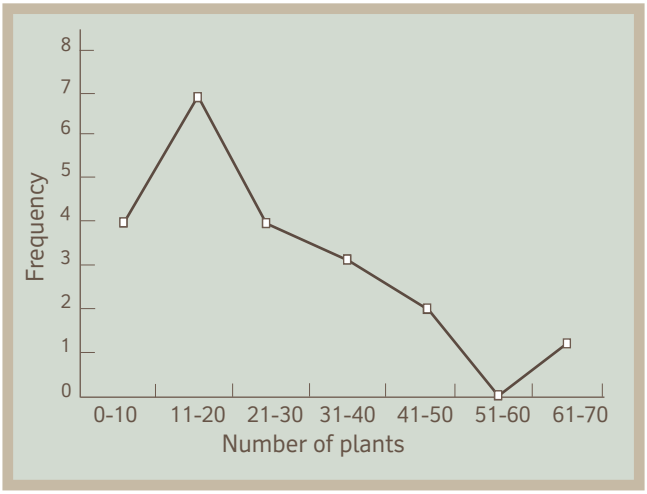

Figure 1.5b: Number of plants in monitoring squares displayed as a frequency distribution

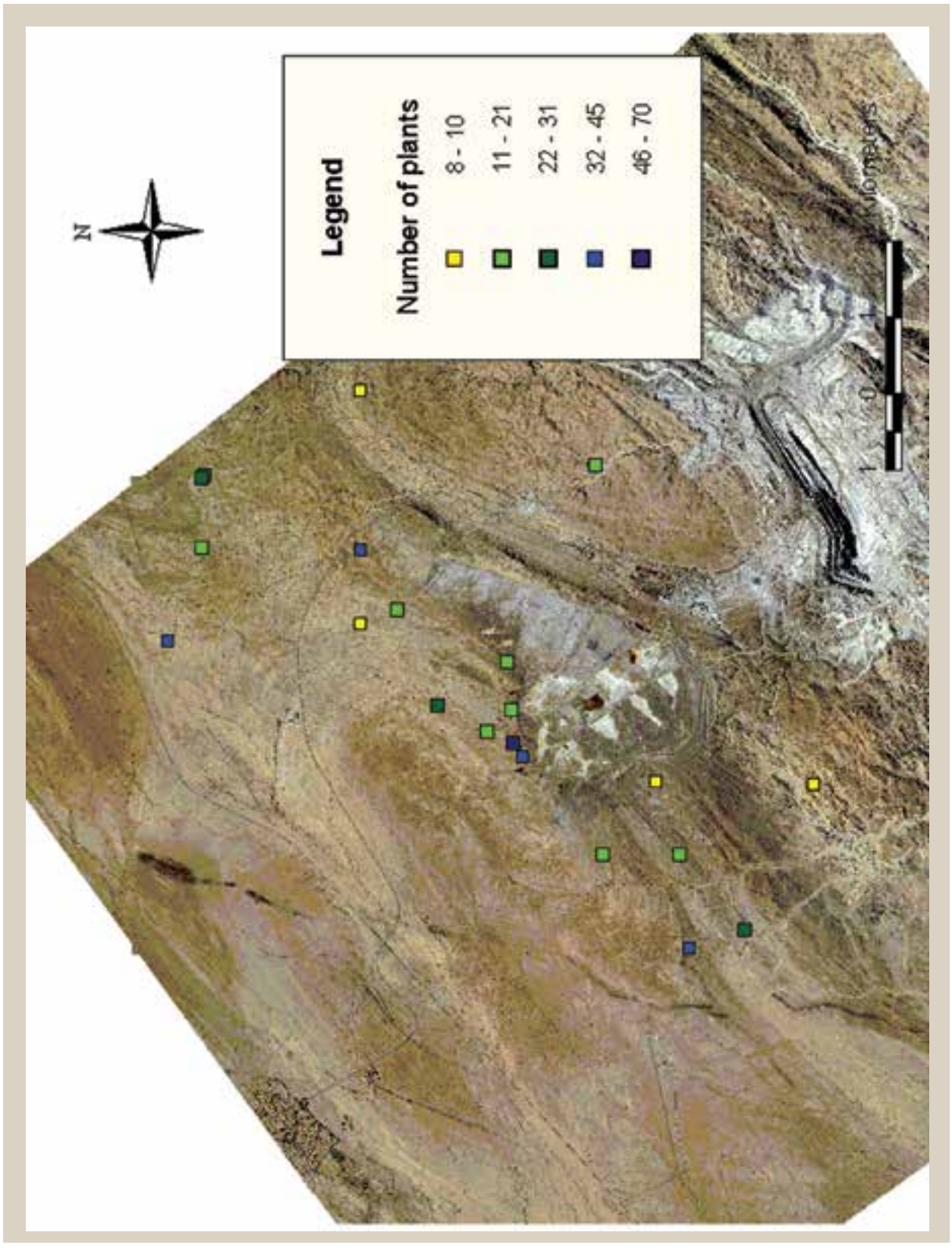

Figure 1.5c: Distribution and number of plants in *L. ruschiorum* monitoring squares.

Figure 1.6a gives the number of *L. ruschiorum* plants at each of the sampling sites and Figure 1.6b expresses this as a frequency distribution. The frequency of sites with fewer plants is much higher compared to sites with many plants.

Figure 1.6c and Figure 1.6d show the density at each site, and the frequency of sites with low, medium and high densities respectively. Sites with a medium density occur more frequently than those with low or high densities.

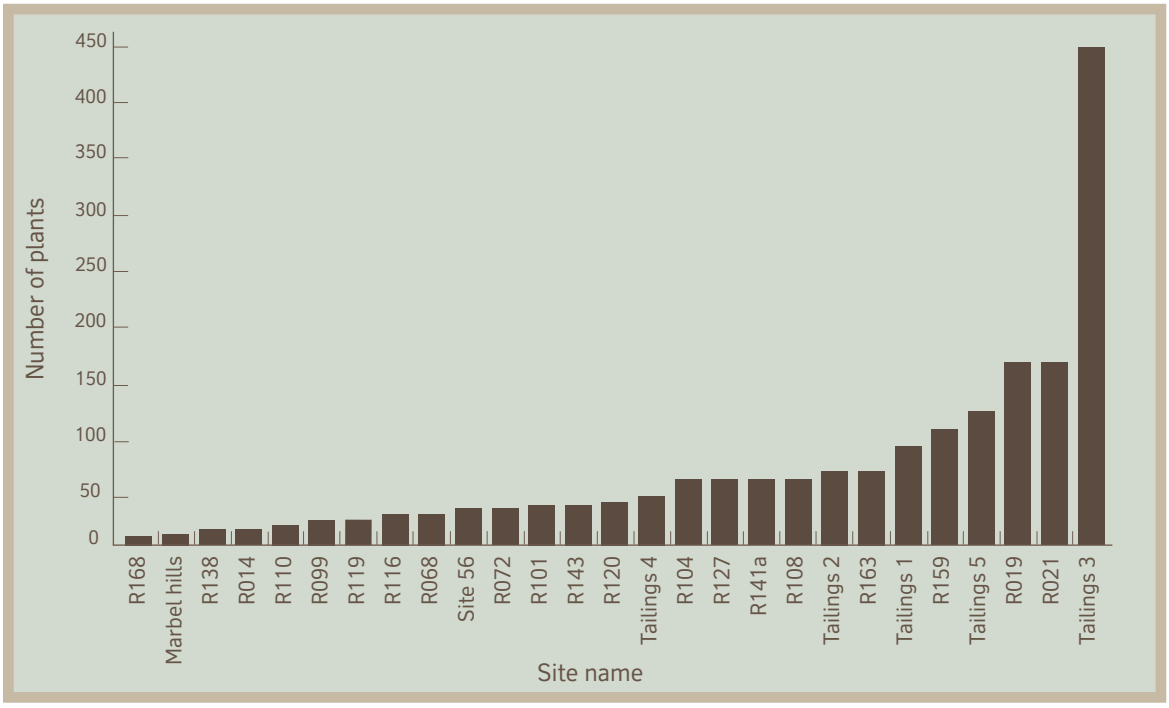

Figure 1.6a: Number of *L. ruschiorum* plants at each sampling site

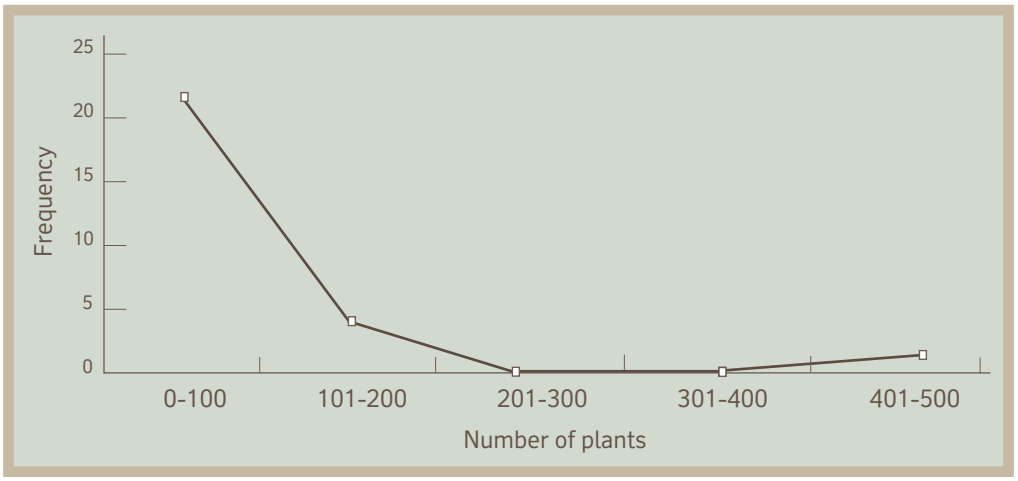

Figure 1.6b: Frequency of population size groups

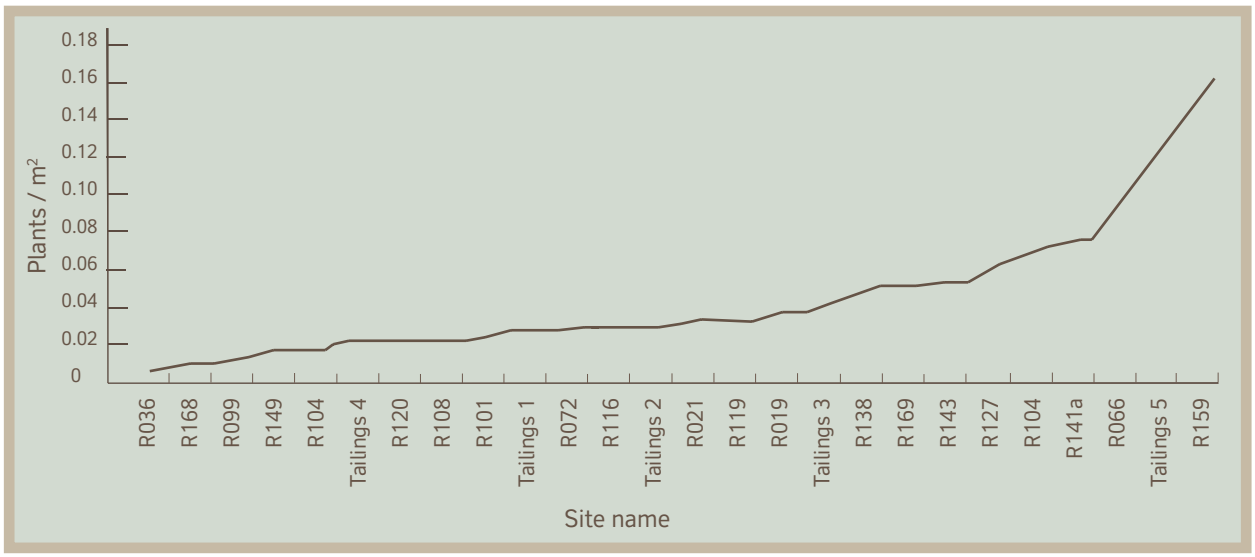

Figure 1.6c: *L. ruschiorum* density at respective sampling sites

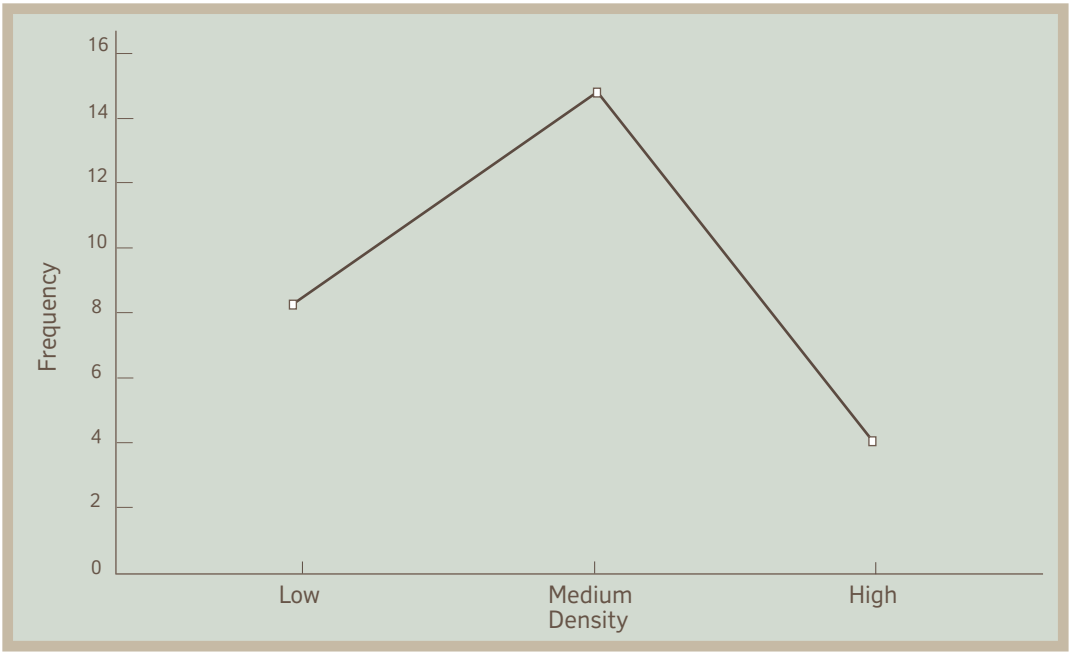

Figure 1.6d: Frequency of density groups

Table 1.1 presents three criteria: a) number of plants, b) density and c) number of plants in the monitoring square. The sampling sites that have more than 40 plants, a density of more than 0.02 plants/m² and have more than 15 plants in the monitoring square are regarded as the most important areas for *L. ruschiorum* at RUL (see map in Chapter 3, Figure 3.21). Note that five of the twelve most important sampling sites for *L. ruschiorum* are located directly adjacent to the tailings dam.

Where there were sufficient plants present, a single *L. ruschiorum* specimen was collected per sampling site. This was done in order to ensure that collecting would not be detrimental to the survival of the population, but at the same time that the species would be sufficiently represented in WIND. Some 20 specimens were collected at RUL for incorporation into the collection, which makes this species the best represented of some 16 *Lithops* species occurring in Namibia.

Site name	Number of plants	Density	Plants in monitoring square	Site important for conservation
R036	6	0.00336		
R149	7	0.01333		
R168	8	0.00726		
R138	11	0.04741		
R014	13	0.01526	8	
R110	16	0.16	16	
R099	22	0.0086		
R119	24	0.02938	10	
R116	25	0.02626		
R066	33	0.10092		
R072	39	0.02508	8	
R101	45	0.02108	10	
R143	48	0.04878	16	•
R120	48	0.01894	18	
Tailings 4	56	0.01857	15	
R104	64	0.0678	17	•
R127	64	0.05834	31	•
R141a	66	0.07277	28	•
R108	69	0.01924	15	
Tailings 2	75	0.02659	16	•
R163	77	0.04756	29	•
Tailings 1	97	0.02417	21	•
R159	111	0.15546	38	•
Tailings 5	137	0.12768	44	•
R019	178	0.03331	36	•
R021	183	0.0288	45	•
Tailings 3	440	0.03715	70	•

Table 1.1: *L. ruschiorum* sites at RUL that should be targeted for conservation

Distribution and density of A. pechuelii *in the RUL licence area*

Some 226 *A. pechuelii* plants were recorded in the RUL licence area and are regarded as belonging to a single population, although determining population boundaries proved difficult. Most plants were encountered at 30 of the predetermined sampling sites, but a significant number of individuals was recorded on roads and tracks between sampling sites, and these were assigned new site numbers.

Figure 1.7 maps the distribution of *A. pechuelii* in the RUL licence area. At a number of sampling sites specimens were collected and photographs taken of *A. pechuelii* (Appendix 5). The distribution of *A. pechuelii* at RUL suggests that a proportion of the population was destroyed by the establishment of the tailings facility and the open pit area. Quantifying this proportion would be difficult, however.

Figure 1.8a shows the number of plants at each of the *A. pechuelii* sampling sites.

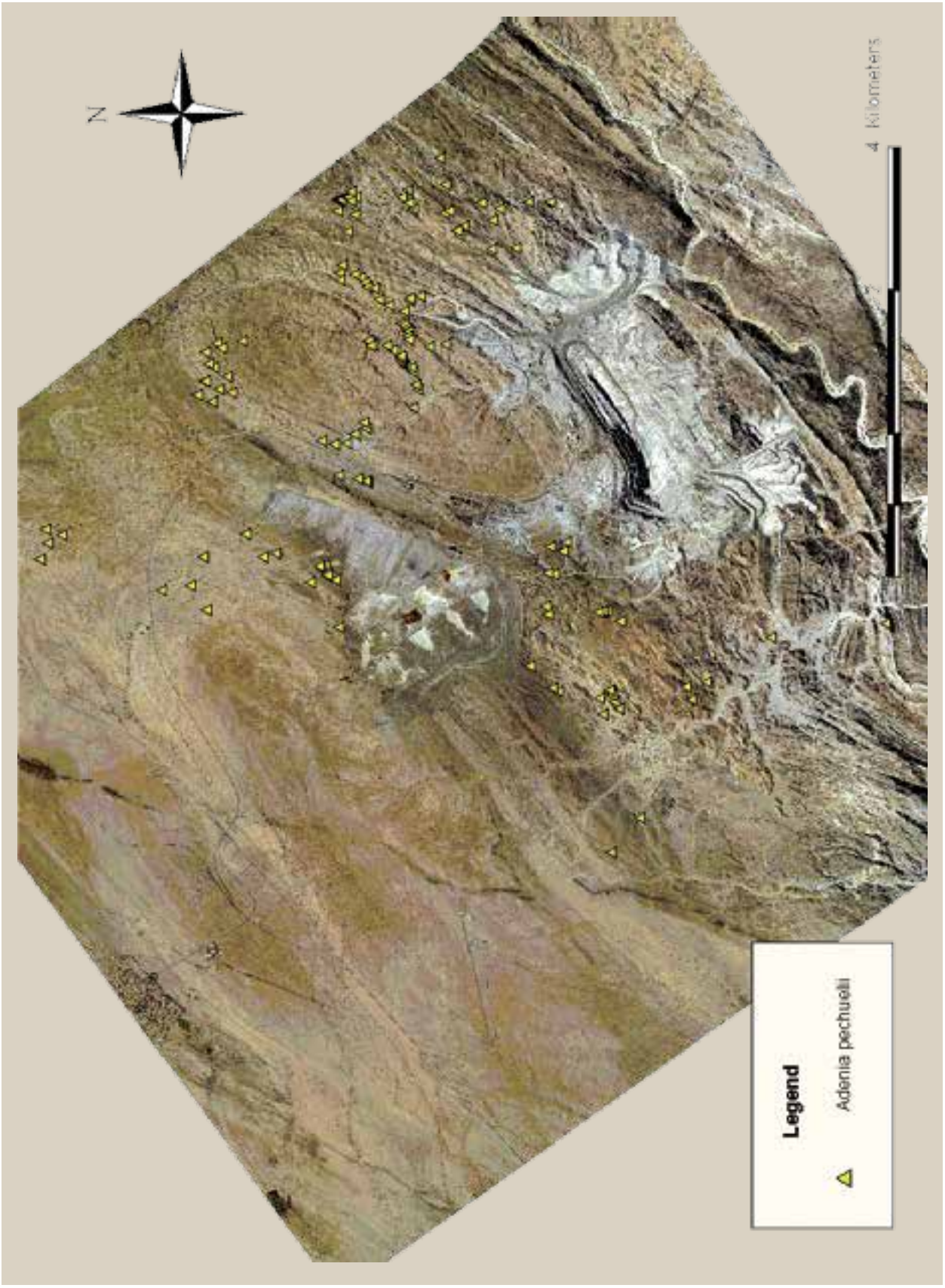

Figure 1.7: Distribution of *A. pechuelii* in RUL licence area

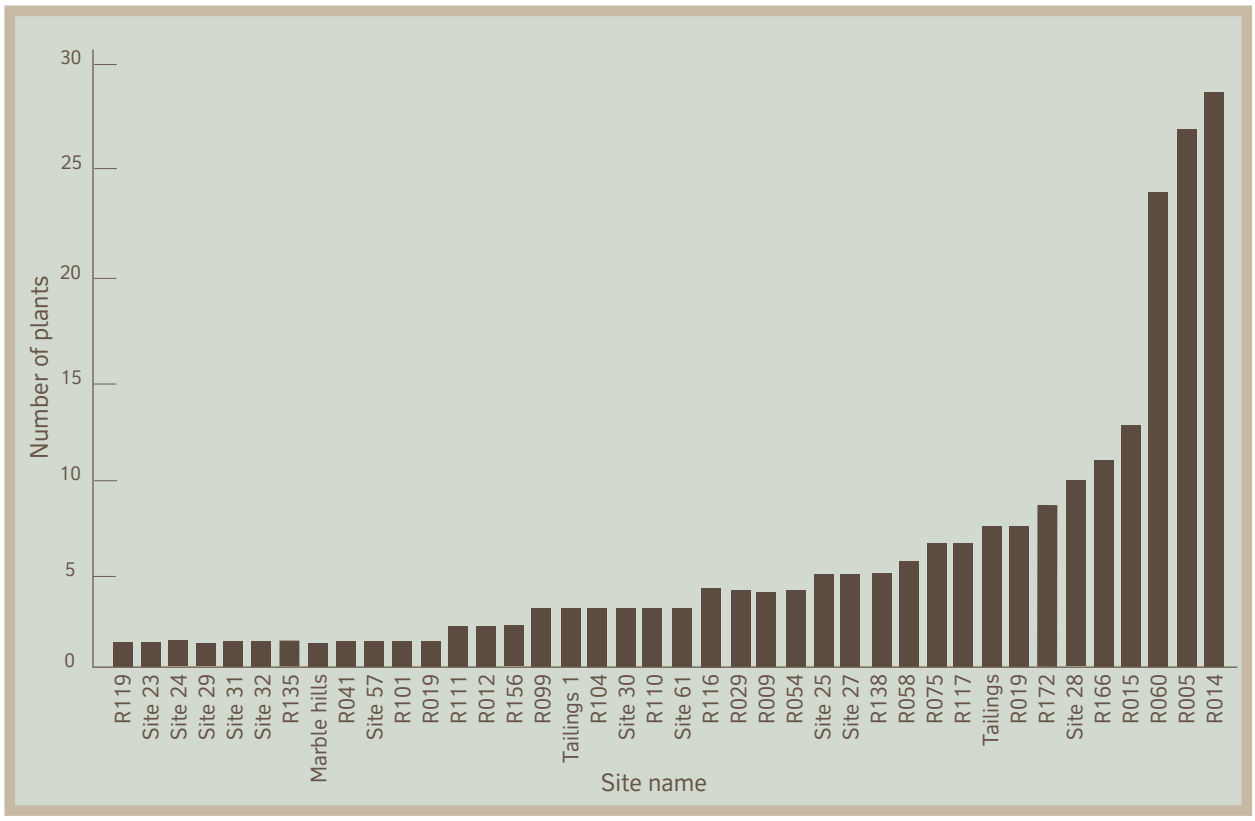

Figure 1.8a: Number of *A. pechuelii* plants at every sampling site

Field work revealed that individuals occur mostly alone or in small groups of up to nine plants (Figure 1.8b). Only six sampling sites had ten or more plants and Figure 3.9 (Chapter 3) maps these sites. Within RUL these sites have the highest numbers of plants. Together they contain some 113 individuals, and are therefore important for the conservation and monitoring of the species at RUL.

The density of *A. pechuelii* in the RUL licence area was calculated as 7.024 plants per km². This is a very low density compared to most populations over the rest of the distribution range of the species. Figure 6.13 in Appendix 6 maps the distribution of *A. pechuelii* at RUL and the prospective Valencia Uranium mine and how the densities of the two populations compare.

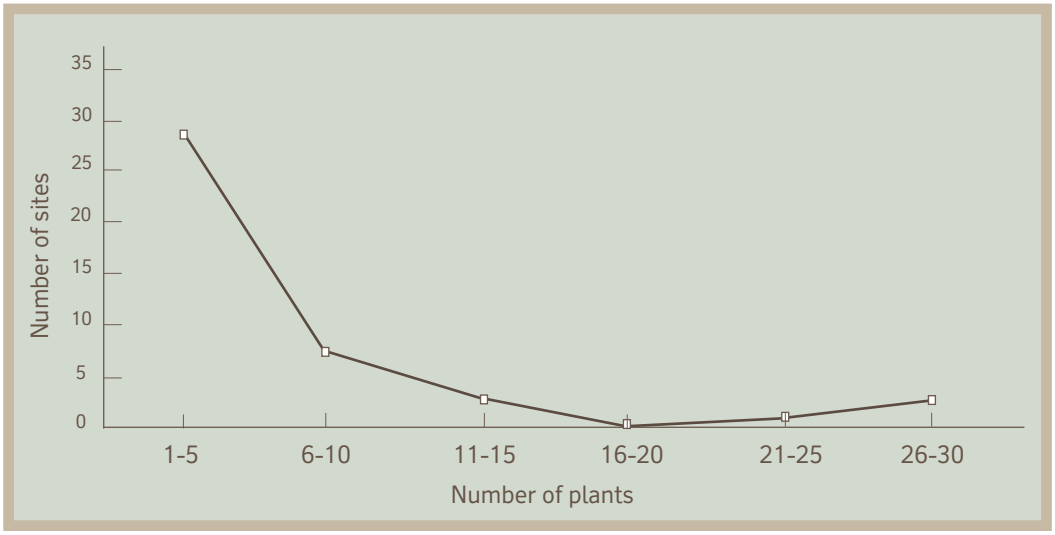

Figure 1.8b: Number of *A. pechuelii* plants per sampling site as a frequency distribution

CHAPTER 2: NATIONAL ASSESSMENT OF *L. RUSCHIORUM* AND *A. PECHUELII*, WITH COMPARISONS TO RUL LICENCE AREA

Background

According to the concept note that was developed for the project, Red List field assessments were to be conducted on at least 50 known populations of *L. ruschiorum* and *A. pechueli*i (Project Output 1). However, it was not possible to define population boundaries in all instances, especially for *Lithops*. It therefore became necessary to distinguish between a site and a population for the purposes of the survey.

A site was defined as a group of plants that occur together on the same topographic feature, for example a ridge, slope, plain, outcrop or hillside, and in which the plants are not separated by unsuitable habitat. A population was defined as a group of sites occurring together at the same general location, for example the RUL licence area or the Rössing Mountain. Sites within a population can be separated by unsuitable habitat.

However, in such cases cross pollination between the sites is possible, as they are not separated by long distances. Populations are separated from one another by significant distances and unsuitable habitat, and the possibility of cross pollination between them is unlikely. In some instances, for example the population of *A. pechuelii* at Leeukop in the Namib Naukluft Park (NNP), there is only one site, and this constitutes a population.

A total of 35 sites of *A. pechuelii*, which constitute some 24 populations, were surveyed. A total of 19 sites of *L. ruschiorum*, constituting some eleven populations, were surveyed, including the one at RUL. This brings the total number of sites that were surveyed to 54, but they probably only represent some 35 populations. It should be noted that not all the previously recorded sites of the two target species were surveyed.

The first target conservation outcome of the project was "improved awareness of the conservation status and national distribution of target species and relevant importance of sites found at RUL". This chapter focuses on comparing the sites of the two target species at RUL with sites that were surveyed over the rest of their distribution ranges, in terms of distribution, abundance, density and relative importance for conservation.

Methods

The same methods were applied for the survey on *L. ruschiorum* and *A. pechuelii* sites outside RUL as for those inside the RUL licence area (see methods section in Chapter 1), with some exceptions. Sites outside the RUL licence area were not divided into grid squares and no sampling sites were established. Sampling started as soon as *L. ruschiorum* or *A. pechuelii* could be located. Each new site was given a new site number. The red iron droppers that were used to establish monitoring squares were not permanently fixed with cement, and monitoring squares in the Skeleton Coast Park (SCP) were marked with rocks instead of red iron droppers. Some 400 *A. pechuelii* individuals from four populations were tagged with metal tags to facilitate future monitoring. This was not done at RUL and will have to be taken up as part of the monitoring plan.

In order to locate previously recorded localities of the two species, distribution data were obtained by querying the WIND Specimen Database. In many cases, people who work or live in the vicinity of the localities were consulted as to the plants' whereabouts.

Field work and analysis were conducted from October 2006 to September 2008.

Results

Appendix 6 maps the location of the surveyed *L. ruschiorum* and *A. pechuelii* sites on Landsat 7 ETM satellite images. Appendix 3 lists the plant species that were recorded as occurring in association with *L. ruschiorum* and *A. pechuelii* over their entire distribution range.

Distribution, abundance and density of surveyed populations of A. pechuelii

During the course of the project some 35 sites of *A. pechuelii* were surveyed over its distribution range.

Figure 2.1 (on the next page) maps the national distribution of the *A. pechuelii* sites that were surveyed.

The numbers of plants that were recorded for the 13 largest *A. pechuelii* sites is shown in Figure 2.2a (on page 18) and expressed as a frequency distribution (Figure 2.2b on page 18), showing that most sites had fewer than 100 plants. In terms of numbers of plants recorded, RUL rated third overall. It should be noted, however, that for most sites, time constraints meant that only a proportion of the plants could be counted as some sites cover large areas and their extent could therefore not be determined. Absolute counts were obtained for only four sites, namely Leeukop, Valencia, RUL and the one in the Munitum valley at the SCP boundary.

A total of 2,671 individuals of *A. pechuelii* were recorded, of which 226 are from the RUL licence area. This gives the proportion of the *A. pechuelii* plants at RUL as 8.5 percent. However, had it been possible to record all the A. pechuelii plants at each site, this percentage would be lower. It is therefore reasonable to say that RUL contains not more than 8 percent of the total population of *A. pechuelii* in Namibia.

The density of the 12 sites where more than 40 plants were recorded was calculated in order to establish how RUL compares with other sites (Figure 2.3a on page 18). Therefore, for sites such as the "Garden Route", where only a proportion of the population was counted, density was calculated only for that proportion of the population.

Figure 2.3b (on page 19) indicates that most sites had between 100 and 200 plants per km² and only two sites had more than 400 plants per km². The population at Leeukop

in the Namib Naukluft Park has both the highest density and the most individuals recorded. The high density there can be explained by the fact that all the plants occur on a single inselberg which covers a very small area. The population at RUL, with most plants being far apart, has the second-lowest density.

Density was not calculated for sites with fewer than 40 plants. Small populations like the ones in the Namib Rand Nature Reserve therefore do not feature in the comparisons, but they are important for indicating the extent of the distribution of the species. The populations in the Namib Rand Nature Reserve possibly indicate the end of the species' range to the south, at close to 26° latitude (Figure 2.1).

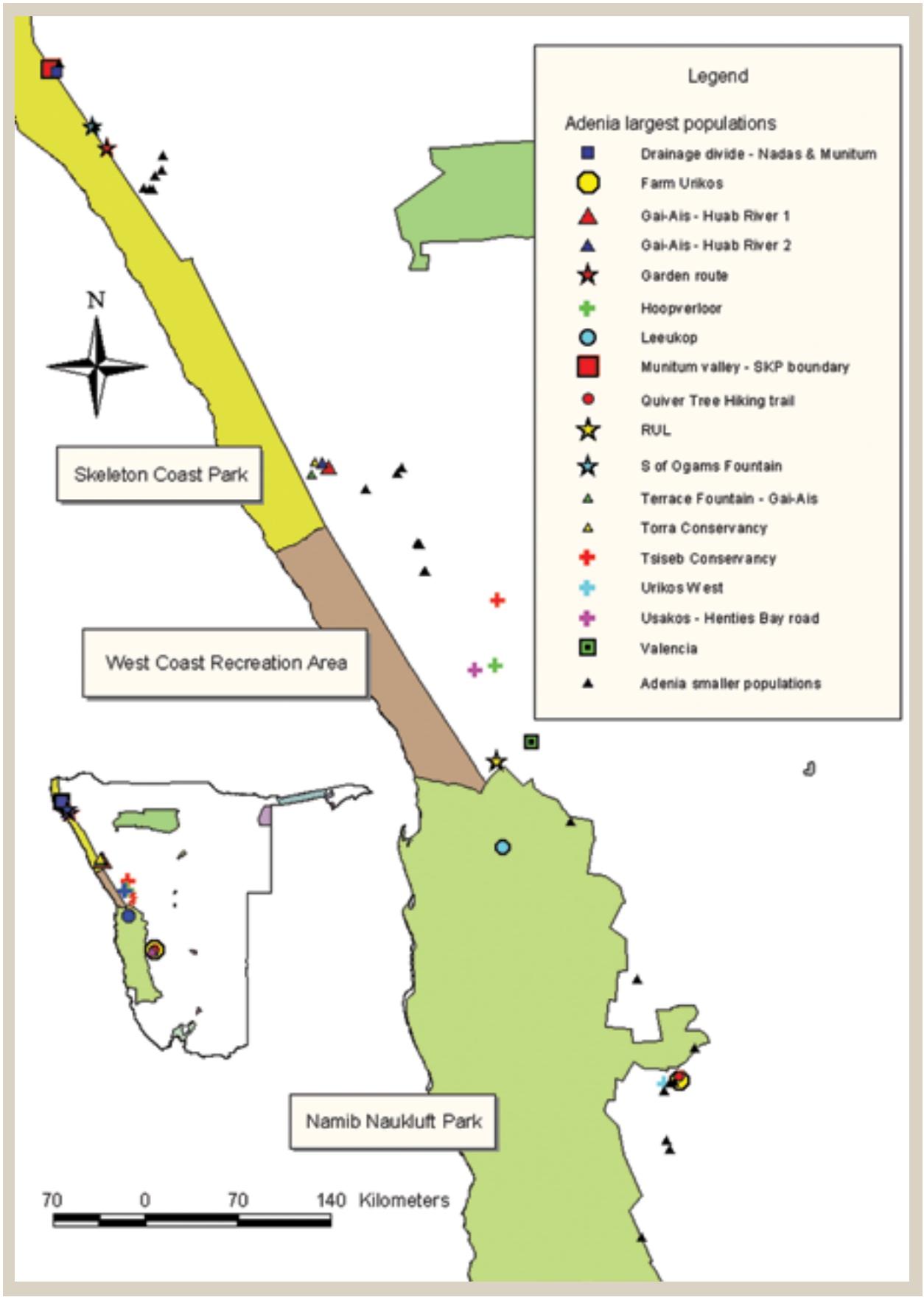

Figure 2.1: Distribution of surveyed *A. pechuelii* sites

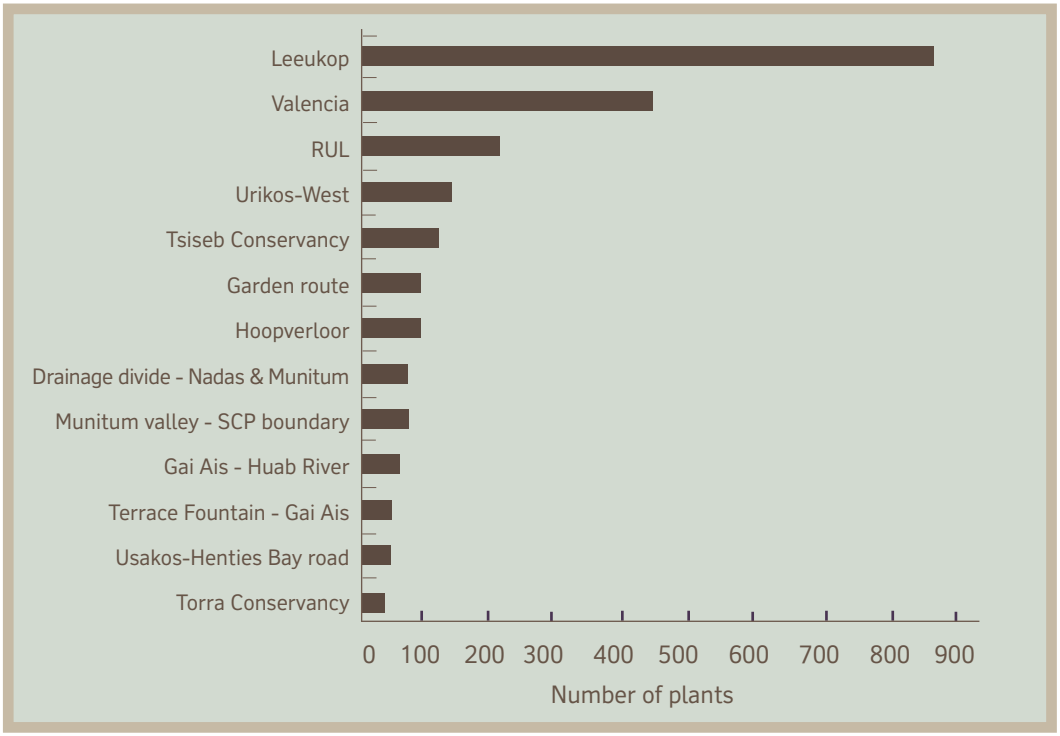

Figure 2.2a: Number of *A. pechuelii* plants recorded at the largest sites

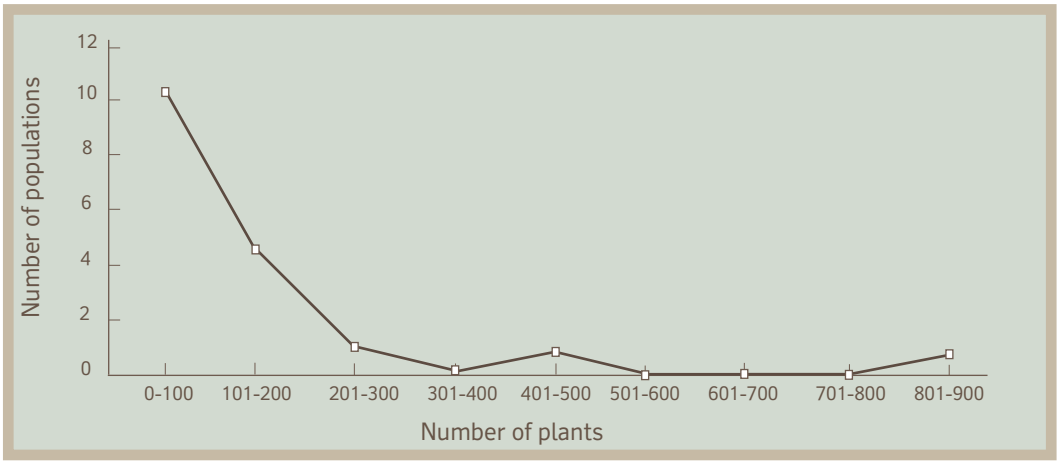

Figure 2.2b: Number of plants expressed as a frequency distribution

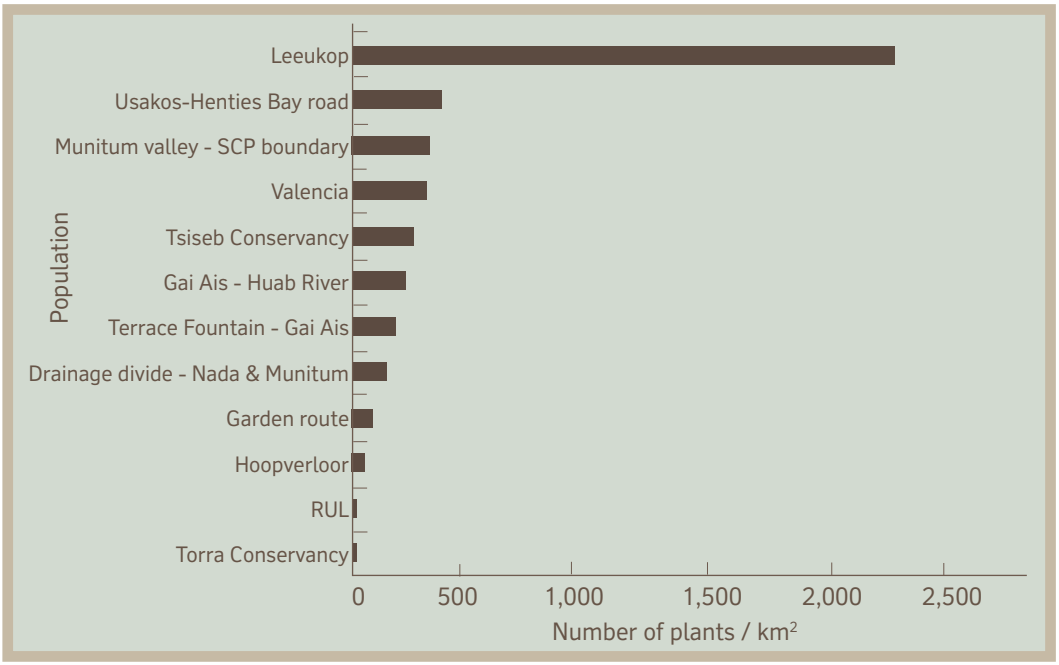

Figure 2.3a: *A. pechuelii* density at RUL compared with other larger sites

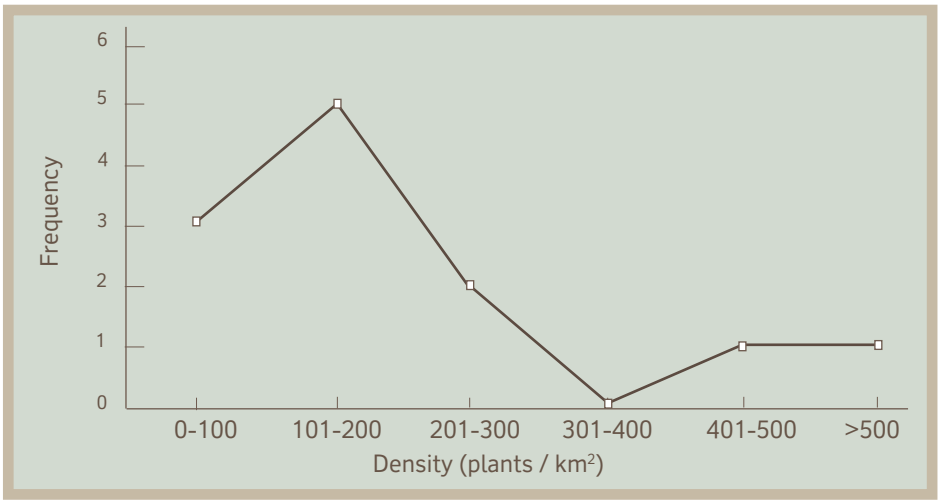

Figure 2.3b: *A. pechuelii* density expressed as a frequency distribution

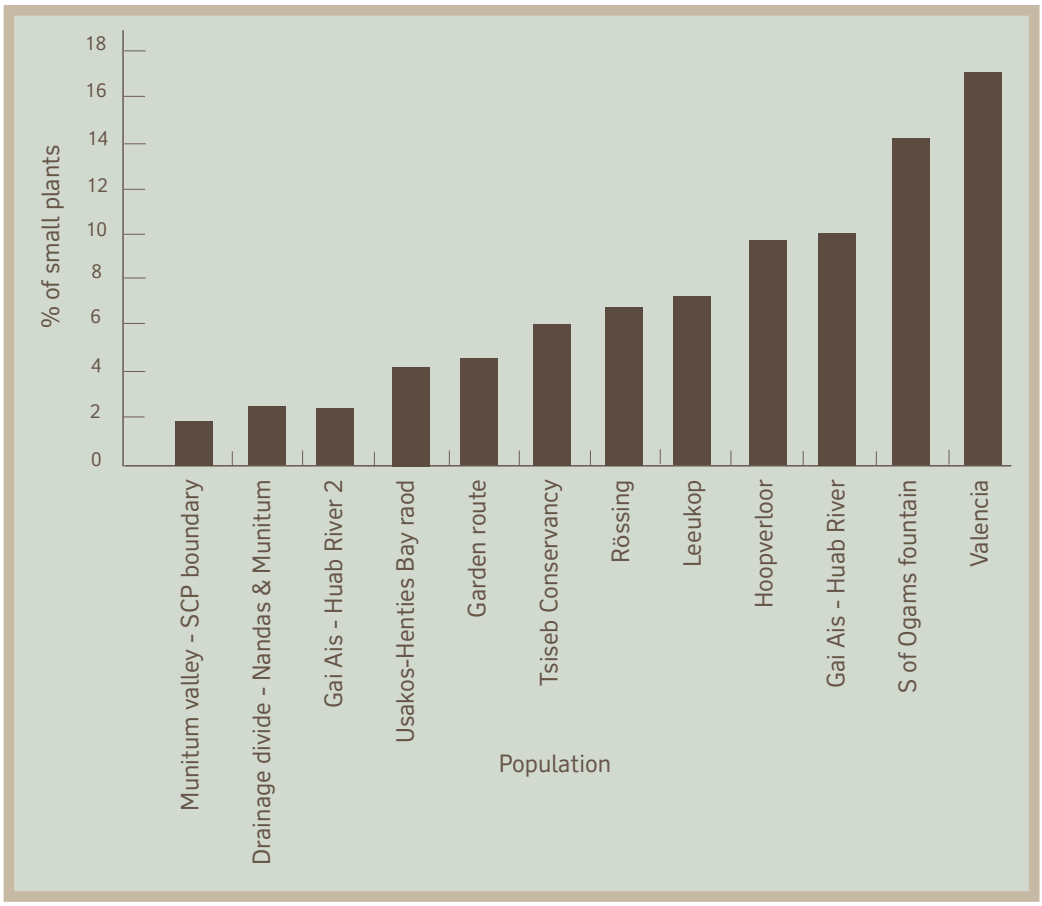

Figure 2.4: Percentage of small *A. pechuelii* plants in selected sites

Figure 2.4 (on page 19) gives the proportion of small plants per site, expressed as a percentage of the total number of plants recorded. Plants were considered "small" when the height of the main stem was measured to be less than 20 cm. This does not mean, however, that these plants had not reached maturity yet. Establishing whether a plant was mature or immature (juvenile) was not possible at the time of the survey as information on determining the age of the plants, at what age they start to flower, set seed and how big they are when they reach maturity is not currently available. The height of the main stem was generally only recorded for individuals that were tagged. Therefore this information is only available for some sites.

Table 2.1 lists the 13 most prominent sites of *A. pechuelii*, ranking them according to their density and the number of plants recorded. All these sites are regarded as important for conservation. Only four populations have a high density as well as a large population size (highlighted in dark green). RUL and Hoopverloor do not have high densities, but they do have a relatively large population size (highlighted in medium green). Sites with a high density but a small population size are highlighted in light green.

Population name	Density (plants / km²)	Number of plants recorded
Torra Conservancy	4.669	43
RUL	7.024	226
Hoopverloor	48.37	111
Garden route	110.7	111
Drainage divide - Nadas & Munitum	123.6	76
Terrace Fountain - Gai Ais	133.3	45
Gai Ais - Huab River	149.3	58
Tsiseb Conservancy	179.0	123
Valencia	213.8	412
Munitum valley - SCP boundary	282.1	72
Usakos-Henties Bay road	443.7	43
Leeukop	2111.0	871
Urikos-West	Not calculated	159

Table 2.1: Sites of *A. pechuelii* outside RUL that should be targeted for conservation

Distribution, abundance and density of surveyed populations of L. ruschiorum

Over its distribution range, 19 sites of *L. ruschiorum* were surveyed, which account for some nine distinct populations.

A total of 8,367 *L. ruschiorum* plants were recorded over the distribution range of the species. Some 2,011 individuals were recorded at RUL, giving the proportion of *L. ruschiorum* in the licence area as 24 percent and making it the second-largest population recorded. However, due to time constraints and the remoteness of some populations, it was not possible to survey all populations as extensively as the

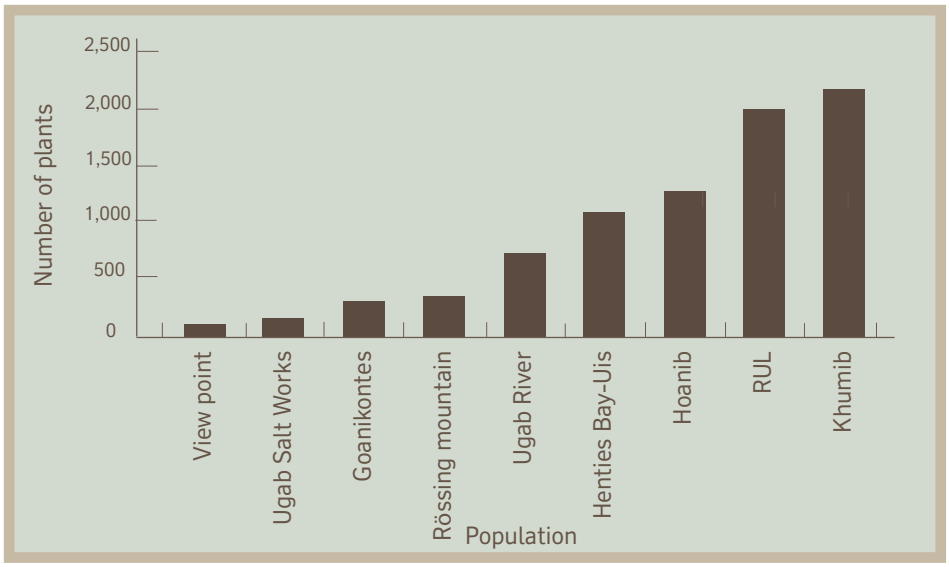

Figure 2.6a: Population sizes of *L. ruschiorum* compared across its distribution range

Figure 2.6b: Population sizes of *L. ruschiorum* as a frequency

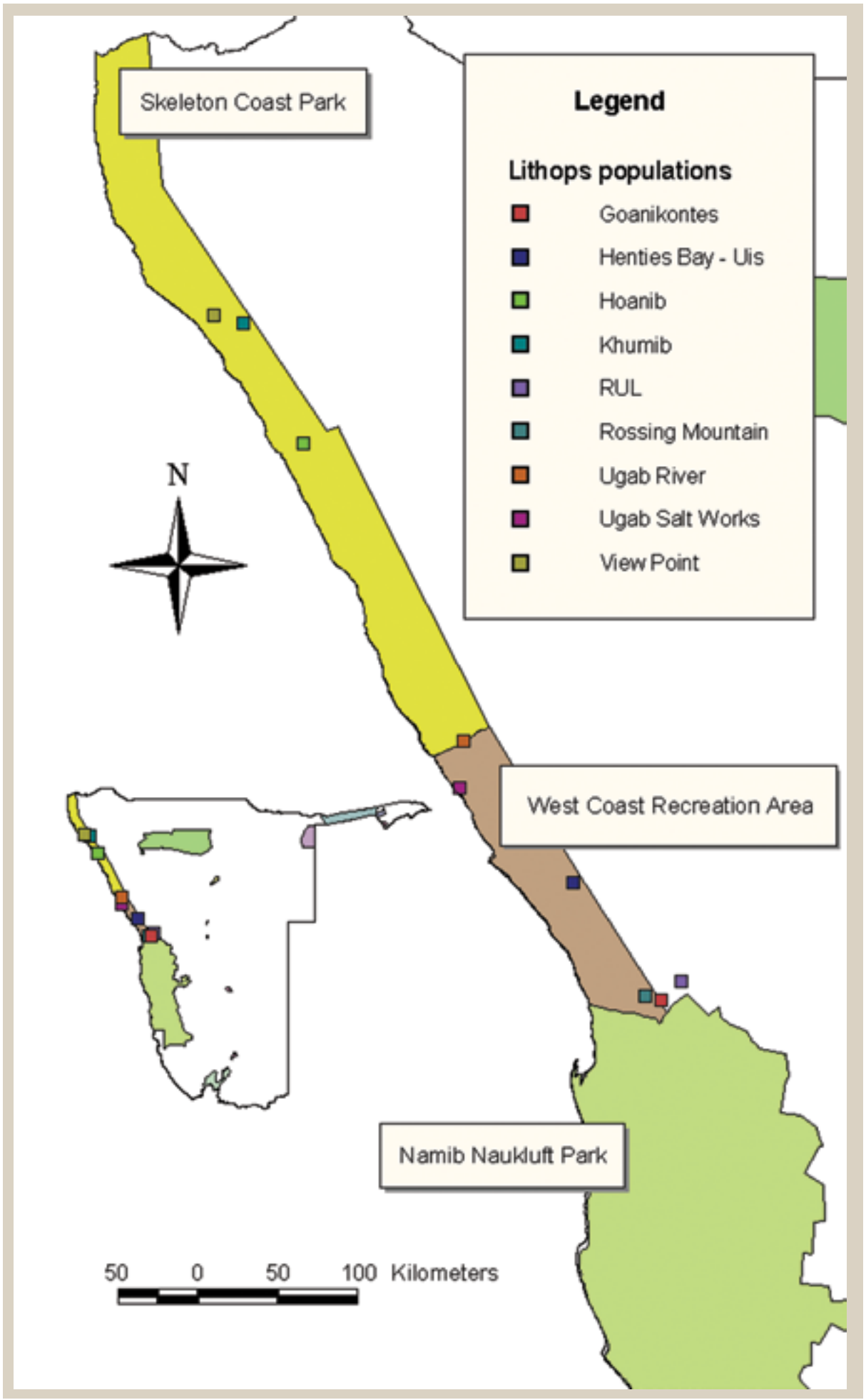

Figure 2.5: Distribution of surveyed *L. ruschiorum* populations

one at RUL. The extent of every population could not be determined and some populations, for example the ones in the Skeleton Coast Park, are suspected to extend over several square kilometres. This meant that absolute counts could not be obtained for most populations, and population sizes recorded should therefore only be used as a guide. Based on data collected and observations made during the survey, it is deemed likely that the proportion of *L. ruschiorum* at RUL is lower than 24 percent.

Figure 2.5 (on page 21) maps the distribution of the nine *L. ruschiorum* populations that were surveyed. Figure 2.6a (on page 20) compares the number of plants recorded at these populations and figure 2.6b (also on page 20) expresses

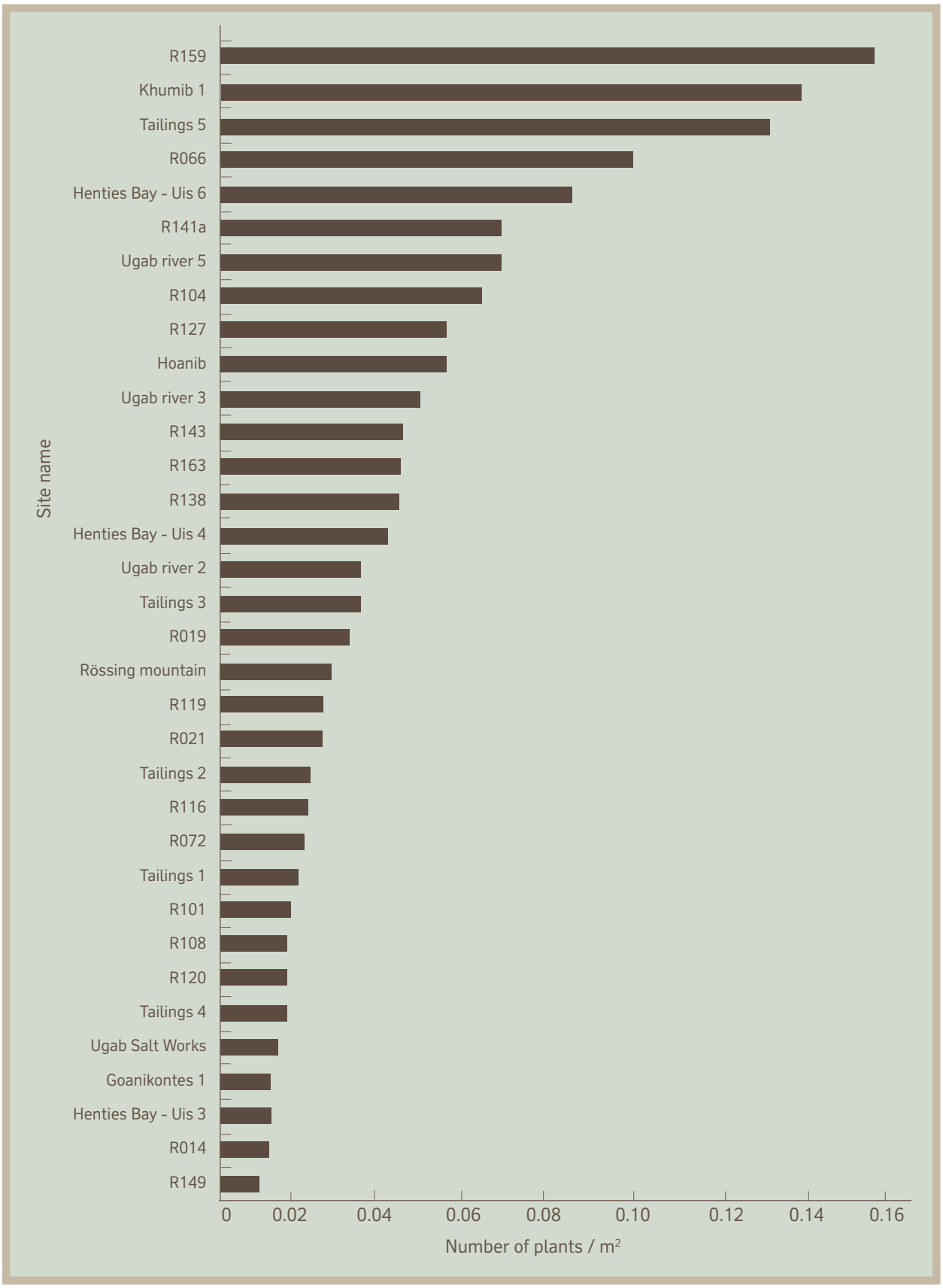

Figure 2.7a: Densities at the most prominent *L. ruschiorum* sites

population size as a frequency, showing that populations with between 1 and 500 plants have the highest frequency.

Individual *L. ruschiorum* sampling sites at RUL can also be compared to other sites by contrasting their densities (Figure 2.7a on page 20). Six of the RUL sites feature among the top ten with respect to density. R159 and Tailings 5 have the highest and third-highest density, respectively.

Figure 2.7b displays these densities as a frequency distribution, showing that most sites have a density of below 0.04 plants per m².

Figure 2.8a (on page 24) compares the number of *L. ruschiorum* plants in all the monitoring squares over the distribution range of the species. Tailings 3, Tailings 5, R021 and R159 at RUL are among the top eight in terms of number of plants recorded in monitoring squares across the distribution range.

Figure 2.8b displays the number of plants in the squares as a frequency distribution and shows that over 40 percent of the squares contain less than 20 plants.

Table 2.2 (on page 25) ranks 14 sites of *L. ruschiorum* outside RUL according to density and number of plants recorded. These are regarded as the 14 most significant sites for the species, all of which are important for conservation.

Figure 2.7b: Density of *L. ruschiorum* sites expressed as a frequency distribution

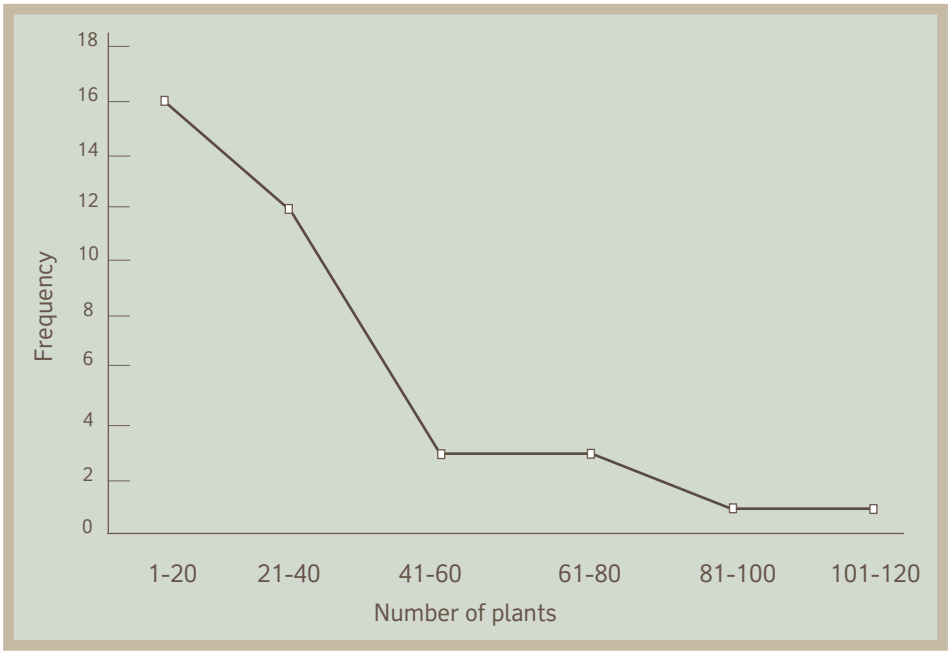

Figure 2.8b: Number of *L. ruschiorum* plants in 36 monitoring squares as a frequency distribution

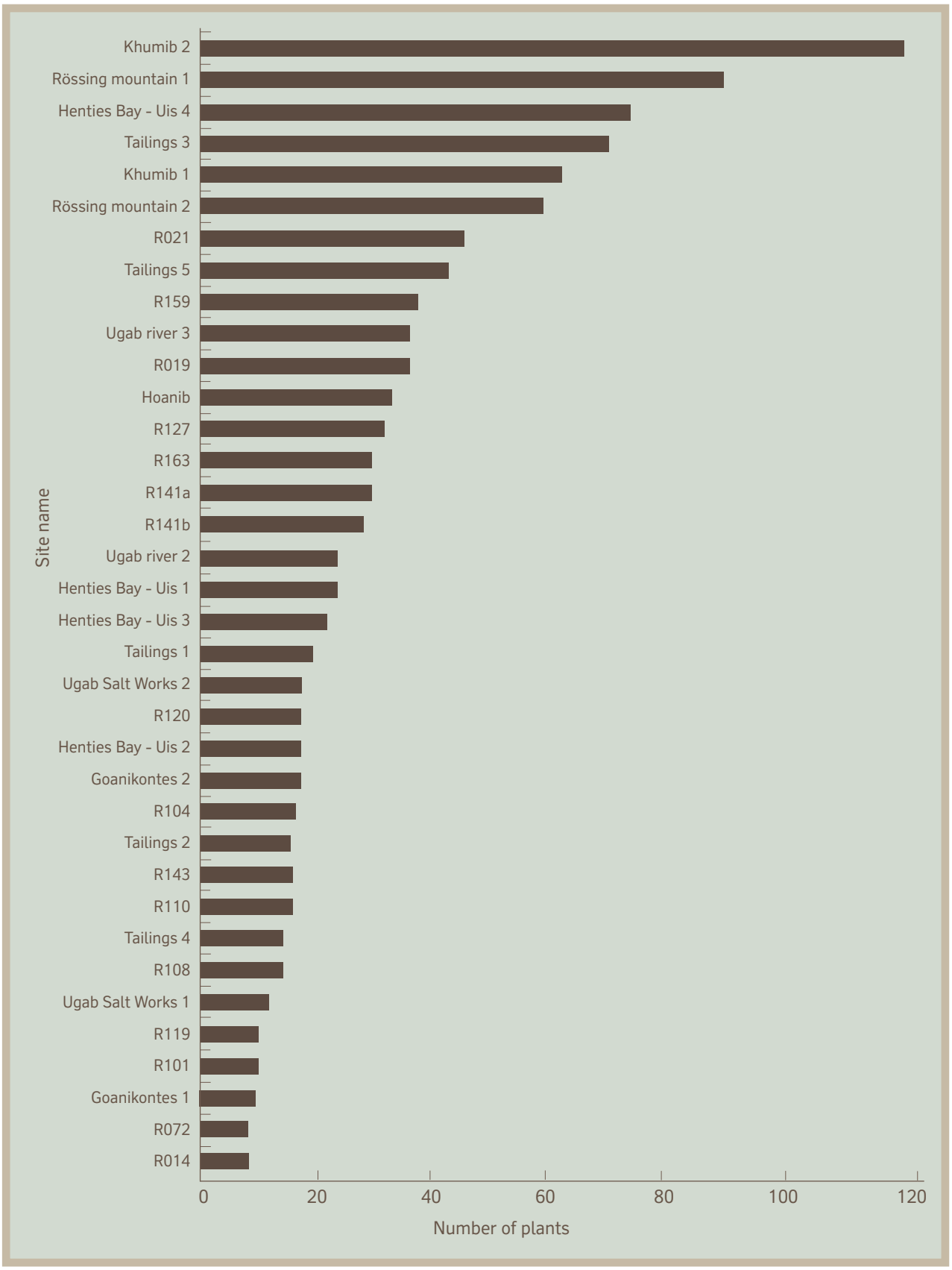

Figure 2.8a: Number of *L. ruschiorum* plants in 36 monitoring squares across the distribution range

Site name	Density	Number of plants
Khumib	0.138	2213
Henties Bay - Uis 6	0.086	107
Ugab river 5	0.072	174
Hoanib	0.057	1357
Ugab river 3	0.052	232
Henties Bay - Uis 4	0.045	621
Ugab river 2	0.038	314
Rössing mountain	0.030	340
Ugab Salt Works	0.016	148
Goanikontes	0.016	307
Henties Bay - Uis 3	0.016	140
Henties Bay - Uis 2	0.007	156
Henties Bay - Uis 1	0.005	86
View point	Not calculated	92

Table 2.2: Fourteen *L. ruschiorum* sites outside RUL ranked according to density and number of plants recorded

CHAPTER 3: SPECIES MANAGEMENT AND MONITORING PLANS

Background

A three-year project was undertaken to determine the proportion of the national populations of *A. pechuelii* and *L. ruschiorum* that occur within the RUL licence area. Project Output 4 was to develop species management/conservation plans for the target species and to implement them at RUL. Project Output 5 was to develop and have in place long-term monitoring strategies for the target species. These are two of the major outputs of the project.

The species management plans aim to capture the results from both the Red List assessments (Project Output 1) and seed conservation activities (Project Output 3) and make specific *in situ* (plants in their natural habitat) and *ex situ* (plants conserved outside their natural habitat) management recommendations. The long-term monitoring strategy will enable the assessment of changes in the status of populations.

This will include, but not be limited to, follow-up field assessments between 2013 and 2015. It will enable the NBRI to review the Red List status, and, if possible, evaluate reasons for any changes in the populations of target species and make subsequent recommendations to RUL and MET. RUL have expressed an interest in supporting the costs of this component under their commitments to the Rio Tinto Biodiversity Strategy.

There are no specific vegetation or habitat restoration based activities currently being undertaken by RUL and no nursery facilities. Only a proportion of the species identified in the recent biotope study (Burke, 2005) are being held in the form of seeds in the NPGRC and the MSB, UK, and in small samples only.

To facilitate future restoration work (post mine closure), and to provide a long-term insurance strategy for these plant species of conservation importance, banking large quantities of seeds from these species should be a priority. Opportunities for cultivating plants and plant translocation can also be considered in the future.

Adenia pechuelii: Species Management Plan

Background information (Species and site information)

Taxonomic notes:

Family: Passifloraceae

Genus: *Adenia*

Species: *pechuelii*

Infra-specific: None

Common names:

Elephant's foot (English); Wüstenkohlrabi (German)

Description:

A dwarf tree with very large, squat, swollen, almost-round trunk and succulent, green, finger-like branches, orientated in all directions. Smooth bark, cream to light grey-green in colour. Few, small, grey-green leaves. Small, greenish flowers. Fruit is a three lobed capsule, red when ripe. The flowers are inconspicuous but the fruit is conspicuous when ripe (Curtis and Mannheimer, 2005).

Conservation status:

NT (Loots, 2005); endemic (although there are unofficial reports that the species also occurs in Angola); worthy of protection (Curtis and Mannheimer, 2005); currently down-listed to LC (this report), should be considered for protection under the Nature Conservation Ordinance.

Threats:

Habitat destruction is a potential threat to some populations, as is the international pachycaul trade. Plants are unisexual, which could mean skewed sex ratios in some populations possibly resulting in poor recruitment, which poses another potential threat.

National distribution:

Figure 3.1 maps the national distribution of *A. pechuelii*.

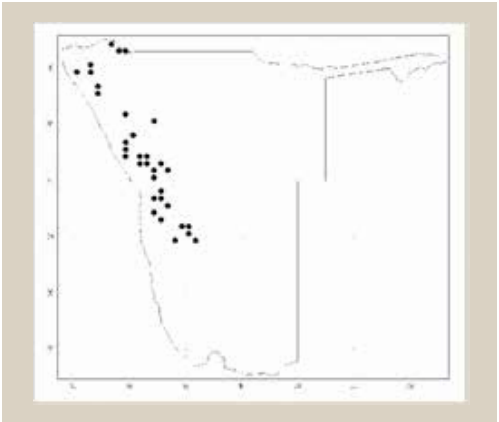

Figure 3.1: National distribution of *A. pechuelii*

Site Distribution:

Figure 3.2 maps the distribution of *A. pechuelii* at RUL, with the biotopes (Burke, 2005) in which the species occurs.

Ecology:

Over its entire distribution range *A. pechuelii* occurs in association with a wide range of plant species, including *L. ruschiorum* (Appendix 3). Plants are often covered in ants, especially when in flower, and occasionally with hairy caterpillars, which probably only browse the leaves. Branches are often browsed by game, such as gemsbok, and rodents. The main stem is often damaged, probably by porcupine.

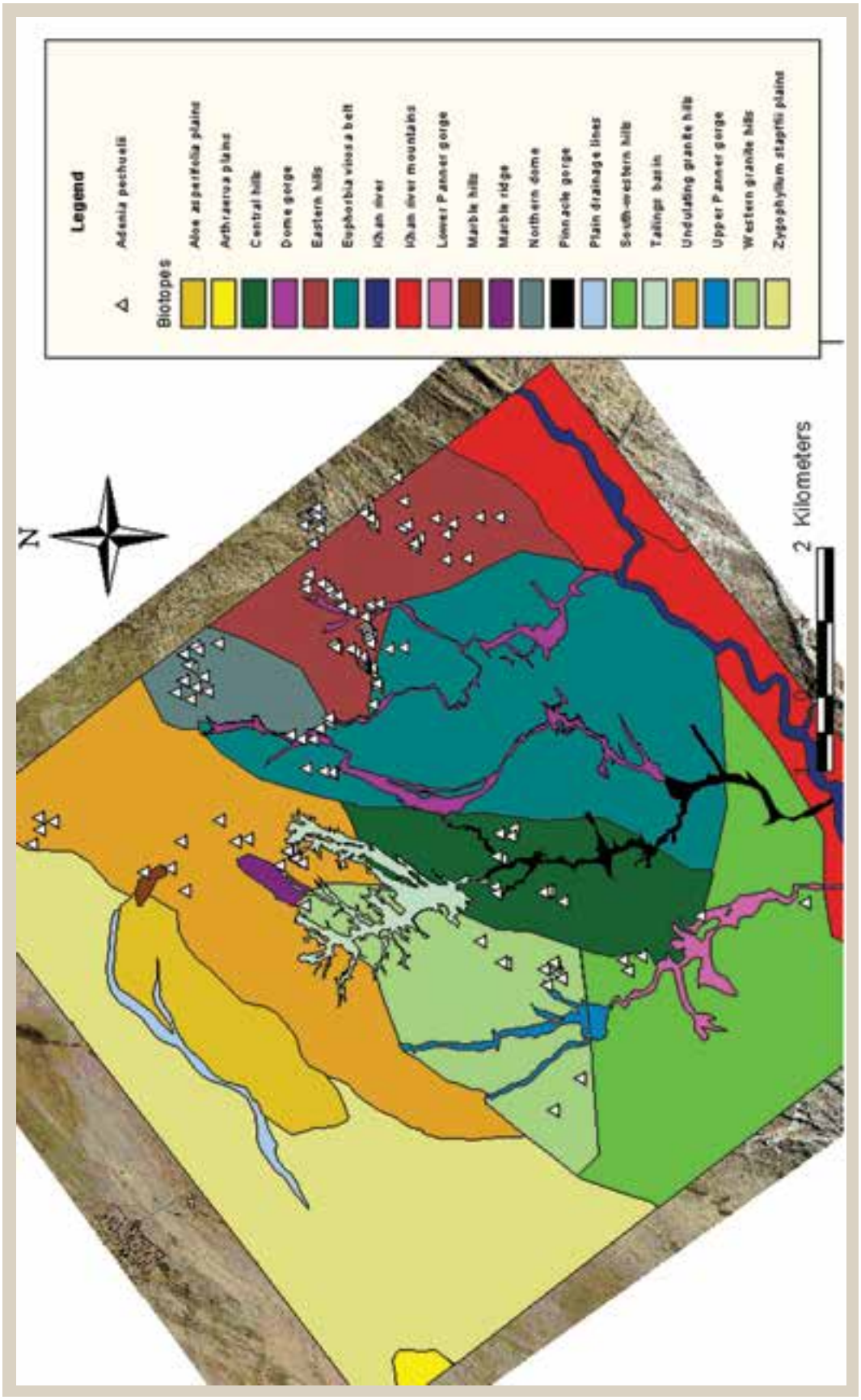

Figure 3.2: Distribution of *A. pechuelii* at RUL

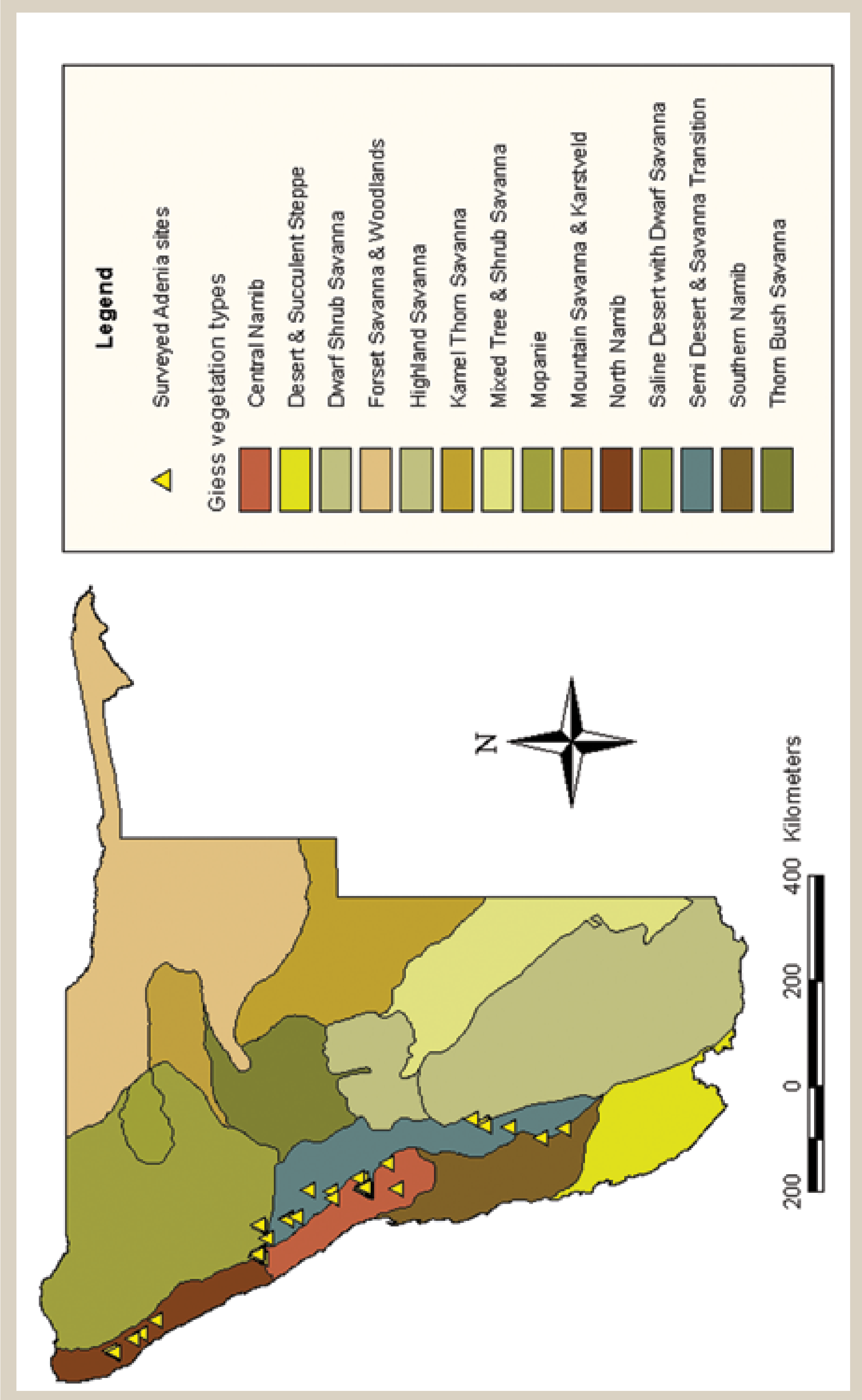

Figure 3.3: Distribution of surveyed *A. pechuelii* populations according to Giess (1971) vegetation types

Habitat:

Along the escarpment; mostly on hillsides and mountain slopes, rocky ridges and outcrops; on all aspects of moderate to very steep slopes; sometimes wedged between rocks in very little soil or growing out of cracks in bare rock; often on banks of dry river courses; very occasionally on plains; mostly in exposed situations, but sometimes found in half shade under overhanging rocks.

Vegetation types:

Figure 3.3 (on the next page) shows the vegetation types (Giess, 1971) in which the *A. pechuelii* populations that were surveyed, occur.

Lithology:

Figure 3.4 shows the rock types in which *A. pechuelii* occurs over its entire distribution range.

Aspect:

Figure 3.5 shows the aspect preference of *A. pechuelii* over its entire distribution range. This species occurs on all aspects, but has a preference for northwest- and west-facing slopes.

Gradient:

Figure 3.6 shows the gradient ranges in which *A. pechuelii* occurs over its distribution range.

Altitude:

Figure 3.7 shows the altitude ranges in which *A. pechuelii* occurs over its distribution range

Soil pH:

Soil pH ranged between 7.9 and 9.84 over the distribution range of *A. pechuelii*.

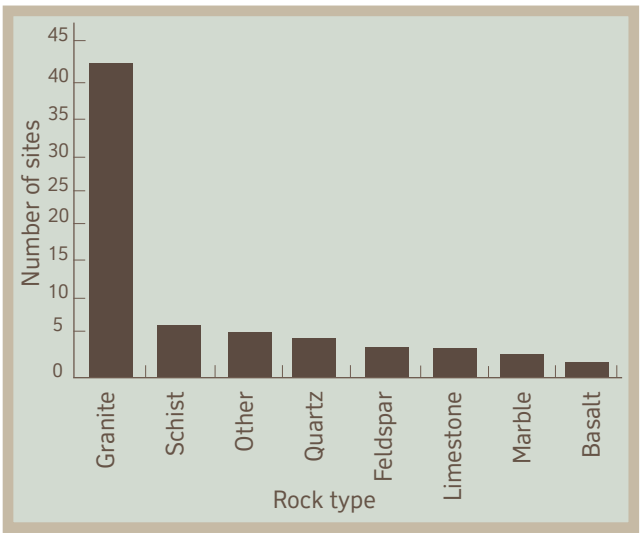

Figure 3.4: Lithology preference of *A. pechuelii*

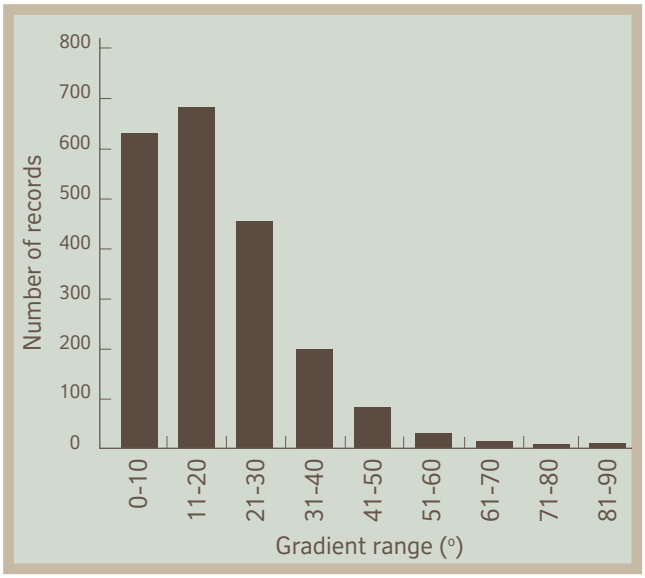

Figure 3.6: Preferences for gradient ranges of *A. pechuelii*

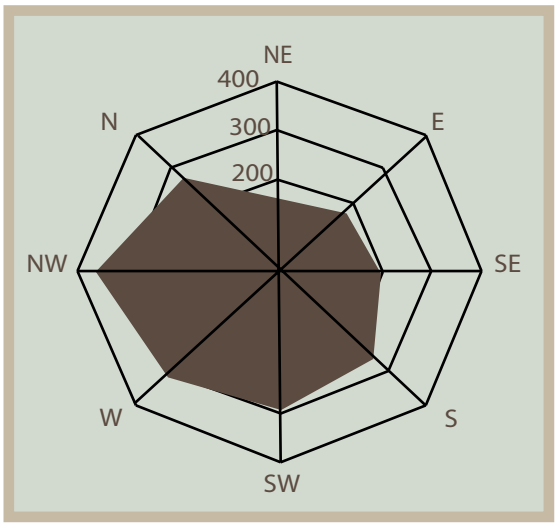

Figure 3.5: Aspect preference of *A. pechuelii*

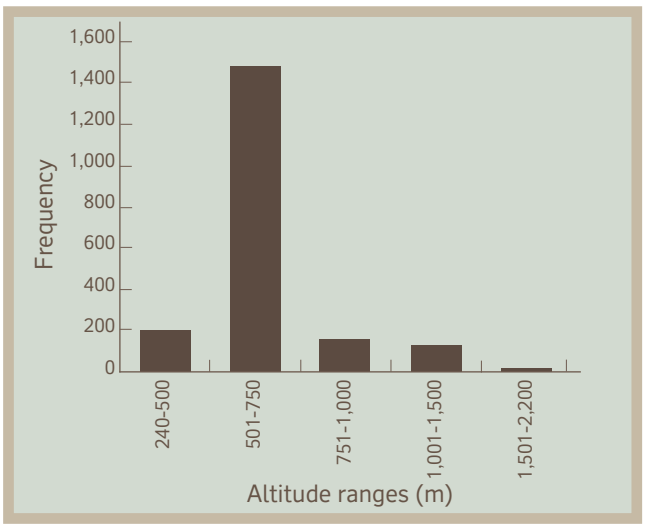

Figure 3.7: Altitude ranges of *A. pechuelii*

Soil type:

Figure 3.8 shows the soil type preference of *A. pechuelii* over its distribution range.

Seed biology:

The ripe fruit is a red 3-lobed capsule, usually containing three seeds. Seeds were collected in April and July 2006, March 2007 and April and July 2008. Capsules are often empty or seeds not fully developed (pers. obs.), therefore collections are small.

Proportion of global population found at RUL:

No more than 8 percent of the Namibian population of *A. pechuelii* occurs at RUL.

Other information:

Flowering occurs from February to June (Curtis and Mannheimer, 2005). Flowers were also observed in July and August (pers. obs). Males and females cannot be told apart unless in flower or fruit. Plants were found in fruit in March, May, June and August. Plants probably flower and fruit after good rains. In some populations, male and female plants seem to flower at different times.

MSB generated information

(See Appendix 10 E)

Management, conservation and monitoring recommendations

In situ *management and conservation:*

1. RUL management should consider special protection of areas that were identified as important for *A. pechuelii* (Figure 3.9 on the next page). Responsibility – RUL

2. RUL should distribute maps and educate relevant staff on locations of important areas for *A. pechuelii*, in order to ensure protection of maximum number of plants. Responsibility – RUL

3. If possible, *A. pechuelii* plants should not be removed from their natural habitat. Responsibility - RUL

Ex situ *management and conservation:*

1. To facilitate future restoration work (post mine closure) and to provide a long-term insurance strategy for these plants, banking of seeds should be a high priority. The field work conducted from 2006 to 2008 proved that finding enough seeds per population to bank according to international standards is a challenge. The ideal number of seeds of this species, which should be banked by the NPGRC and duplicated at the MSB in the UK, is 1,000. Finding a sufficient number of seeds to bank would mean constant monitoring of the populations to ensure that optimal use can be made of the opportunity when a population is fruiting. The population at RUL should therefore be monitored on a regular basis, in order to determine if plants are in fruit, i.e. after every rainy season/during every growing season. Responsibility – RUL

2. If any *A. pechuelii* plants occur in an area of RUL where development is taking place, thus making it impossible to leave them in their natural habitat, they should be carefully removed, ensuring that the root system remains intact. Arrangements should then be made with the NBRI for the plants to be planted in the desert house, to be distributed to other botanic gardens, or to be transplanted on the site. Responsibility - RUL

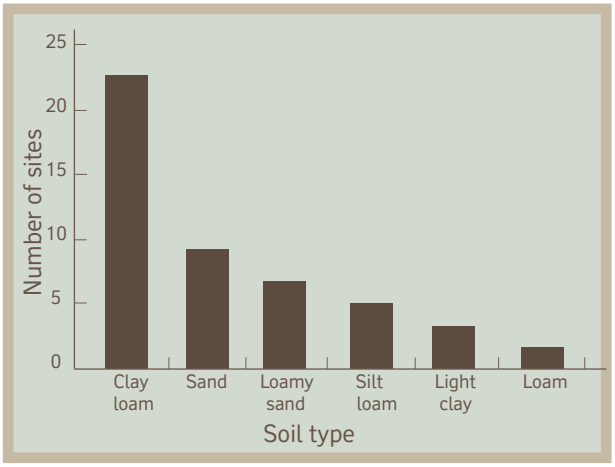

Figure 3.8: Soil type preference of *A. pechuelii*

Long-term monitoring strategy:

After commencement of the project it was deemed necessary to be proactive with regards to the monitoring of populations of *A. pechuelii*. Some 400 plants from a number of the larger populations were fitted with metal tags in order to detect changes in these populations over time. A maximum of 100 plants per population were tagged, with each tag having a number. This number and the GPS coordinates were recorded, so that the plants can be found again. In addition to tagging the plants, the height of the main stem was also measured in order to try to determine the growth rate of the tagged plants in the long term.

The following is recommended for the* A. pechuelii *population at RUL:

1. Design a field form for monitoring sessions based on data that were recorded during the assessments. A draft form has been designed (Appendix 9). Responsibility – RUL and NBRI.

2. Tag 100 plants within the RUL licence area before the end of 2010. The tagged plants should not all be in the same area, but rather spread over several different zones of use, for example some in the tailings area, some near the offices, some in the sand pit area. This will ensure that the tags are distributed over several biotopes. Consult Figure 3.9 for important *A. pechuelii* sites. Responsibility – RUL.

3. When plants are tagged, a photograph should be taken of each tagged plant for later comparisons during monitoring sessions. Responsibility – RUL.

4. Conduct the first round of monitoring of the tagged plants in 2013 and every five years thereafter. This should also be done in other populations that were tagged at roughly the same time. Responsibility – RUL and NBRI

5. Only six sampling sites have ten or more plants and these sites should be specially conserved, since together they contain more than 100 plants. They are Sites 28, R166, R015, R014, R060, and R005 (Figure 3.9). Responsibility – RUL.

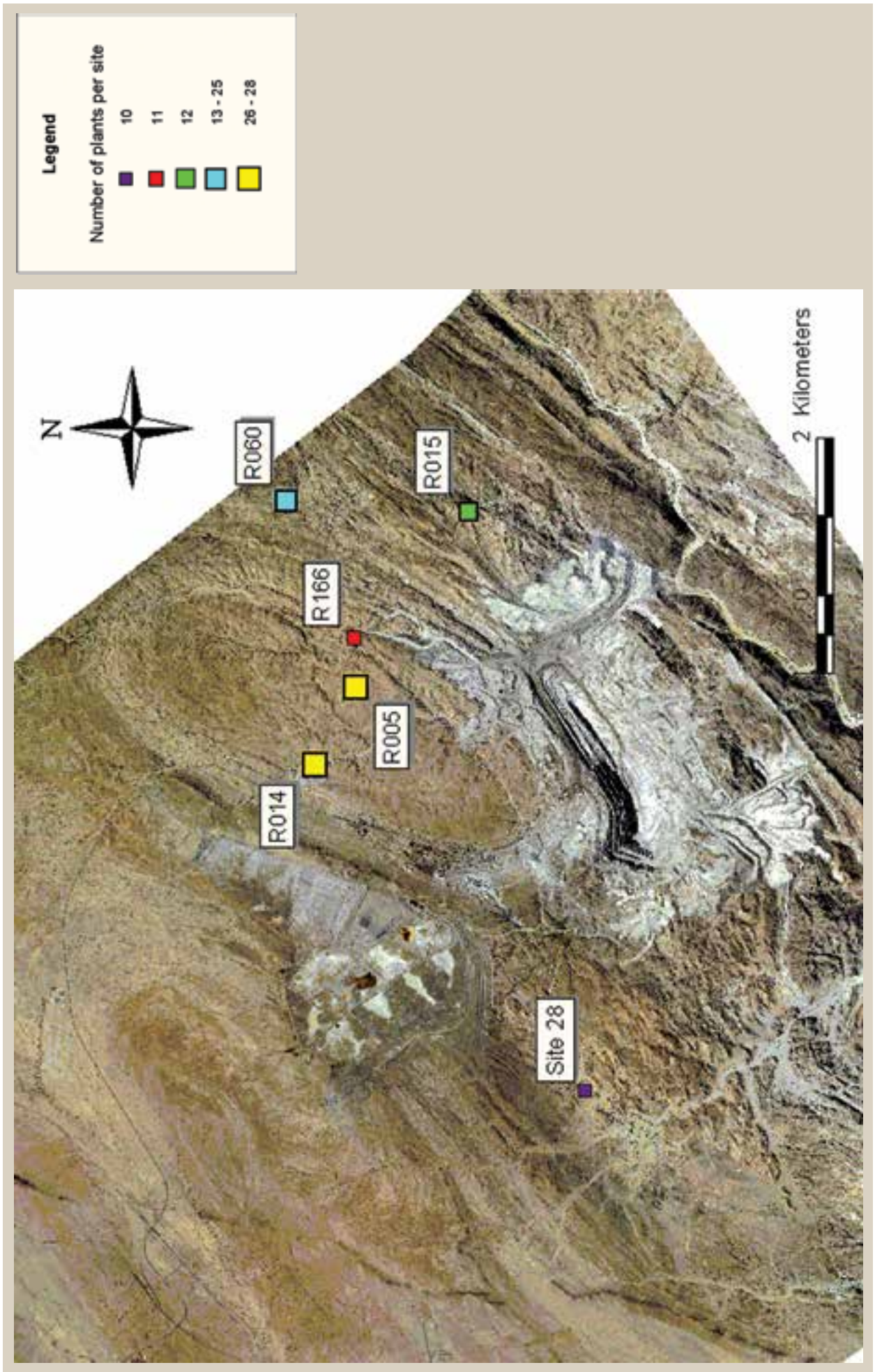

Figure 3.9: Locations of the six most important *A. pechuelii* sites within the RUL Licence area

Lithops ruschiorum: Species Management Plan

Background information (Species and site information)

Taxonomic notes:

Family: Aizoaceae

Genus: *Lithops*

Species: *ruschiorum*

Infra-specific: var. *ruschiorum* and var. *linearis* (according to some taxonomists)

Common names:

Stone plants (English); Beeskloutjies (Afrikaans); Blühende Steine (German)

Description:

Dwarf succulent. Leaves cordate in profile, usually very distinctly convex, faces white to fleshy coloured, somewhat elevated, elliptic reniform, smooth to very slightly rugose, mostly ca. 25 x 20 mm, fissures deep; margins absent; markings finely reticulate. Rubrications often completely absent, otherwise a number of lines, dashes or dots, sometimes forming a coarse, broken network, often obscure, dull orange-brown to orange-red. Flowers yellow. Capsule 5-6-locular, top flat to slightly peaked (Cole, 1988).

Conservation status:

Least Concern (Loots, 2005); Endemic; Protected under Nature Conservation Ordinance 4 of 1975.

Threats:

Collecting is a potential threat to some populations, as is off-road driving. Habitat destruction through mining activities is a potential threat to one population.

National distribution:

Figure 3.10 maps the national distribution of *L. ruschiorum*.

Site distribution:

Figure 3.11 (on the next page) maps the distribution of *L. ruschiorum* in the RUL licence area, showing in which biotopes (Burke, 2005) the species occurs.

Ecology:

Occurs in association with a wide range of plant species (Appendix 3), including *A. pechuelii*. Browsing of the plant bodies by animals (possibly springbok, hares, grasshoppers, armoured crickets and birds) often result in the death of the plants. This does not happen on a large scale, however, probably due to the species' ability to blend in with its habitat.

Habitat:

Mostly on undulating hills, gravel plains, rocky quartz ridges as well as outcrops, gentle to steep slopes and hill tops; occasionally on mountain slopes; usually in very gravelly soil; occasionally in rock cracks with very little soil; usually in fully exposed positions, but occasionally in half shade.

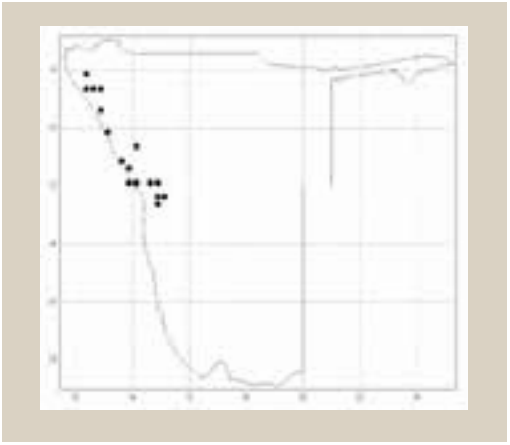

Figure 3.10: *L. ruschiorum* national distribution

Vegetation types:

Figure 3.12 (on page 34) shows the vegetation types (Giess, 1971) in which the surveyed *L. ruschiorum* populations occur.

Lithology:

Figure 3.13 (on page 35) shows the rock types with which *L. ruschiorum* is associated over its distribution range.

Aspect:

Figure 3.14 (on page 35) shows the aspect preference of *L. ruschiorum* over its distribution range. *L. ruschiorum* has a distinct preference for south-, west- and southwest-facing slopes.

Gradient:

Figure 3.15 (on page 35) shows the gradient preferences of *L. ruschiorum* over its distribution range.

Altitude:

Figure 3.16 (on page 35) shows the frequency of the altitude ranges in which *L. ruschiorum* occurs over its distribution range.

Soil pH:

Soil pH ranged between 8.5 and 9.72 over the distribution range of *L. ruschiorum*.

Soil type:

Figure 3.17 (on page 35) shows the soil type preference of *L. ruschiorum* over its distribution range.

Seed biology:

Fresh capsules generally contain large numbers of seeds and it is not difficult to obtain the minimum number of 1,000 seeds for an accession. Seeds have been collected in March and May, but since seeds remain viable inside the capsule for extended periods of time, it should be possible to collect capsules at any time of the year. See Loots (2005) for a generalised diagram of the structure of the capsule of species that belong to the family Mesembryanthemaceae.

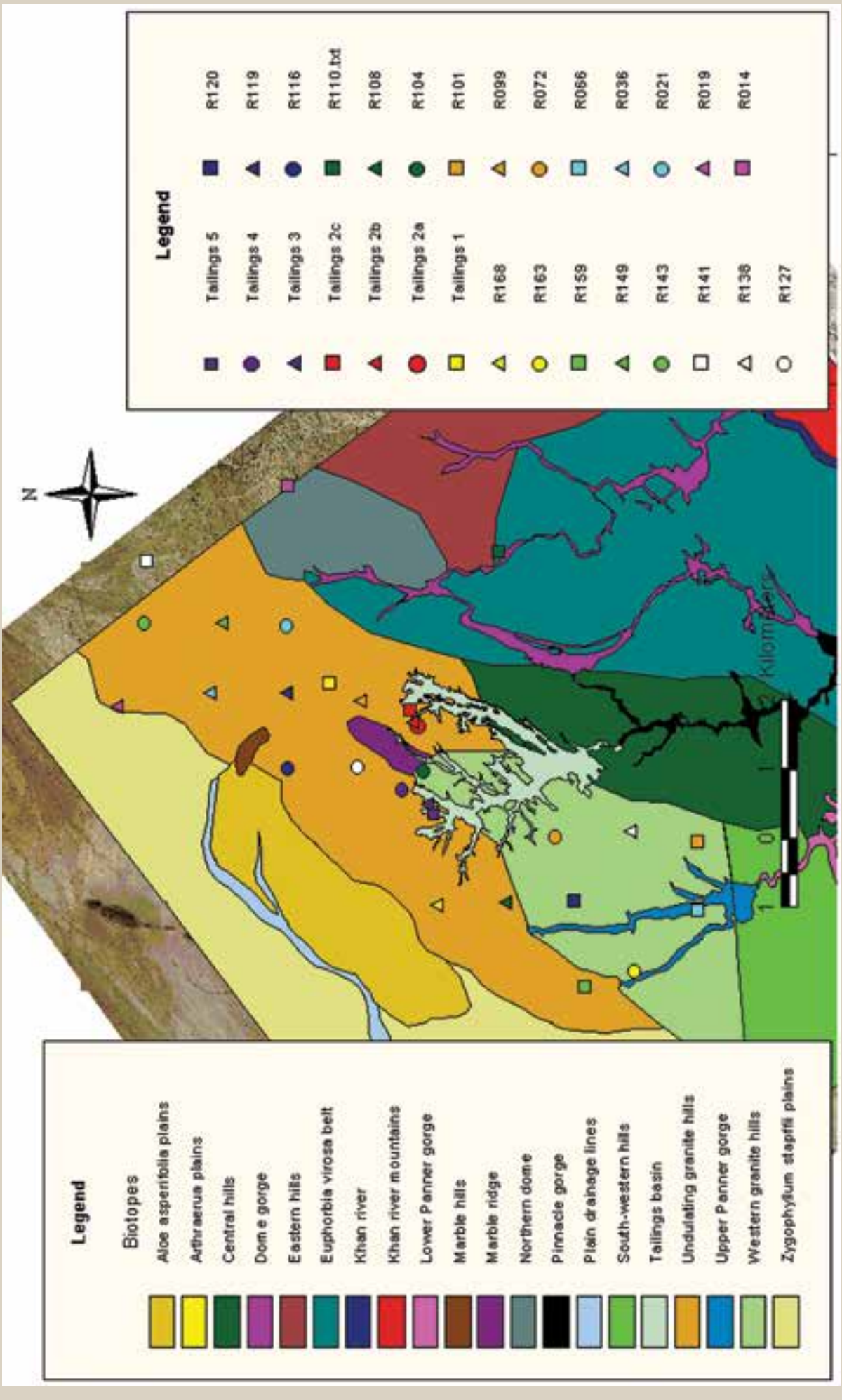

Figure 3.11: Distribution of *L. ruschiorum* in the RUL licence area and associated biotropes (Burke, 2005)

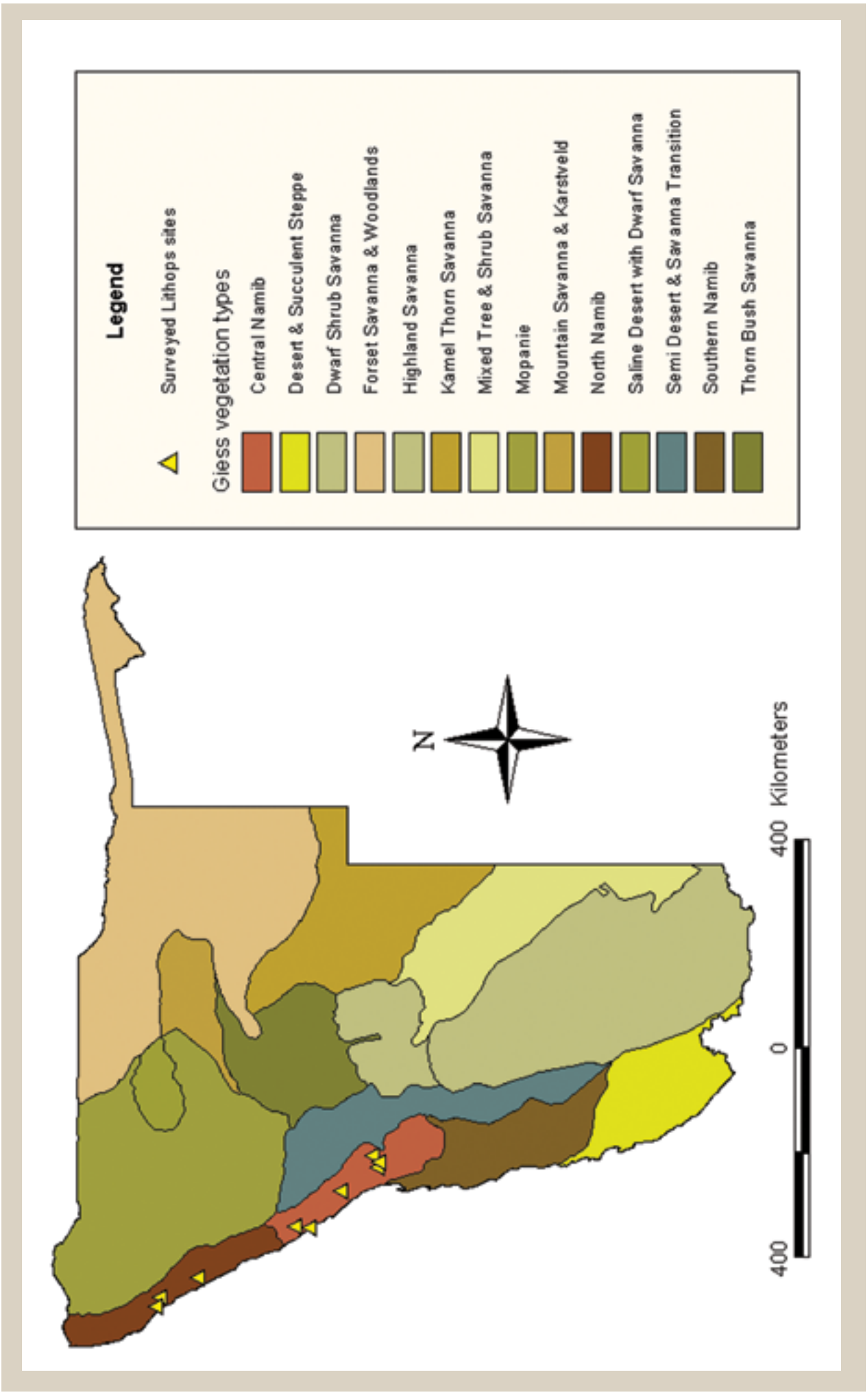

Figure 3.12: Distribution of surveyed *L. ruschiorum* populations in Giess vegetation types

Proportion of global population at RUL:

No more than 24 percent of the total number of plants in the species occurs within the RUL licence area.

Other information:

Flowering and fruiting occurs after sufficient rainfall. Members of the genus *L. ruschiorum* have considerable potential as ornamentals and are indeed very popular among succulent collectors, hence the threat of illegal collecting of live plants.

Since the species is fairly widespread and seed production is prolific, it may be possible to collect a sufficient number of seeds for managing a small project on raising seedlings.

These could be sold in indigenous nurseries and thus serve as a cash income to marginalised communities.

However, the feasibility of such an endeavour would have to be investigated further.

MSBP generated information

(See Appendix 10 E)

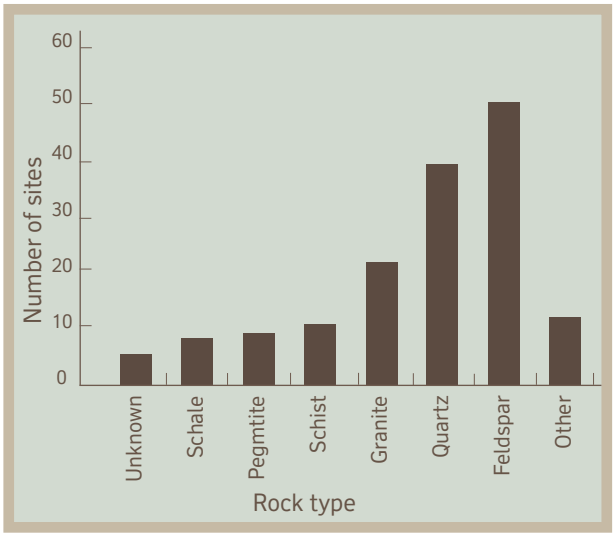

Figure 3.13: Lithology preference of *L. ruschiorum*

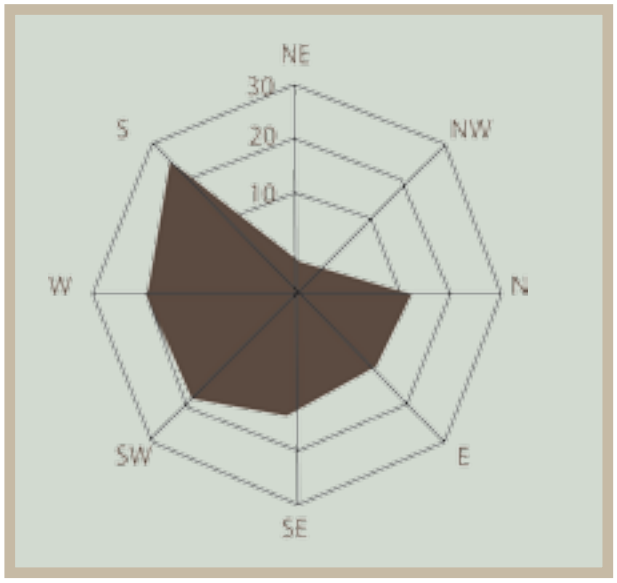

Figure 3.14: Aspect preference of *L. ruschiorum*

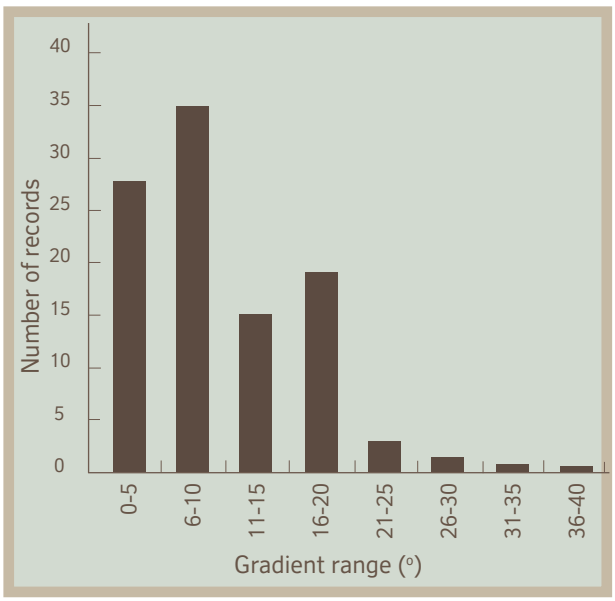

Figure 3.15: Gradient preference of *L. ruschiorum*

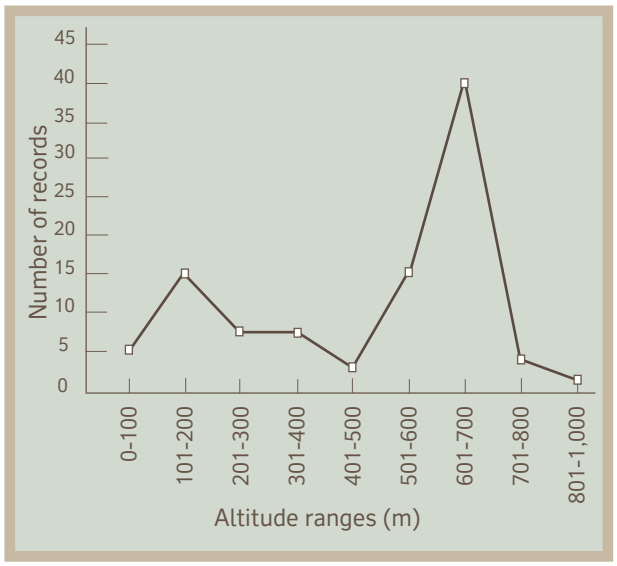

Figure 3.16: Altitude preference of *L. ruschiorum*

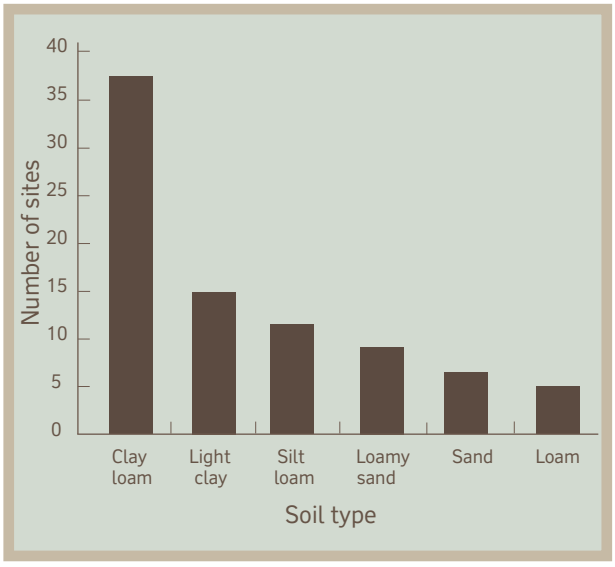

Figure 3.17: Soil type preference of *L. ruschiorum*

Management, conservation and monitoring recommendations

In situ *management and conservation:*

RUL has been pro-active in the protection of the *L. ruschiorum* sites north of the tailings facility by establishing a "no-go area" (Figure 3.18 on next page) at the northern side of the tailings dam. The "no-go area" contains at least 1,074 individuals of *L. ruschiorum*, which constitutes over half of the total number of plants recorded in the licence area. The combined monitoring squares in this area contain 228 plants.

1. The "no-go area" should be maintained in its current natural state until closure of the mine, and not be considered for any further development. The map of this area should be distributed to relevant staff.

2. The monitoring squares contain the densest part of each surveyed site. They should be maintained as such until closure of the mine. RUL should make relevant staff aware of the importance of the monitoring squares as a conservation and monitoring tool. The map of the locations of the squares should be made available to RUL's management staff as well as those who drive bulldozers and are responsible for grading of roads. Care should be

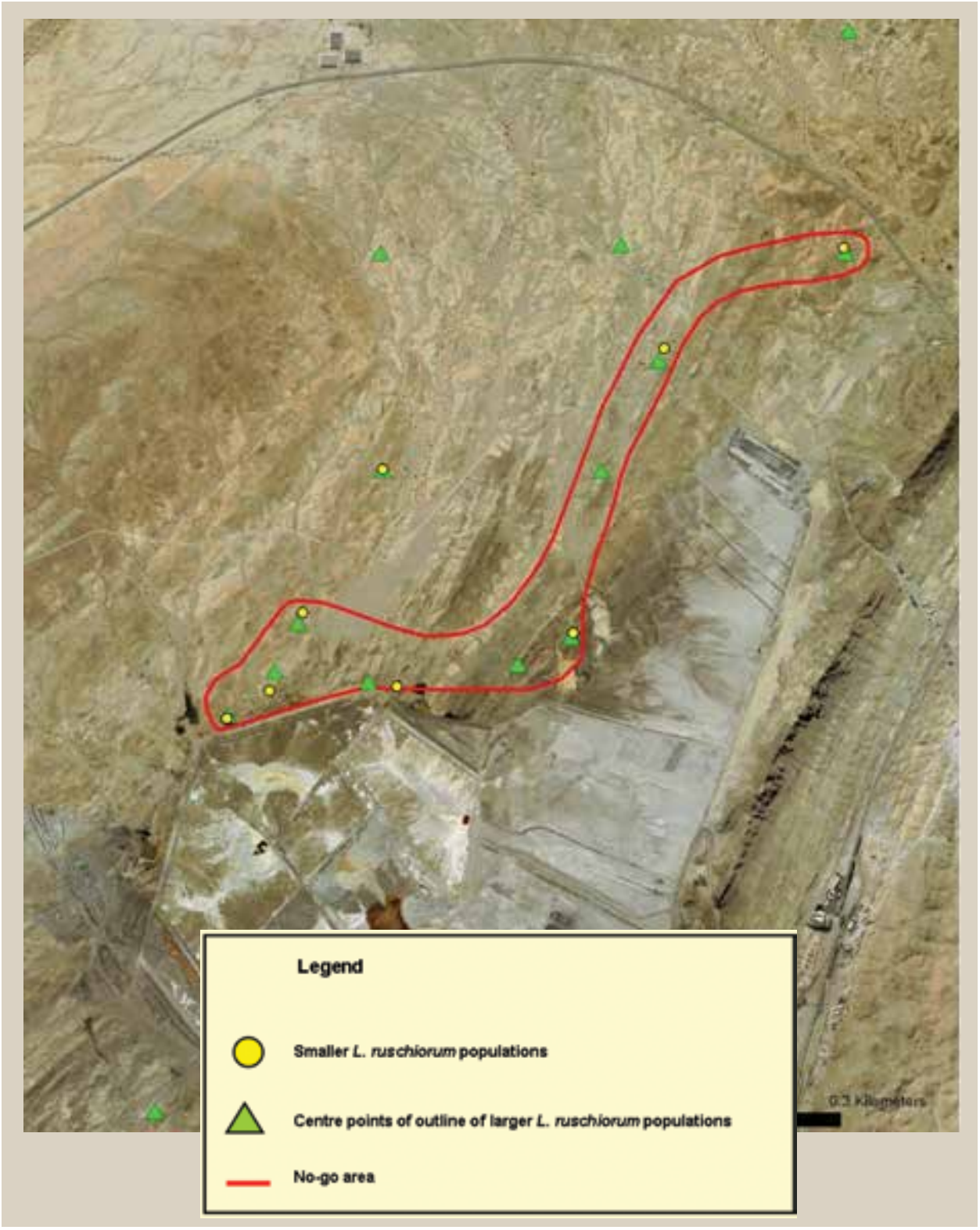

Figure 3.18: *L. ruschiorum* "no go" area along the northern side of the tailings facility at RUL

Figure 3.19: Contractor fixing yellow poles with cement

Figure 3.20: Contractors permanently fixing poles in the "no-go" area

taken not to disturb the monitoring squares in any way as this could influence the results of monitoring the number of plants in the squares over time. The total area covered by the monitoring squares is 2,100 m². This is a small area and avoiding it is only a matter of looking out for the yellow poles demarcating the monitoring squares. RUL has been cooperative by carrying out the recommendation to permanently fix the iron droppers that demarcate the monitoring squares. These have been replaced by four 120 mm x 20 mm iron droppers (painted yellow) and fixed with cement. (See Figures 3.19 and 3.20).

3. It is recommended that all the sites that were identified as important for *L. ruschiorum* should be conserved. RUL should provide relevant staff with a map of these areas (Figure 3.21 on page 38 and Appendix 4). Some of these sites fall outside the "no-go area".

Ex situ ***management and conservation:***

1. To facilitate future restoration work (post mine closure) and to provide a long-term insurance strategy for these plants, banking of seeds should be a high priority. The field work conducted from 2006 to 2008 proved that finding enough seeds per population to bank according to international standards is not a serious challenge, as the plants readily flower after good rains and seed setting is normally very good (pers. obs). The ideal number of seeds of this species, which should be banked by the NPGRC and duplicated at the MSB in the UK, is 1,000. Although a number of accessions have been collected, no seed collection has been made from the RUL licence area. The population at RUL should therefore be visited at least three months after a good rainy season to collect mature capsules. Capsules should have a dry, woody appearance when they are mature. A fleshy appearance indicates that the capsules are not ready to be collected. Seeds are only ripe when the capsule opens of its own accord when moistened. See Appendix 2 for a photograph of a mature capsule. See Appendix 10 for instructions on the correct procedure for collecting an accession.

2. If any *L. ruschiorum* plants occur in an area of RUL where development is taking place, thus making it impossible to leave them in their natural habitat, they should be carefully removed, ensuring that the root system remains intact. Arrangements should then be made with the NBRI for the plants to be planted in the desert house, to be distributed to other botanic gardens, or to be transplanted on the site.

Long-term monitoring strategy:

The first round of monitoring the *L. ruschiorum* monitoring squares was conducted at RUL in October 2008. Such a monitoring session should preferably be conducted after good rains, in order to maximise the detection of the plants, as they will be more visible then. In very dry months the plants tend to shrink due to water stress and can become obscured by soil and gravel. This trend was confirmed during the monitoring session when, out of 21 squares, the number of plants that were originally recorded could only be found in four of the squares. However, it will not always be feasible to wait for a good rainy season as many years can pass between seasons with good rainfall.

The following is recommended for monitoring the surveyed* L. ruschiorum *populations:

1. Experience has shown that it is advisable to have two or more persons looking out for the plants during monitoring of the squares, as more plants are detected this way. However, not more than five people should be used as this could result in trampling of the plants, especially in denser squares during good rainy seasons. Responsibility – RUL and NBRI.

2. The monitoring squares at RUL should be surveyed every year, irrespective of whether or not there has been sufficient rain. This will ensure that squares are not damaged by mining activities without the authorities being aware of it. Responsibility – RUL.

3. Monitoring of all the squares across the distribution range of the species should be conducted annually, if resources are available. Long-term monitoring of the squares can reveal trends in the population. Ten monitoring sessions could possibly reveal whether or not populations are declining, increasing or remaining stable. It is highly unlikely, however, that all populations will receive sufficient rain every year and this may affect the monitoring results. Conclusions regarding the trends in populations should not be drawn before ten years have passed since conducting the original survey. Responsibility – NBRI.

4. It is advisable to monitor the entire surveyed population, which was measured using a GPS, once in 10 years in order to ascertain if the trends in the monitoring squares are reflected in the rest of the population. Responsibility – NBRI.

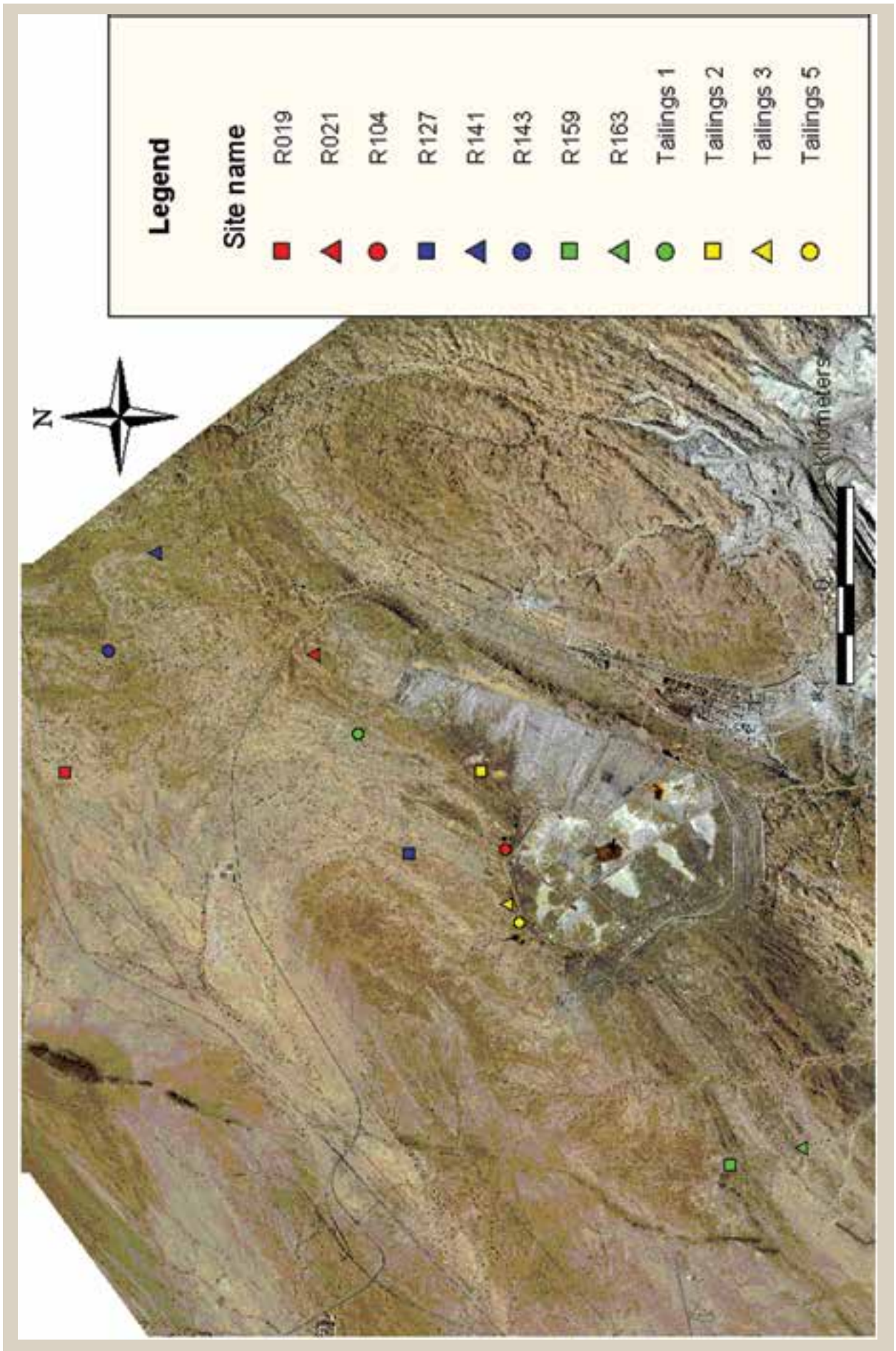

Figure 3.21: Important sites for the conservation of *L. ruschiorum*

CHAPTER 4: DISCUSSION

General discussion

Accurate information pertaining to factors threatening plant populations as well as their distribution and abundance is usually very scant. The time and resources required for conducting a detailed survey on any species of conservation concern makes it an expensive undertaking. The funding received for this project therefore presented a rare opportunity for conducting detailed surveys on two target species.

The project also highlighted the importance of conducting field assessments. At the start of the project, it was suspected that the largest population of *L. ruschiorum* occurs at RUL, and although this is a substantial population, field assessments demonstrated that there is at least one larger population in the SCP. Individual *A. pechuelii* plants were thought to be few and far between, but new information reveals that there are large populations in terms of numbers of individuals and the size of the area that they occupy.

Project Output 1 was to complete field assessments of at least 50 currently known populations of the target species. By the end of the project, 54 sites of the target species had been surveyed, accounting for some 35 populations. Chapters 1 and 2 outline the results for this output.

The first target conservation outcome of the concept note was "improved awareness of the conservation status and national population distribution of target species and relevant importance of populations found at RUL". The purpose indicator linked to this outcome is "IUCN ratings for species are reviewed, based on more detailed knowledge/ information acquired and if necessary, amended by the end of 2009, leading to more accurate assessments." The newly acquired information will therefore be updated on RAMAS Red List, the software used for assessing species under the IUCN Red List categories and criteria, and forwarded to IUCN before the end of 2009.

Project Output 2 was to raise the capacity of MET and RUL staff to undertake Red List field assessments, seed collecting and monitoring. Training of MET staff to conduct field assessments was not fully pursued as the Ministry did not officially indicate that it intended to participate in the project. Training was given to RUL staff by the MSBP in order to identify species that occur within the licence area, as well as to collect seed accessions. A guide was developed for this purpose (Appendix 10). Further training of RUL staff focused on locating the monitoring squares and the *L. ruschiorum* individuals within them, in order to enable staff to conduct monitoring surveys.

Additional training may be necessary to teach RUL staff to monitor the *A. pechuelii* population. Training was given to E. Klaassen of the NBRI, focusing on data collection, the use of field recording instruments and the establishment of monitoring squares. She was also exposed to the RAMAS Red List software to enable her to assess the status of species. A number of NBRI staff was given hands-on training in practical field procedures during field assessments.

Project Output 3 was to collect and bank seeds from target species and other endemic species occurring at RUL. Appendix 10 consists of a full report on the contribution of the MSBP towards this output. During the course of the project, 5 accessions each of *A. pechuelii* and *L. ruschiorum* were collected and banked.

Project Output 4 was to develop and implement the species conservation plans for the target species at RUL. Project Output 5 was to develop and apply a long-term monitoring strategy for the target species. These two major outputs are combined in Chapter 3 as species management plans.

Appendix 7 is a report on the range prediction modelling and locality targeting for *L. ruschiorum* and *A. pechuelii*, compiled by S. Bachman from the Royal Botanic Gardens, Kew. The range prediction models were partially meant to aid field work planning and prioritisation. Unfortunately, the first iteration which was carried out at the beginning of the project, resulted in areas that were too large to investigate, as information at this stage was limited. Field work was therefore planned based on information from herbarium specimens.

A second iteration was performed after data from the first field trips were added to the original data and this produced more refined results, although the areas predicted to contain *L. ruschiorum* and *A. pechuelii* were still too large to investigate.

A third iteration would probably have resulted in areas small enough to investigate, but this was not carried out. In addition, as the project progressed, it became clear that time would not allow the investigation of additional areas during the three-year period, as investigating known localities took longer than expected. However, with the amount of data that are now available for these two species, a further iteration of the range prediction modelling would be useful in the search for new localities for future surveys.

Some 124 days were spent searching for, travelling to or surveying populations of *L. ruschiorum* and *A. pechuelii*. As can be expected, it was time consuming to conduct a national survey on two species with a relatively wide distribution range, especially as significant distances had to be covered and finding the target populations was not guaranteed. Conducting such an extensive survey became possible through the establishment of the partnership, as most of the field work was conducted by NBRI staff in the public service.

The survey provided an important basis for monitoring populations in the long term, which will make it possible to detect a decline in population sizes over time, for example. This is a very important criterion for assigning a conservation status to any species. However, the considerable amount of time spent on this partnership project meant that other activities of the Threatened Plants Programme of the NBRI were somewhat neglected for three years, and this backlog will have to be addressed as soon as possible. It will therefore be a challenge to enter into similar partnerships as long as manpower at the NBRI is limited.

L. ruschiorum discussion

The fairly comprehensive field assessments conducted at RUL helped to explain the high density of *L. ruschiorum* at the northern side of the tailings dam. The map showing the distribution of the *L. ruschiorum* in the licence area (Figure 1.4) reveals that the plants are spread in a band running from north-east to south-west, with the tailings dam in the centre of this band. It appears therefore that the tailings dam was constructed in the middle of a large *L. ruschiorum* population, thereby partially destroying its natural habitat. The dense clusters directly to the north of the tailings dam seem to be what remains of a once much larger population.

This observation makes the conservation of these remaining *L. ruschiorum* vital. RUL therefore has an important responsibility to protect this area and the company has been pro-active by proclaiming it a "no-go area" (Figure 3.18). This essentially means that the area will not be considered for further development.

The fact that the "no-go area", with more than 1,000 plants is now deemed one of the most important areas for the conservation of *L. ruschiorum* is interesting, since the predetermined sampling sites did not adequately cover that area. It was deemed crucial to survey this area, since previous work had indicated substantial numbers of *L. ruschiorum* occurring there and as a result, five extra sampling sites were selected.

Caution should be exercised when prioritising populations for conservation, based on population size alone, because the full extent of most populations is not known. For example, only a small part of the Rössing Mountain could be sampled, and it is possible that the population extends over all the south-west-facing slopes of the mountain. The same could apply to other populations as well.

The time available for conducting field surveys often limited the extent to which a population could be surveyed. Other important factors should also be considered when prioritising populations for conservation, for example, density, threats, genetic erosion, whether a population is fragmented or isolated, population reduction and continuing decline in habitat size and quality.

A number of previously documented populations of both target species could not be located. In some cases the locality descriptions for *L. ruschiorum* populations were obtained from the *Lithops* locality data (Cole, 2002). These locality descriptions are deliberately vague so as to prevent illegal collecting, making it more challenging to find them. Despite GPS coordinates being available, a population in the central Namib could not be located. Locality descriptions on herbarium specimens are often not detailed enough to relocate a population.

Defining *L. ruschiorum* population boundaries at RUL was a challenge, because the suitable habitat for the species continues for several square kilometres and could stretch over several sampling sites. Suitable habitat is usually interrupted by visible geographic boundaries that separate groups of plants, for example dry riverbeds or unsuitable lithology.

However, since *L. ruschiorum* are probably pollinated by bees that can presumably travel considerable distances, it would not be entirely unreasonable to assume that all the *L. ruschiorum* within the RUL mining licence area belong to the same biological population, with densities varying from one site to another. Conducting molecular studies to determine the degree of genetic diversity within and between populations could shed more light on the issue.

The number of juvenile *L. ruschiorum* at any given sampling site was almost certainly under-estimated. Due to their excellent camouflage and small size, young plants are easily hidden beneath the gravel in which they grow. It is not known to what degree their numbers have been under-estimated. Juveniles were only encountered at a few sites. Attempting to determine the number of juveniles in any *L. ruschiorum* population does not seem feasible, as it is very time consuming, and thus impractical.

When the first surveys were conducted, the area occupied by each site was measured with the area calculation function of the GPS. However, the accuracy of this function was questionable as the GPS only recorded 4-5 points and the outline of the site or population was thus not accurately recorded. After consultation with Rainer Schneeweiss at RUL, it was decided to use the track log function, which consequently proved to be far more accurate in terms of recording the outline of the population.

The overall population density at a particular sampling site was usually lower than that of the monitoring squares. This is because a denser part of the population was always selected to establish a monitoring square. In this way more plants can be protected, as the squares at RUL should serve as conservation areas. This method was applied in all surveyed *L. ruschiorum* populations. A random approach to the selection of the squares would probably have shown a more equal density of the overall population compared to that of the monitoring squares.

The monitoring squares with the highest densities were established at the population just north of the Khumib River (Skeleton Coast Park), at Rössing Mountain, at the population between Henties Bay and Uis, and at Tailings Area 3, just north of the tailings dam at RUL. With 70 plants, this last square has the highest number of *L. ruschiorum* within the licence area and the fourth-highest number compared to all other populations.

RUL is the only site where the monitoring squares will be actively protected. Although squares established in the Skeleton Coast Park will not be actively managed, they are passively protected because the park is a national conservation area. Two of these squares occur in areas that are not accessible to the general public.

However, squares established on the road between Henties Bay and Uis, the Ugab Salt Works as well as Rössing Mountain and south-east of Rössing Mountain are completely exposed to human interference. Monitoring these squares over time could reveal what effect active protection will have compared to passive protection or no protection at all. The fact that the squares are visibly marked may attract attention to them.

The population of *L. ruschiorum* that was recorded at View Point in the Skeleton Coast Park seems to be somewhat isolated from other *L. ruschiorum* populations by long distances. This particular population is therefore vulnerable to stochastic events (a random occurrence like a flood, fire, other natural disasters), which could destroy the entire population.

Over half of the 92 plants in this population are damaged and the site is frequented by visitors, which can lead to

illegal collecting becoming a potential threat. It is for these reasons that the population was identified as important for conservation. No monitoring square was established here, because the plants are too far apart, yet the population is small enough to be monitored as a whole.

In order to test the usefulness of more widely used sampling methods for determining the density of *L. ruschiorum*, a transect was laid out and tested in two populations and a plot-less sampling method (the closest individual – nearest neighbour, Cottam & Curtis, 1956) was tested at three sampling sites. This method was found to be problematic as the *L. ruschiorum* individuals often occur in small clusters that are far apart.

This meant that distances between the same individuals were measured repeatedly, as at least 30 measurements had to be recorded. The transect method was found to be destructive, as workers did not look out for the *L. ruschiorum* during the setting up process, and a number of plants were accidentally trampled.

This problem will be more pronounced in denser populations and after good rains when the plants have taken up a lot of water. Therefore, other methods of estimating population densities of *Lithops* species need to be tested.

Red List / Conservation status of *L. ruschiorum*:

The population at RUL has been reduced in terms of habitat size and quality, largely due to the original development of the mine. Although it is not possible to determine the proportion of the population which was lost, it is unlikely to represent a large percentage of the national population. The assessment carried out for the Red Data Book (Loots, 2005) inferred that the largest population contains no more than 1,100 mature plants.

The new information collected during the project has shown that the largest population that was surveyed contains over 2,000 plants. There was no evidence to suggest that any of the populations surveyed outside the RUL licence area have declined significantly in terms of population size or the quality and size of the habitat. Indications are that the number of juveniles in each population is grossly underestimated.

Thus, it can be assumed that recruitment is taking place in most populations. The current national status of LC therefore remains valid.

The fact that *L. ruschiorum* is not threatened with extinction does not mean that it is not of conservation concern. On the contrary, the field work which was conducted suggests that *L. ruschiorum* is vulnerable to habitat destruction. Bulldozer tracks going through some parts of the *L. ruschiorum* habitat at RUL have not been re-colonised by *L. ruschiorum* since the inception of the mine, some thirty years ago.

In other populations where the habitat was disturbed by off-road driving, no *L. ruschiorum* were recorded in the vehicle tracks. It was, however, not possible to determine the age of the tracks in these cases.

A number of sites are vulnerable to off-road driving as well as illegal collecting, most notably the ones between Henties Bay and Uis, where no form of protection exists. All *Lithops* species are still vulnerable to illegal collecting of seeds and removal of live plants from their natural habitats.

A. pechuelii discussion

Surveying populations of *A. pechuelii* proved more challenging than anticipated at the start of the project. In most populations, plants were numerous but very far apart, so that workers had to cover long distances over rugged terrain in order to survey a significant part of the population.

Reports that *A. pechuelii* is common on the plateau of the Brandberg could not be confirmed, possibly because the area is vast and long distances had to be hiked over very difficult terrain. Another possibility is that previous collectors could have confused it with *Kleinia longifolia*, which is extremely abundant on the mountain and at first glance very similar to *A. pechuelii*, especially from afar.

At the time when the concept note for the project was developed, the available information about *A. pechuelii* indicated that plants are scattered and few in number. This created the impression that counting all individuals in a population would be feasible.

This idea was enhanced when field work at RUL started because within the licence area, *A. pechuelii* does indeed occur either individually, or in small groups of 3-10 plants. It was therefore possible to get a fairly accurate indication of the number of *A. pechuelii* plants within the RUL licence area. However, once assessments started in other areas, it became apparent that most populations extend over several square kilometres and cover large areas, and it became very difficult to record every single individual.

The populations at Leeukop in the Namib Naukluft Park, at RUL and at Valencia were the only large populations in which an attempt was made to record all the plants. The population at Leeukop could be extensively surveyed, because the plants are confined to a relatively small inselberg.

Despite its relative small size and isolation, it took ten days to survey this population. It became clear then that recording individual plants is extremely time consuming and consequently unworkable for the other populations that were surveyed.

The population at the prospective Valencia Uranium mine is the only one for which the height of all the individuals (450) were measured, and therefore the percentage of small plants recorded here (17 percent) is fairly accurate. The recruitment in this population thus seems to be fairly healthy. Measuring the height of all the plants recorded was only possible through the considerable efforts of 6 field workers over a period of 4 days.

Red List/Conservation status of *A. pechuelii*:

The Red List assessment conducted on *A. pechuelii* for the Red Data Book (Loots, 2005) was largely based on data from literature, herbarium specimens and expert opinion. The assessment suggested that plants are mostly uncommon to rare and occur in small groups. It was inferred that there are currently no more than 2,500 mature individuals in the species, and it was estimated that there has been a population reduction of up to 25 in the past. In addition, it was suspected that there is a continuing decline in the number of mature individuals and that no sub-population contains more than 70 mature plants. Based on this information, a Red List status of NT was assigned.

The more detailed knowledge accumulated during the survey revealed that there are at least 2,671 individual plants in the wild and that the largest population contains more than 800 plants. Knowing now that some populations occupy extensive areas, it could be said with a fair degree of certainty, that there are easily as many as 4,000 mature plants left in the wild.

The mining activities at RUL may have resulted in a small population reduction, but it is highly unlikely that it was as high as 20-25 percent. No evidence could be found to support the existence of a continuing decline in the number of mature individuals in any population, although this is still possible.

Based on this new information, the national Red List status has therefore been down-listed from NT to LC. This simply means that a taxon has been evaluated against the criteria and does not qualify for Critically Endangered, Endangered, Vulnerable or Near Threatened (IUCN, 2001).

The fact that *A. pechuelii* is not threatened with extinction, does not mean that it is not of conservation concern. On the contrary, although it is difficult to determine the age of *A. pechuelii* plants, it is reasonable to assume that they are extremely slow growing and that large individuals may be several hundreds of years old.

In addition, the field work which was conducted suggests that seed setting is poor in all the surveyed populations, resulting in poor recruitment (establishment of juvenile plants) as well. Indeed, in most populations, less than 10 percent of the plants were small (Figure 2.4) and in the long run, this may prove to be a threat to the survival of the species. Populations with poor recruitment will be vulnerable to illegal collecting, trade in pachycauls (thick-stemmed plants) and possibly climate change (Loots, 2005).

CONCLUSIONS

The work conducted through the partnership has resulted in an increase in important information on the two target species. The more detailed knowledge that now exist means that population size can be estimated with a fair degree of accuracy, whereas previously these numbers had to be guessed. There is also fair certainty that neither species is threatened with extinction, although both are still a conservation concern.

The support provided by Rio Tinto Group, RUL, the NBRI and RBG (Kew) to conduct Red List assessments has been particularly beneficial to the Namibian National Plant Conservation objectives as it provided a basis for the monitoring of populations of the two target species. The trend to set up monitoring squares or other means of monitoring populations will be applied to other species of conservation concern, especially threatened species, as an ongoing activity of the Threatened Plants Programme of the NBRI.

The project has provided an opportunity for RUL to make a valuable contribution to the conservation and management of two species of national conservation concern, both inside and outside their licence area. It is hoped that the commitment by RUL and Rio Tinto will serve as an example to be followed by other mining companies.

Assessing the proportion of the global population of a species on a mining licence area and making specific recommendations for the management of these species could also be of relevance to other Rio Tinto business units as they strive to achieve a positive effect on biodiversity. Lessons learnt from this initiative could possibly be used to inform the design of similar projects elsewhere.

An important lesson learnt from the project is that conducting a national survey on any plant species with a wide distribution range is a huge undertaking. The more widespread the species is, the more time-consuming and involved the process becomes and the more resources are required, especially in terms of manpower. With present manpower constraints, perhaps only one species should be assessed at a time.

The methods for estimating abundance of populations of small succulents such as *Lithops* species should be further tested in order to find the most suitable method. Plot-less sampling methods seem to have more potential than methods where transects have to be set up. Although the nearest neighbour/closest individual method did not seem to provide accurate results for *L. ruschiorum*, the method could possibly be adapted to be more suitable for small succulents that occur in small clusters, or a different method applied. Ideally, all plot-less sampling methods should be tested and the most appropriate one(s) selected. Some methods could be more appropriate for certain genera than others. Combined with a critical review on the conservation status of all *Lithops* species in Namibia, this work should be carried out as part of an advanced study.

The recruitment in populations of *A. pechuelii*, should be monitored, as poor recruitment will lead to a population decline in the long term, a potential threat. Recent work conducted on *Aloe pillansii* in the south of Namibia concluded that the species is more threatened than previously thought because no small plants could be found (Hoffmann, T., pers. comm., 2009). More work could be done on determining the age of plants and at what stage they begin their reproductive cycle and how big they are at this stage. A study should be carried out to shed light on the reasons for poor seed setting in most populations.

More work should be conducted to determine population boundaries in both target species. This would aid in estimating population sizes and assigning a conservation status.

Molecular studies could reveal how much genetic diversity there is within and between populations of both target species. Populations that are genetically very diversified have a better chance of survival than those that are genetically more uniform or that have lost a significant portion of their gene pool.

ACKNOWLEDGEMENTS

I am grateful to Rio Tinto Group for providing the funds necessary to conduct the field work and obtain equipment for the work. RUL provided financial support for field work that was conducted within their licence area. RUL staff provided logistical assistance during assessments in the licence area. They also assisted with mapping of the results for the RUL licence area and are gratefully acknowledged for their support. Ben Strohbach of the NBRI assisted with mapping and data analysis, for which I am extremely grateful. Most of the transport costs as well as much of the Daily Subsistence Allowances were covered by MAWF. Support from the SADC Plant Genetic Resources Centre (SPGRC) is also acknowledged. Appendix 11 lists individuals who contributed to the project in various ways and they are gratefully acknowledged for their invaluable input.

REFERENCES

Akçakaya. H.R. & Ferson S. 2001. RAMAS Red List Threatened species Classifications Under Uncertainty Version 2.0. Copyright © 2001 by Applied Biomathematics.

Arc View GIS version 3.2a. Copyright 1992 – 2000. Environmental Systems Research Institute, Inc.

Burke, A. 2005. RUL's Biodiversity strategy: Biotope mapping, reconstruction of the pre-mining situation and assessment of biodiversity value. Phase 2 report. 21 pp.

Cole, D.T. 2002. Lithops locality data. Unpublished list. 31 pp.

Cole, D.T. 1988. Lithops flowering stones. Acorn Books. Randburg, South Africa. 254 pp.

Cottam, G. and Curtis, J.T. 1956. The use of distance measures in phytosociological sampling. Ecology 37 (3): 451-460

Curtis, B.A. & Mannheimer, C.A. 2005. Tree Atlas of Namibia. Windhoek: National Botanical Research Institute. 688pp.

Germishuizen, G. and Meyer, N.L. (eds) 2003. Plants of southern Africa: an annotated checklist. Strelitzia 14. National Botanical Institute, Pretoria.

Giess, W. 1971. A preliminary vegetation map of South West Africa. Dinteria 4: 5–114

IUCN. 2001. IUCN Red List Categories and Criteria: Version 3.1. IUCN Species Survival Commission. IUCN, Gland, Switzerland and Cambridge, UK. 30 pp.

Henderson, P.A. and Seaby, R.M.H. Copyright 1999. Density from Distances (DfD). Version 1.1. Pisces Conservation Ltd. IRC House, Pennington, Lymington, UK.

Loots, S. 2005. Red Data Book of Namibian plants. Southern African Botanical Diversity Report No. 38. SABONET, Pretoria and Windhoek. 124pp.

Loots. S. 2005. Unpublished. Assessment and management of Red List and endemic species at Rössing Uranium Mine, Namibia. Rio Tinto / Kew / Rossing / NBRI partnership – concept note, project matrix and budget.

Loots, S. 2013. National conservation assessment and management of *Adenia pechuelii*, with specific reference to the Rio Tinto Rössing Uranium Mine. Dinteria 33: 43-65

Mannheimer, C. & Loots, S. 2012. A Simple Aid to Assessing Cryptic Succulents in the Field. Dinteria 32: 78-80.

National Herbarium of Namibia (WIND). 2009. SPMNDB Database. National Herbarium of Namibia (WIND), National Botanical Research Institute, MAWF, Windhoek, Namibia.

Republic of Namibia. National Planning Commission Secretariat. Second National Development Plan (NDP 2) 2001/2002 – 2005-20062. Windhoek, Namibia

Republic of Namibia. National Planning Commission Secretariat. Third National Development Plan (NDP 3) 2007/2008 – 2011-2012. Windhoek, Namibia

Republic of Namibia. Ministry of Agriculture, Water and Forestry. 2009. MAWF Strategic Plan 2008/2009 – 2012/2013. Windhoek, Namibia. 81 pp.

APPENDICES

National conservation assessment and management of two Namibian succulents with specific reference to the Rössing Uranium Mine

Report on a partnership project
between the National Botanical Research Institute of Namibia,
Rössing Uranium Limited, the Rio Tinto Group and the Royal Botanic Gardens, Kew.

APPENDIX 1:

Field data sheets for *Lithops ruschiorum* and *Adenia pechuelii*

A: Field data sheet for *Lithops ruschiorum*

Date:	Site No.:	Collecting No.:
Assessors:		
Site description:		
Associated vegetation and / or collecting numbers in measured areas within the site:		
Threats:		
Seed collection:		

Total Number of live plants	Mature	Damaged	Juvenile	Total

A	Lat.			Long.		Altitude	
Soil type:				Soil colour:			
Lithology:							
Aspect	Gradient	Aspect	Gradient	Aspect	Gradient	Aspect	Gradients
Juvenile						Total	
Mature						Total	
Mature						Total	
Damaged						Total	
Total Number of plants			Area occupied m²			Density / m²	
Track file name:							

B	Lat.			Long.		Altitude	
Soil type:				Soil colour:			
Lithology:							
Aspect	Gradient	Aspect	Gradient	Aspect	Gradient	Aspect	Gradients
Juvenile						Total	
Mature						Total	
Mature						Total	
Damaged						Total	
Total Number of plants			Area occupied m²			Density / m²	
Track file name:							

C	Lat.			Long.		Altitude	
Soil type:				Soil colour:			
Lithology:							
Aspect	Gradient	Aspect	Gradient	Aspect	Gradient	Aspect	Gradients
Juvenile						Total	
Mature						Total	
Mature						Total	
Damaged						Total	
Total Number of plants			Area occupied m²			Density / m²	
Track file name:							

D	Lat.			Long.		Altitude	
Soil type:				Soil colour:			
Lithology:							
Aspect	Gradient	Aspect	Gradient	Aspect	Gradient	Aspect	Gradients
Juvenile						Total	
Mature						Total	
Mature						Total	
Damaged						Total	
Total Number of plants			Area occupied m²			Density / m²	
Track file name:							

10x10 m monitoring square 1

Lat.				Long.		Altitude
Soil type:			Soil colour:			Lithology:
Lithology:						
Aspect	Gradient					
Juvenile						Total
Mature						Total
Damaged						Total
Total Number of plants					Density / m²	

10x10 m monitoring square 2

Lat.				Long.		Altitude
Soil type:			Soil colour:			Lithology:
Lithology:						
Aspect	Gradient					
Juvenile						Total
Mature						Total
Damaged						Total
Total Number of plants					Density / m²	

Notes:

Photographs

File name	Who	Description

B: Field data sheet for *Adenia pechuelii*

Date:	Site No.:	Collecting No.
Assessors:		
Lat.:	Long.:	
Alt.:	AOO m²	
Site description and condition:		
Associated vegetation and / or collecting numbers:		
Seed collection:		
Soil type:	Soil colour:	
Lithology:		
Threats:		

Total number of live plants	Mature	Damaged	Total

Density of live plants:

Notes:

Number of males:	Number of Females:

B: Field data sheet for *Adenia pechuelii*

		SITE NUMBER:	PAGE NUMBER:								
DATE	PLANT NO.:	LATITUDE S	LONGITUDE E	ALTITUDE (M)	ASPECT	GRADIENT	PLANT HEIGHT	MALE/ FEMALE	PLANT CONDITION	DAMAGED	PHOTO NUMBER

APPENDIX 2:

Photographs of *Lithops ruschiorum* from RUL sampling points.

Juvenile plant

Mature plant wedged in solid rock

Flowering plant in April 2006

Exceptionally large plant about to flower

Well hidden in natural habitat

A plant still flowering in June

Mature plant with developing capsules

Healthy plant with unusual growth form

Mature plant with newly developing leaves, several old capsules and one fresh, matured capsule

R021: Monitoring square and habitat

R019: Habitat

R072: Habitat / Monitoring square

R159: Habitat

Tailings area 1: Monitoring square in future expansion area of the tailings dam

R116: Habitat

R127: Cluster of *Lithops* in habitat

R104: *Lithops* habitat / Cluster of plants

R036: Habitat

R149: Habitat

R143: Habitat

R168: Habitat

R108: Monitoring square

R120: Habitat

R163: Habitat

R138: Habitat with annual *Zygophyllum* species after good rains

R101: Monitoring square and habitat

R066: Habitat

R014: Monitoring square

R110: Habitat

R141: Habitat and Monitoring square A

R141: Habitat and Monitoring square B

Tailings area 3: Monitoring square with highest density of 70 plants.

Tailings area 4: Habitat / monitoring square

Tailings area 5: Partial view of the monitoring square with second-highest density (44 plants), close to the tailings dam

Tailing area 5: Habitat and partial view of the monitoring square

R127 Habitat and partial view of the monitoring square

R104: Habitat and partial view of the monitoring square

Tailings area 2: Habitat and partial view of the monitoring square

R143: Habitat and partial view of the monitoring square

R019: Habitat and partial view of the monitoring square

R119: Habitat and partial view of the monitoring square

R159: Habitat and partial view of the monitoring square

R120: Habitat and partial view of the monitoring square

R163: Habitat and partial view of the monitoring square

APPENDIX 3:

Plant species associated with *Lithops ruschiorum* and *Adenia pechuelii* over their distribution range

Species name	*Adenia pechuelii*	*Lithops ruschiorum*
Acanthopsis sp.		•
Adenia pechuelii		•
Adenolobus pechuelii subsp. *pechuelii*	•	•
Adromischus sp.		•
Aloe argenticauda	•	
Aloe asperifolia	•	•
Aloe dichotoma	•	
Aloe dinteri	•	
Aloe hereroensis	•	
Aloe littoralis	•	
Amaranthus sp.	•	
Anticharis inflata		•
Aptosimum sp.	•	
Arthraerua leubnitziae	•	•
Asparagus sp.	•	
Avonia albissima	•	•
Avonia dinteri		•
Berkheya spinosissima	•	
Blepharis sp.		•
Boscia albitrunca	•	
Calicorema capitata	•	•
Chascanum gariepense		•
Cineraria sp.	•	
Cleome gynandra		•
Cleome sp.		•
Cleome suffruticosa	•	•
Huernia urceolata	•	
Commiphora glaucescens	•	
Commiphora saxicola	•	•
Commiphora tenuipetiolata	•	
Commiphora virgata	•	
Commiphora wildii	•	
Cotyledon orbiculata	•	•
Crassula mesembrianthemopsis		•
Crotalaria sp.		•
Cyphostemma bainesii	•	
Cyphostemma sp.	•	
Dauresia alliariifolia	•	•
Dicoma sp.		•
Emilia marlothiana		•

Enneapogon desvauxii		•
Enneapogon sp.	•	•
Eriocephalus sp.	•	
Eriospermum bakerianum subsp. *tortuosum*	•	•
Euphorbia avasmontana	•	
Euphorbia cibdela		•
Euphorbia damarana	•	•
Euphorbia gariepina subsp. *balsamea*		•
Euphorbia phylloclada		•
Euphorbia sp.	•	
Euphorbia virosa	•	
Faidherbia albida	•	
Foveolina dichotoma		•
Foveolina sp.	•	
Galenia sp.	•	
Geigeria alata	•	
Geigeria ornativa	•	•
Geigeria sp.	•	
Helichrysum roseo-niveum	•	•
Helinus sp.		•
Heliotropium tubulosum	•	•
Hermannia modesta	•	•
Indigofera auricoma		•
Indigofera sp.	•	•
Ipomoea sp.		•
Jamesbritennia maxii	•	•
Jamesbrittenia hereroensis		•
Kirkia acuminata	•	
Kleinia longiflora	•	
Lapeirousia sp.		•
Larryleachia marlothii		•
Lithops ruschiorum	•	
Lophiocarpus polystachyus		•
Lycium sp.	•	
Maerua schinzii	•	
Monechma sp.		•
Monsonia luederitziana		•
Moringa ovalifolia	•	
Myrothamnus flabellifolius	•	
Ophioglossum polyphyllum	•	•
Osteospermum sp.	•	
Othonna lasiocarpa	•	
Othonna sp.	•	
Ozoroa sp.	•	
Petalidium sp.	•	
Petalidium variabile	•	
Polygala guerichiana		•
Polygala pallida		•

Psilocaulon sp.		•
Rhigozum trichotomum	•	
Salvadora persica	•	
Sarcocaulon marlothii	•	
Sarcocaulon sp.	•	
Sarcostemma viminale	•	
Senecio sp.	•	
Sesuvium sesuvioides		•
Solanum sp.	•	
Sterculia africana	•	
Stipagrostis ciliata	•	•
Stipagrostis hirtigluma subsp. *hirtigluma*		•
Stipagrostis sp.	•	
Trachyandra sp.		•
Tripteris sp.	•	
Welwitschia mirabilis	•	
Zygophyllum cylindrifolium	•	•
Zygophyllum simplex	•	•
Zygophyllum stapffii	•	•

Appendix 4

APPENDIX 4:

Outlines of individual *L. ruschiorum* populations found in the RUL licence area

The images revealing close-ups of the individually mapped populations of *L. ruschiorum* in the RUL license area were deliberately omitted from this printed version.

Appendix 4 is available from the author on request.

APPENDIX 5:

Photographs of *Adenia pechuelii* at RUL

R 099: Caterpillar browsing on leaves of *Adenia*

One of the larger specimens at RUL

R104: A plant severely damaged by browsing

R060: An important area for *Adenia* at RUL

R110: An unusual growth form

R060: An important area for *Adenia* at RUL

One of the smaller plants in RUL licence area

Tailings area 1: Specimens with leaves were not often observed

Tailings are 2: One of eight plants very close to the tailings dam

R005: An important area for *Adenia* in the RUL licence area

R015: An important area for *Adenia* in the RUL licence area

R117: An unusual form, growing out of a rock face

R156: Another specimen growing out of sheer rock

Site 28: An important area for *Adenia* at RUL

A very small plant

R 014: An important area for *Adenia* at RUL

R166: An important area for *Adenia* at RUL

APPENDIX 6:

Satellite images mapping the location of surveyed populations of *Lithops ruschiorum* and *Adenia pechuelii*

Figures 6.1 to 6.6 map the surveyed *L. ruschiorum* populations in the central and northern Namib on ETM (Landsat 7) satellite images, starting from the northernmost populations and then proceeding southward.

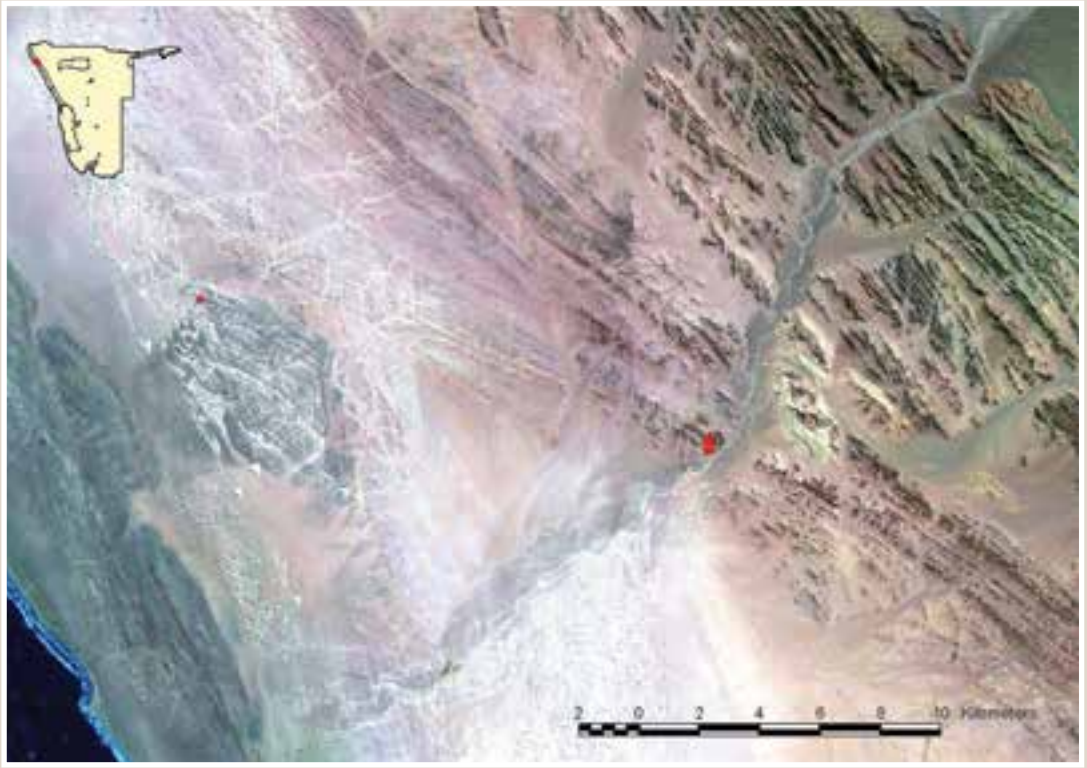

Figure 6.1: Populations of *L. ruschiorum* at View Point and north of the Khumib River in the SCP

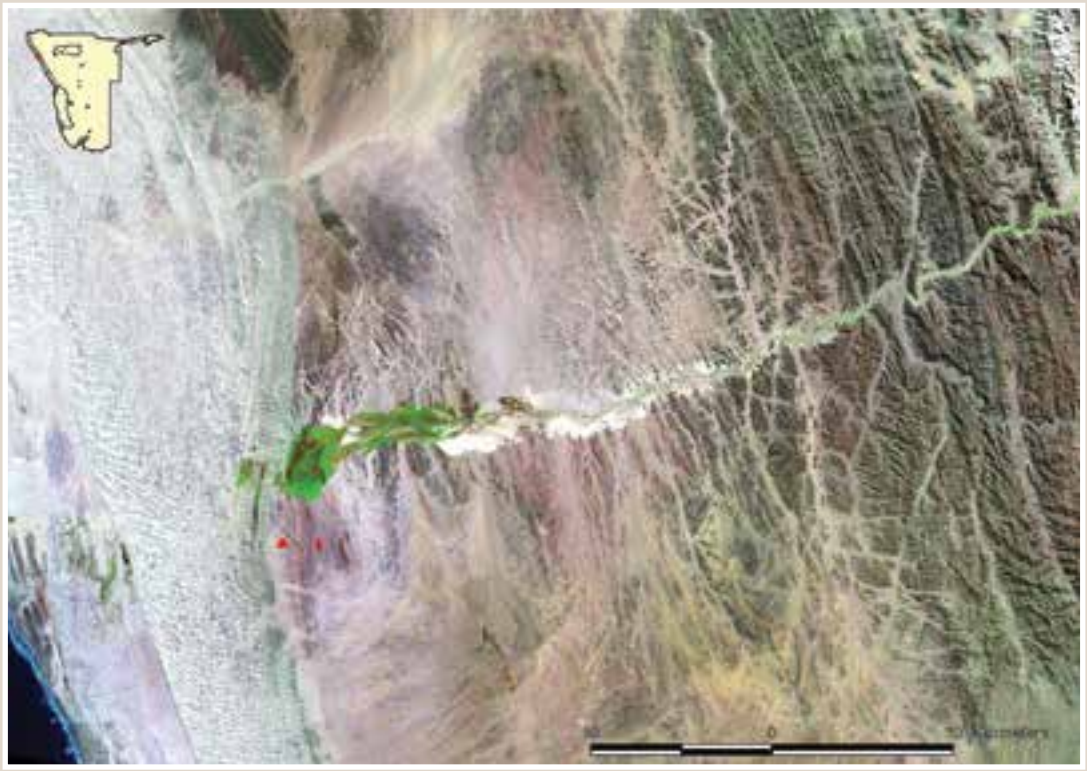

Figure 6.2: Populations of *L. ruschiorum* south of the Hoanib River flood plain in the SCP

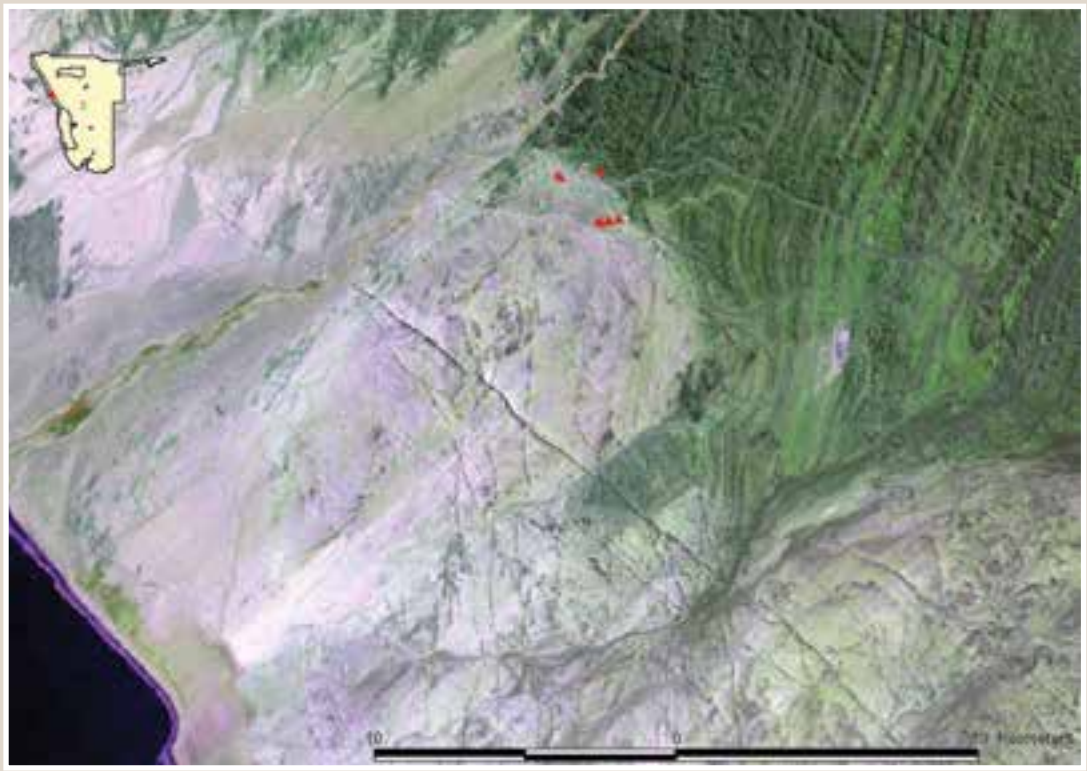

Figure 6.3: Populations of *L. ruschiorum* south of the Ugab River near the SCP border

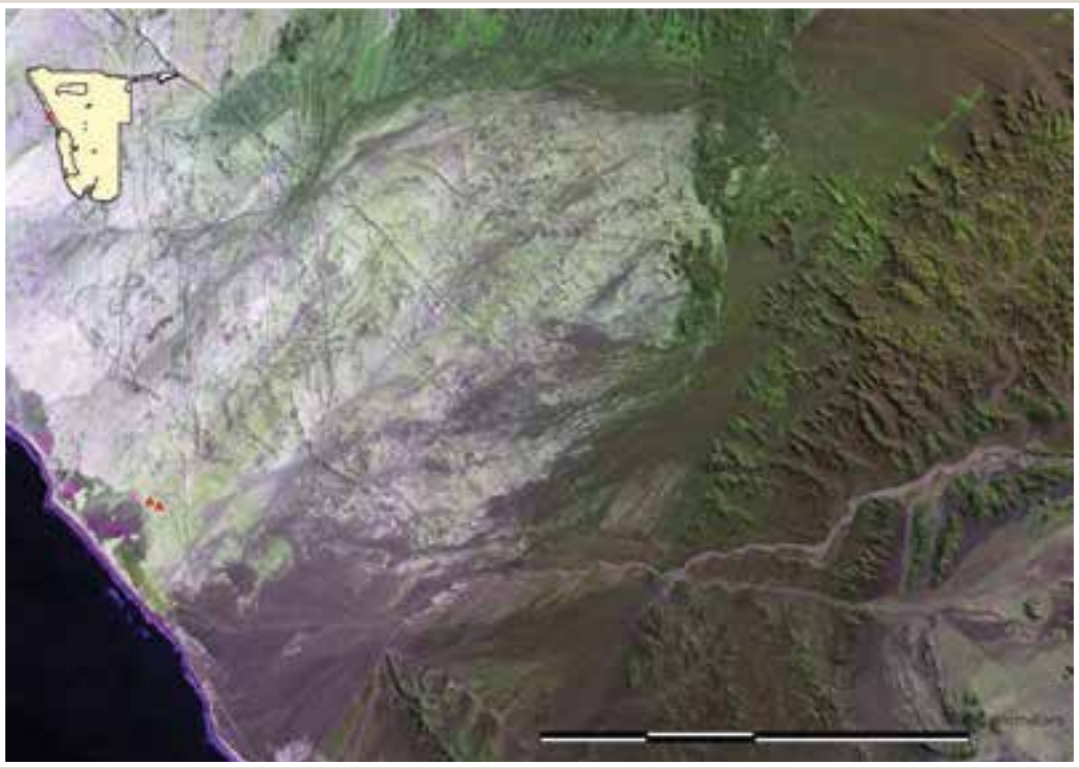

Figure 6.4: Population of *L. ruschiorum* at the Ugab Salt Works

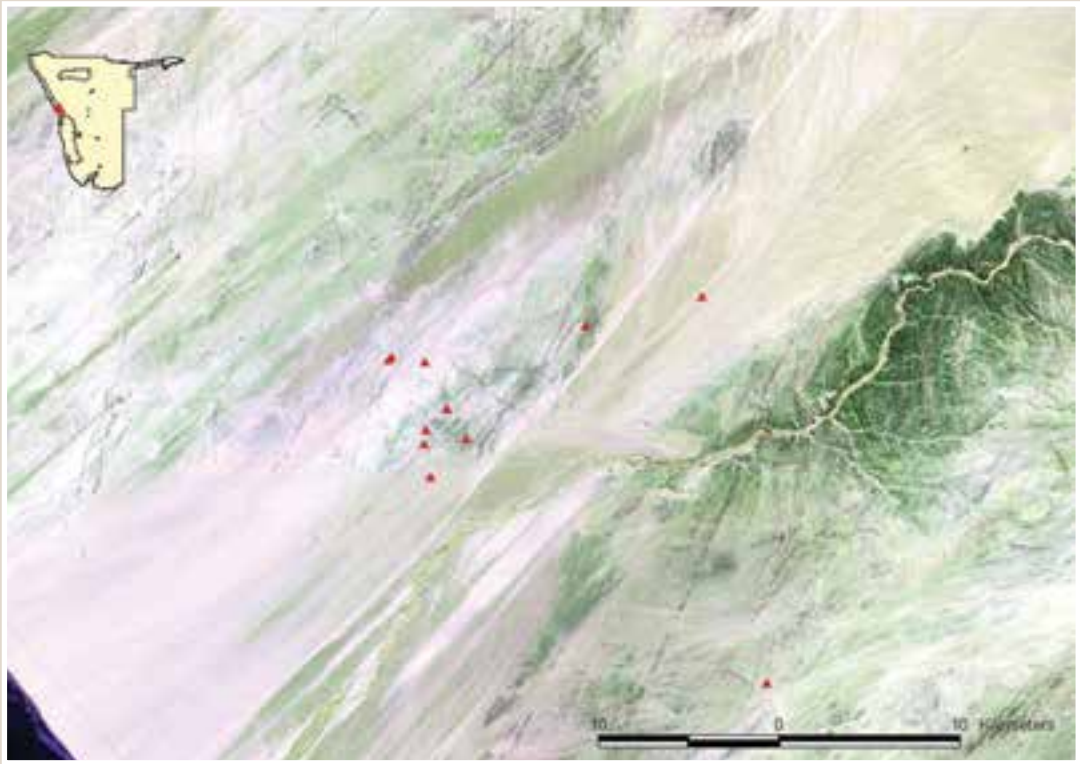

Figure 6.5: Populations of *L. ruschiorum* north and south of the Omaruru River

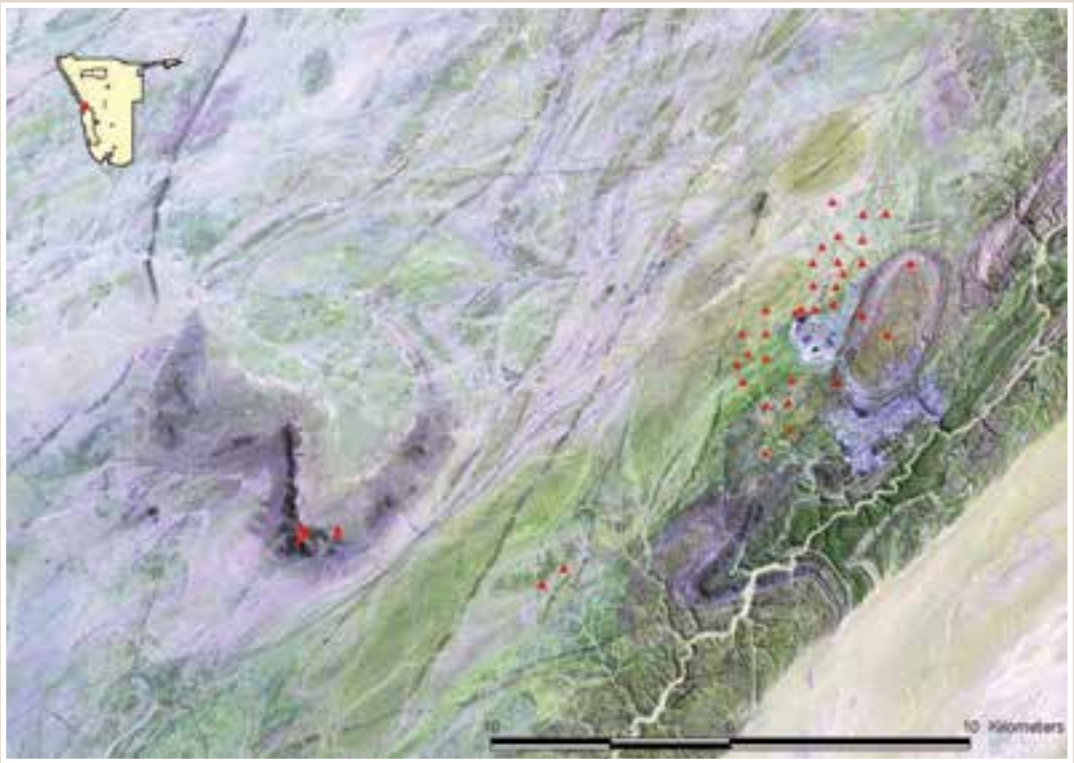

Figure 6.6: Populations of *L. ruschiorum* at Rössing Mountain, near Goanikontes and at RUL

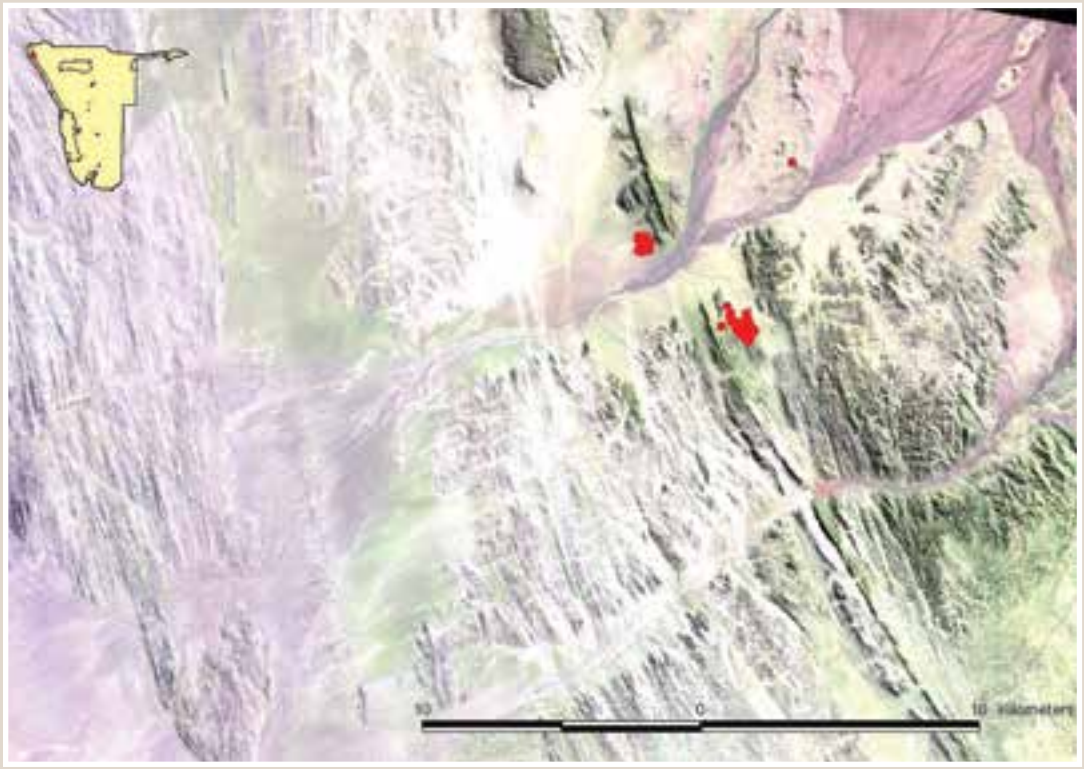

Figure 6.7: Populations of *A. pechuelii* north of the Munitum River on the SCP boundary and between the Munitum and Nadas Rivers

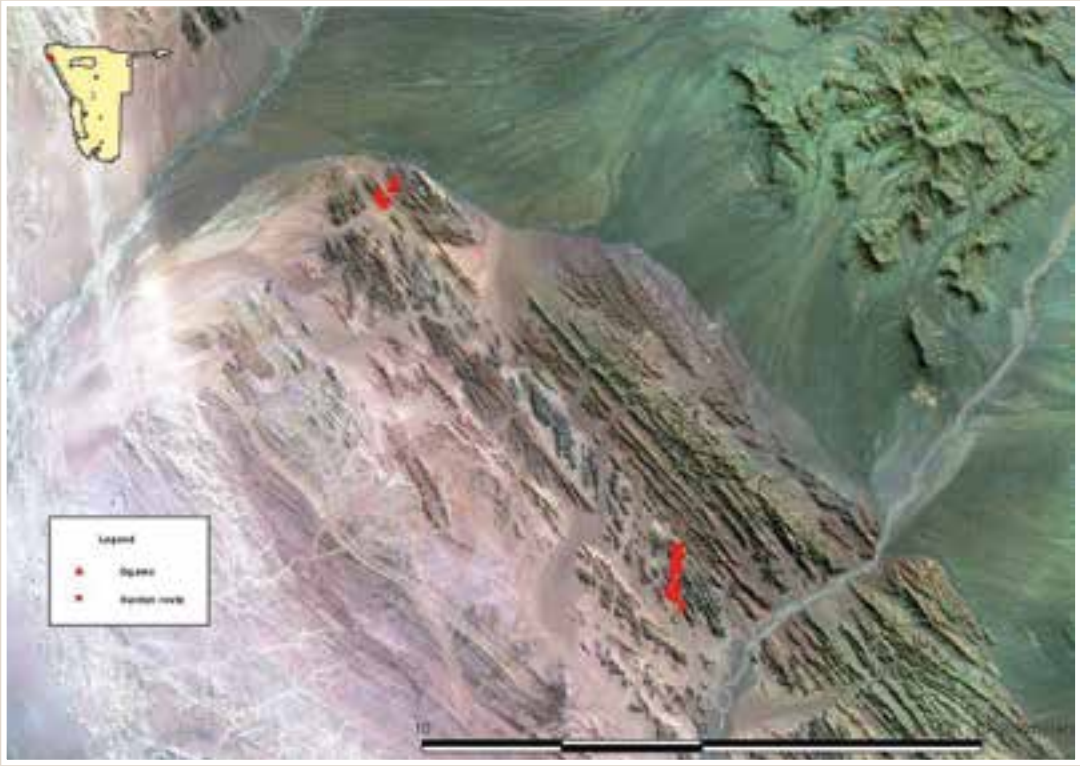

Figure 6.8: Populations of *A. pechuelii* in the "Garden Route" north of the Khumib River and south of the Ogams Fountain

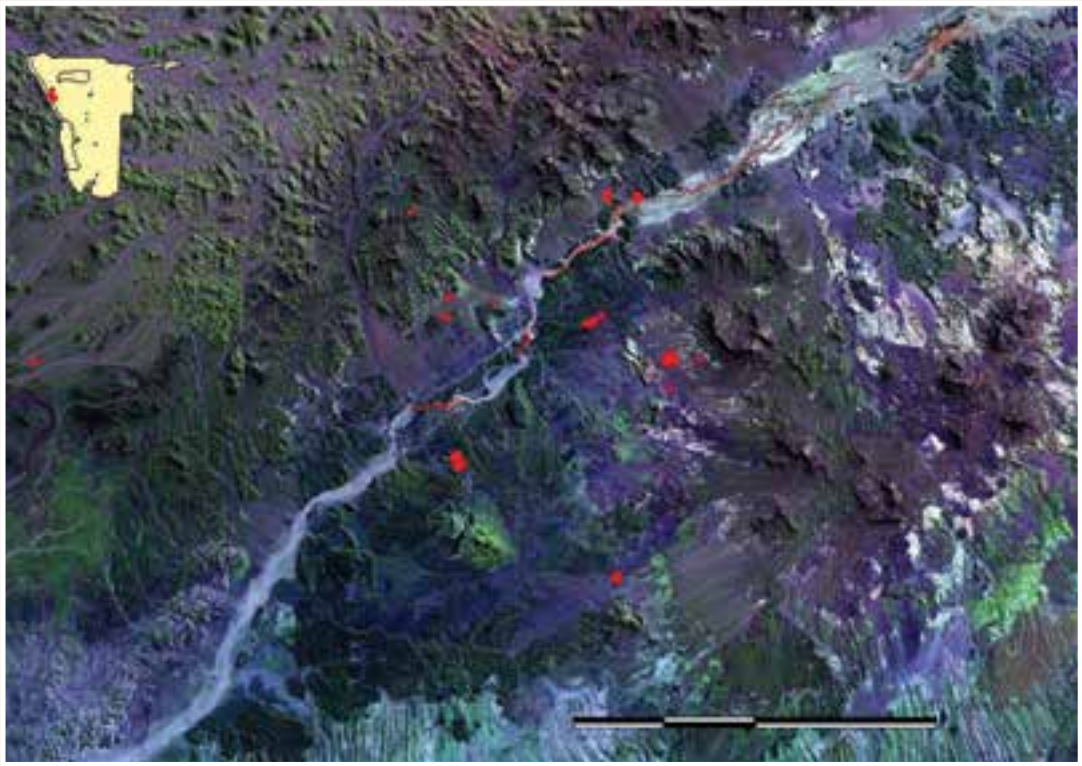

Figure 6.9: Populations of *A. pechuelii*i in the vicinity of the Terrace Fountain north and south of the Huab River

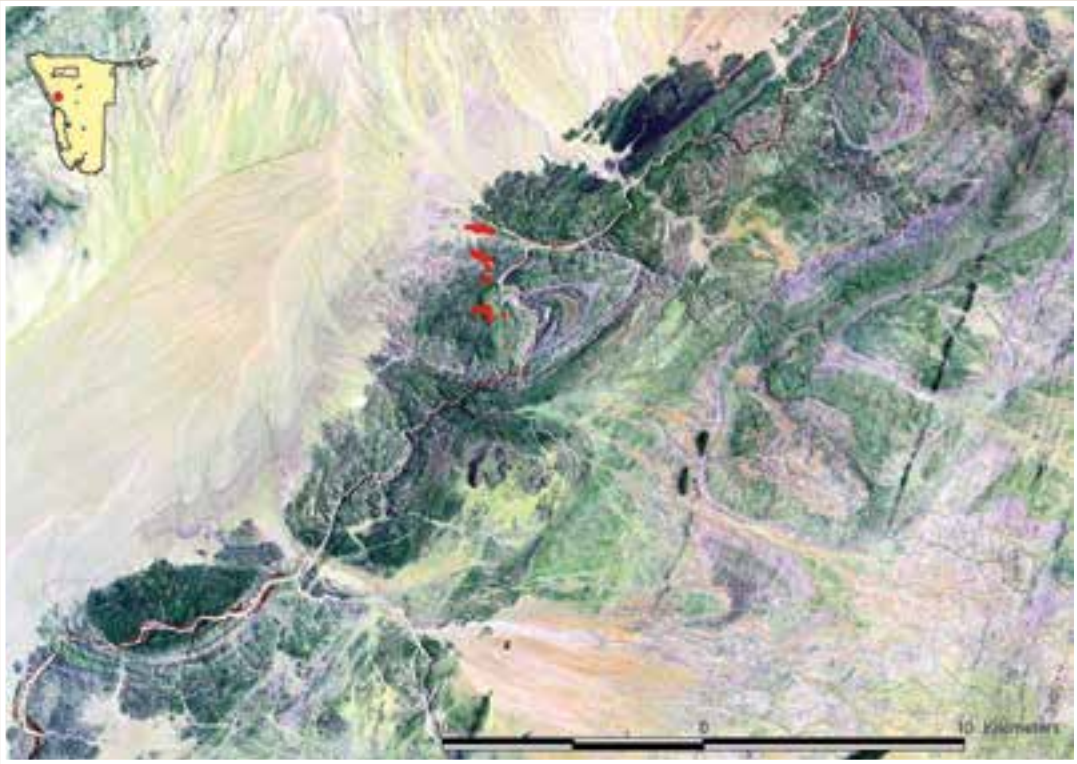

Figure 6.10: Population of *A. pechuelii* north of the Omaruru River in the Tsiseb conservancy

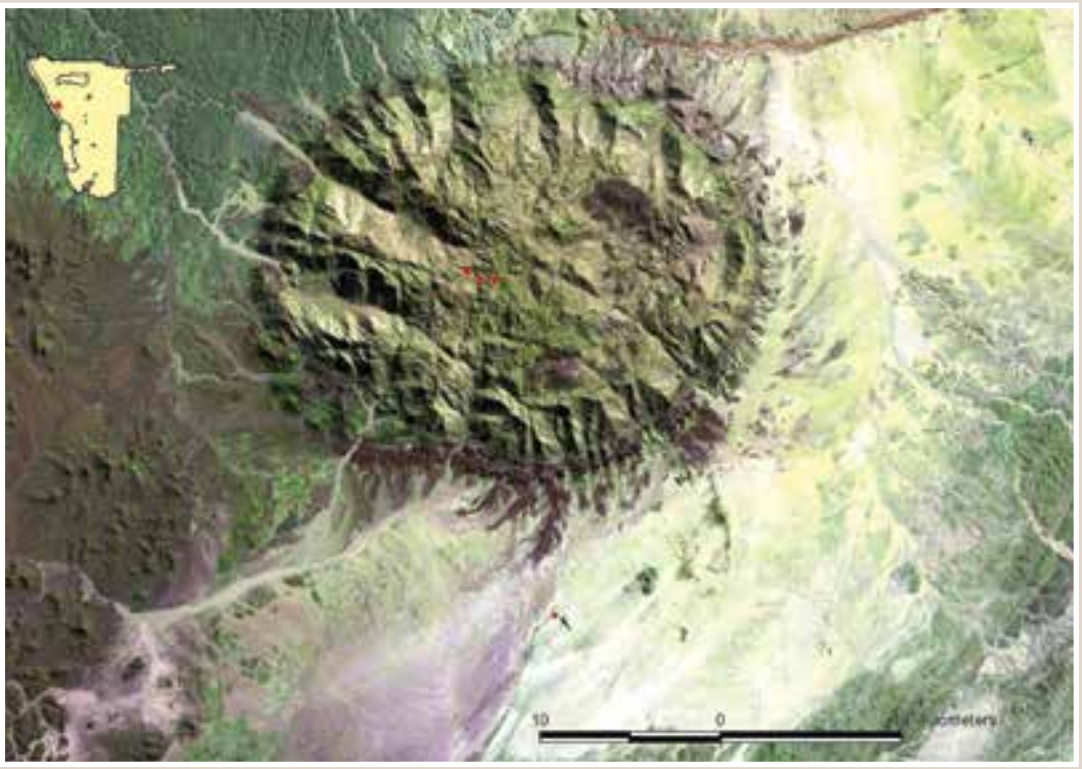

Figure 6.11: Population of *A. pechuelii* on top of the Brandberg and south of the Brandberg

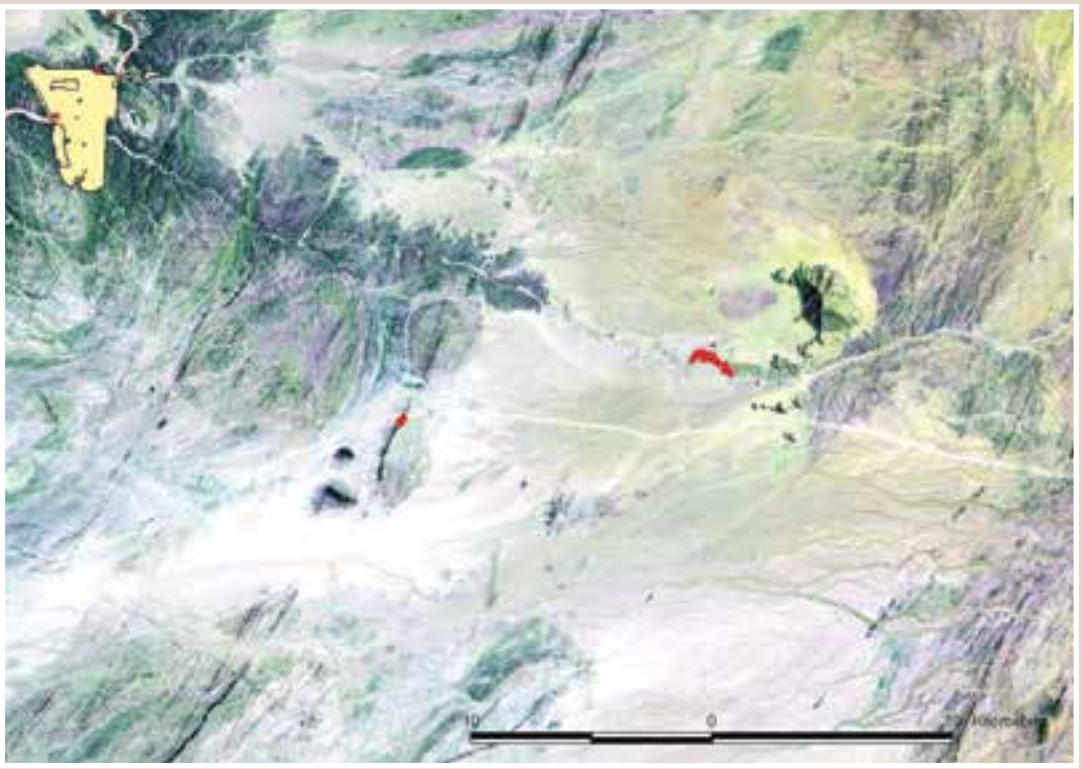

Figure 6.12: Populations of *A. pechuelii*ii south-west of the Spitzkoppe and on the road between Hentiesbay and Usakos

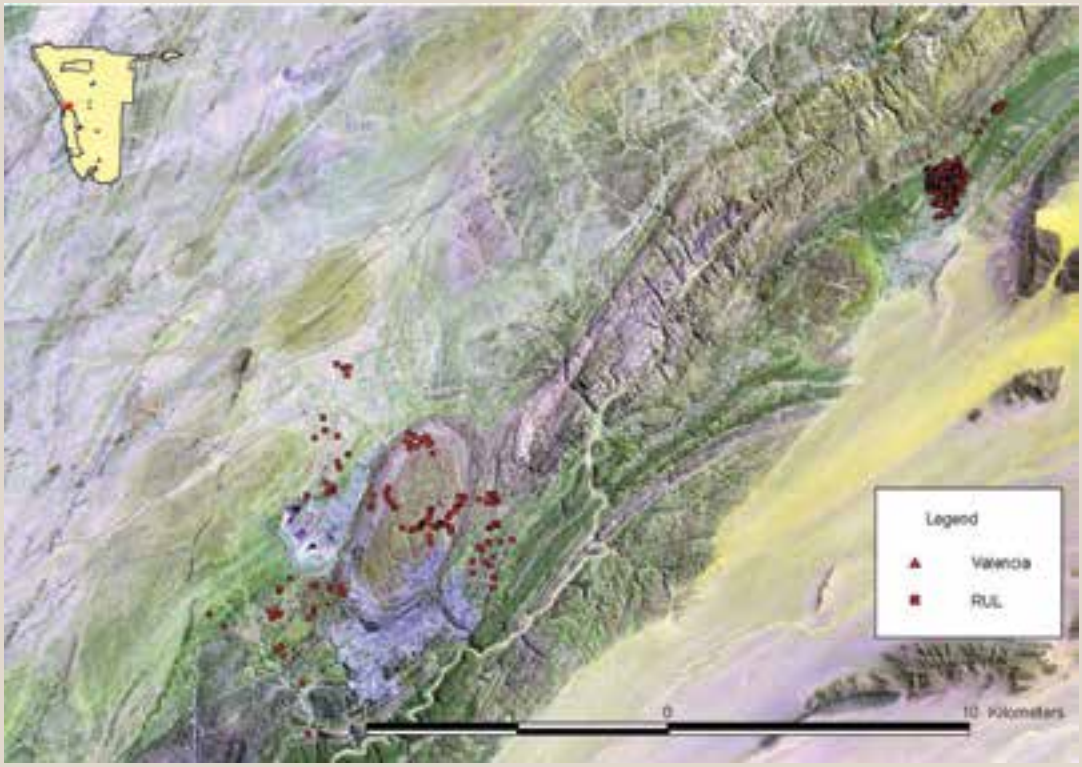

Figure 6.13: Populations of *A. pechuelii* at RUL and the prospective Valencia Uranium mine

Figure 6.14: Population of *A. pechuelii*at Leeukop in the NNP, NE of the Vogelfederberg

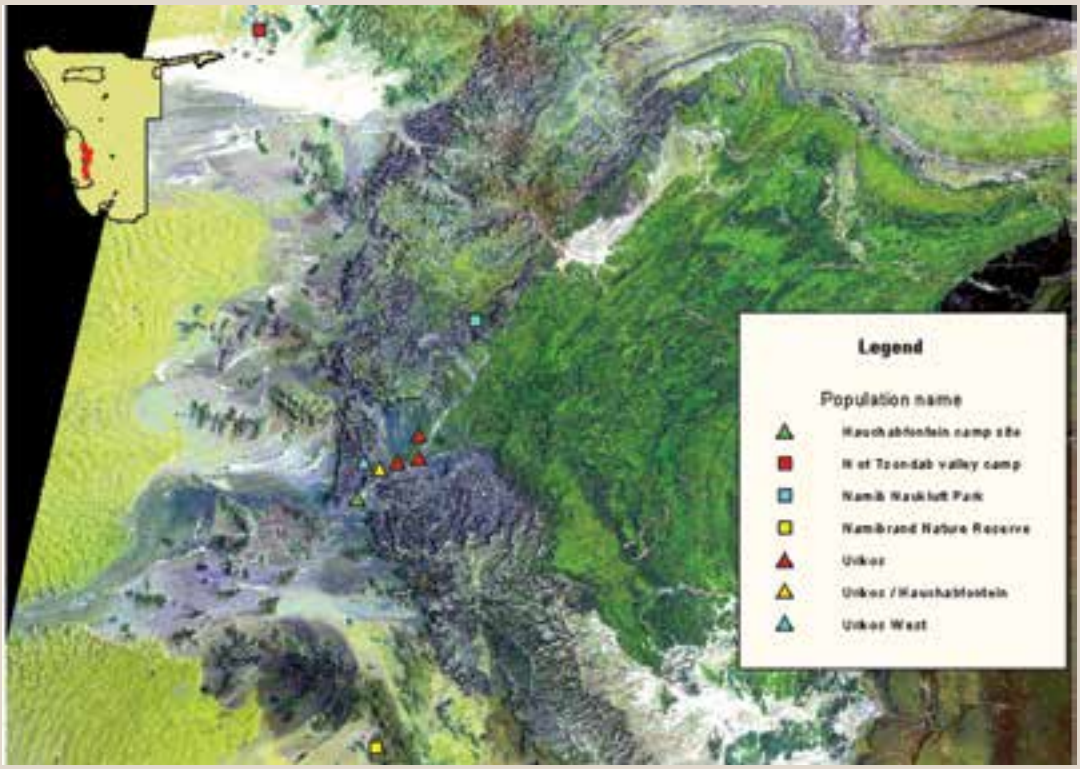

Figure 6.15: Populations of *A. pechuelii* in the NNP, Farm Urikos and Farm Hauchabfontein

APPENDIX 7:

Range prediction modelling and locality targeting for *Lithops ruschiorum* and *Adenia pechuelii*

Steven Bachman
GIS Unit
RBG Kew
2007

Assessment and management of Red List and endemic species at Rössing Uranium mine, Namibia
RBG Kew GIS Unit contribution: Range prediction models and locality targeting for *Lithops ruschiorum* and *Adenia pechuelii*

Background

Two taxa: *Lithops ruschiorum* and *Adenia pechuelii* have been identified as being of conservation concern in the Rössing mine concession area. A partnership has been set up between Rössing, NBRI, RBG Kew and Rio Tinto to assess the conservation status of these taxa. Population data will be gathered and will be used to determine how important the populations at the concession area are with respect to the entire population in Namibia.

The distributions of the two taxa are presently known from herbarium specimen records and quarter degree squares. However, this may reflect an incomplete knowledge of the distributions, for example the range limits may not be fully known and areas, where at present there are no verified collections, may be occupied by these species.

It was proposed that range prediction models or environmental niche models could be used to better understand the range of these taxa so as to aid field work planning and prioritisation. The findings of this analysis are presented in this report along with some recommendations.

Abbreviations

SL Sonja Loots
SB Steven Bachman

Methodology

Specimen data were extracted from the National Herbarium of Namibia in Windhoek for the target species *Adenia pechuelii* and *Lithops ruschiorum.* In combination with a capacity building trip to RBG Kew, SL assisted SB in the georeferencing (assigning co-ordinates) of these specimens. Kew specimens were also digitised and georeferenced and then added to the Windhoek data, although Kew's holdings of these species were small.

Specimen data were then combined with environmental data, e.g. climate, elevation, etc. within a statistical model to calculate the 'niche' of the two target species. This is the environmental space which the species is expected to tolerate and find suitable.

A model that has performed particularly well on a variety of data is the Maximum Entropy (Maxent) model (Dudík et al. 2004, Phillips et al. 2006). Maxent (version 2.3) calculates a probability value for each cell in the study area where 0 is extremely low suitability and 100 is extremely high suitability.

Models were calculated for both target taxa and default values were used for the regularisation value, maximum number of iterations and convergence threshold within the model.

To test whether models are good at discriminating between presence and absence it is necessary to validate the models. Model validation was carried out by splitting the sample data into training and testing points. Five models were produced for each species, each time holding back 25 percent of points for testing. The Area Under the Curve (AUC, Fielding and Bell 1997) was calculated within the Maxent programme and was used to measure the ability of the model to correctly discriminate between presence and absence. The AUC values were then averaged. After the validation stage all specimen data is added to the final model.

Modelling approach

The overall modelling approach is outlined below in Figure 1. From the initial data a range model is produced. This output map can provide guidance for field work, where additional specimen or observation data is gathered. This can feed back into the modelling algorithm, along with any additional environmental data, to produce a second iteration of the model prediction. With each iteration the model should become more refined and will better represent the true range of the species.

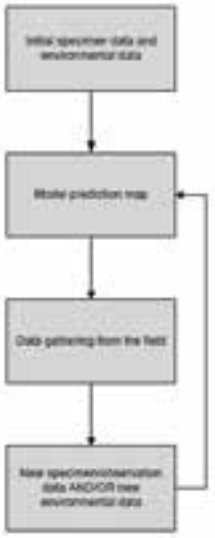

Figure 1: Overview of the modelling approach showing the iterative approach of feeding new information back into the modelling stage

First iteration

A first iteration of the model was run using all available specimen data and the environmental variables as listed in Table 1. To determine a map of presence/absence the prediction between 0 and 100 needs to be split at a threshold, e.g. everything above value 50 is treated as presence and below 50 as absence. In this study the threshold was calculated as the lowest occurrence threshold, i.e. the lowest model value over all specimen localities. This approach ensures zero omission errors, i.e. predicting absence when the species is present.

Second iteration

The second iteration of the model included the same environmental variables as listed in Table 1. However, specimen and observation data from recent fieldwork carried out by SL *et al*. were added to the original data. In addition, some data points were removed from the analysis as they were deemed too poorly georeferenced.

The final model output was reclassified to presence and absence using the lowest occurrence threshold as described above. Finally, the model of presence was clipped by additional data in the form of Soils and Geology (Atlas of Namibia Project, 2002) and Land Cover from the Global Land Cover Dataset (GLCC).

Environmental layers

The environmental datasets used for the models are shown in Table 1.

Grid	Description
Bio1	Worldclim - Annual Mean Temperature
Bio2	Worldclim - Mean Diurnal Range
Bio3	Worldclim - Isothermality
Bio4	Worldclim - Temperature Seasonality
Bio5	Worldclim - Max Temperature of Warmest Month
Bio6	Worldclim - Min Temperature of Coldest Month
Bio7	Worldclim - Temperature Annual Range
Bio8	Worldclim - Mean Temperature of Wettest Quarter
Bio9	Worldclim - Mean Temperature of Driest Quarter
Bio10	Worldclim - Mean Temperature of Warmest Quarter
Bio11	Worldclim - Mean Temperature of Coldest Quarter
Bio12	Worldclim - Annual Precipitation
Bio13	Worldclim - Precipitation of Wettest Month
Bio14	Worldclim - Precipitation of Driest Month
Bio15	Worldclim - Precipitation Seasonality
Bio16	Worldclim - Precipitation of Wettest Quarter
Bio17	Worldclim - Precipitation of Driest Quarter
Bio18	Worldclim - Precipitation of Warmest Quarter
Bio19	Worldclim - Precipitation of Coldest Quarter
DEM	GTOPO30 - Digital Elevation Model

Table 1: List of environmental variable used in the modelling

Results

The results for the first and second iteration of the models for *L. ruschiorum* are shown in Figure 2 and the results for *A. pechulii* are shown in Figure 3. For both species the first iteration shows large areas of predicted presence. However, in both cases the second iteration shows a much more refined model with less commission errors (over predictions).

Validation results

The results in Table 2 indicate that the Maxent algorithm performed well for both species, although slightly better for *L. ruschiorum*.

Model Run	AUC	Interpretation (after Swets 1988, *Science*)
Adenia pechuelii	0.877	Reasonable discrimination
Lithops ruschiorum	0.9714	Very good discrimination

Table 2: Average AUC values for preliminary models of A. pechuelii *and* L. ruschiorum

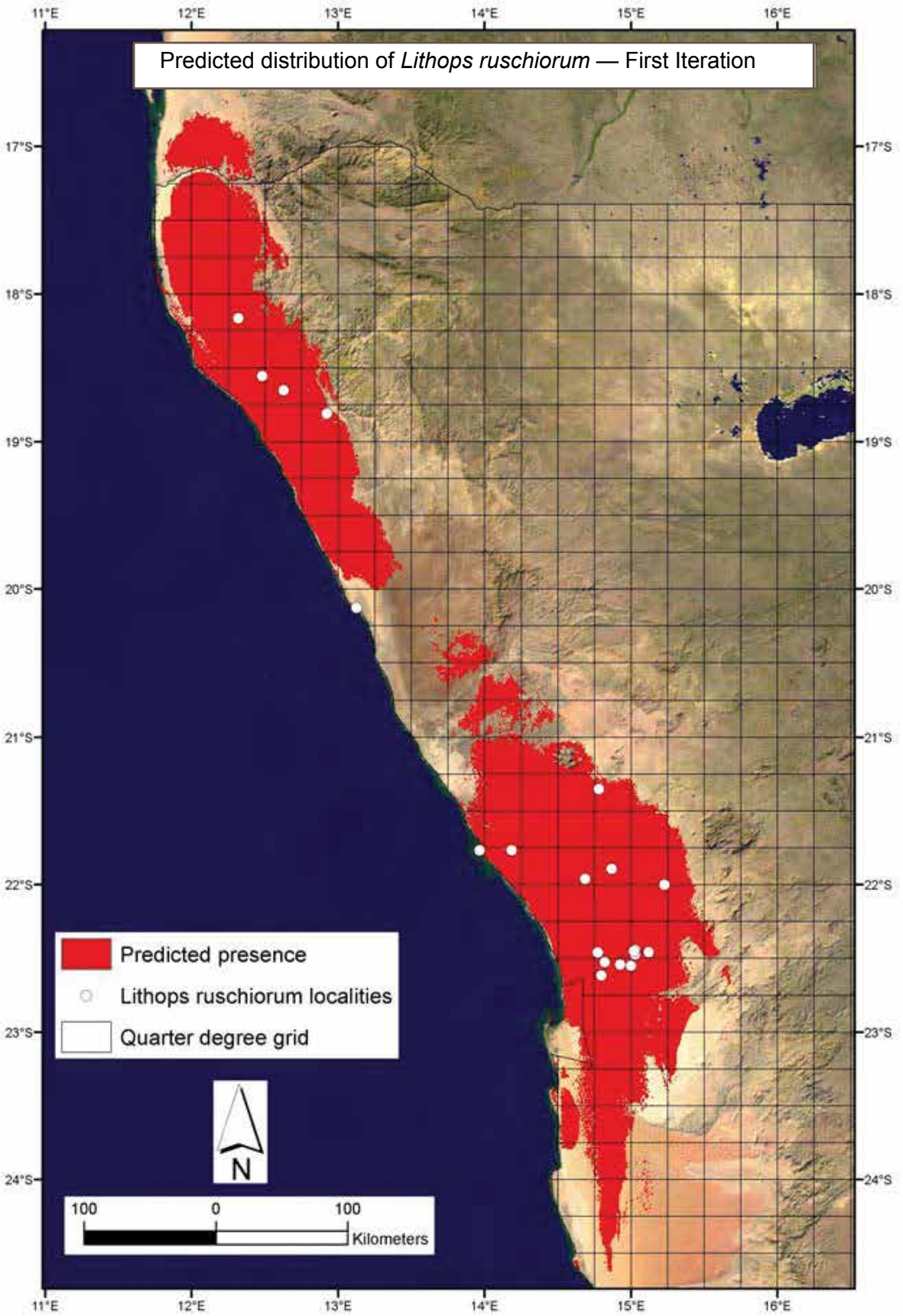

Figure 2a: Model outputs for Lithops ruschiorum *showing first iteration of the model. Red areas show predicted habitat suitability. White dots show georeferenced herbarium specimens.*

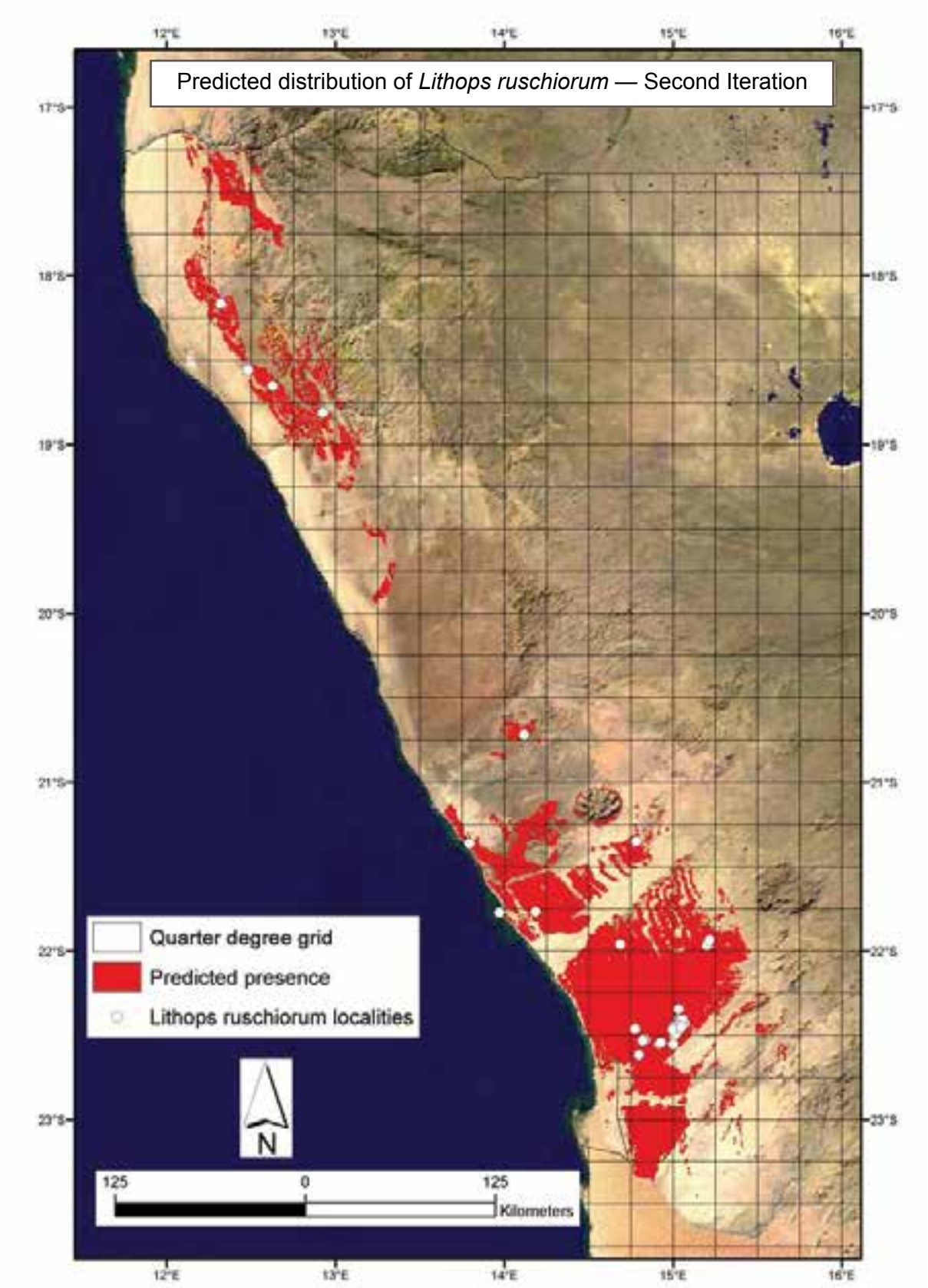

Figure 2b: Model outputs for Lithops ruschiorum *showing the second iteration of the model (left and right images respectively). Red areas show predicted habitat suitability. White dots show georeferenced herbarium specimens.*

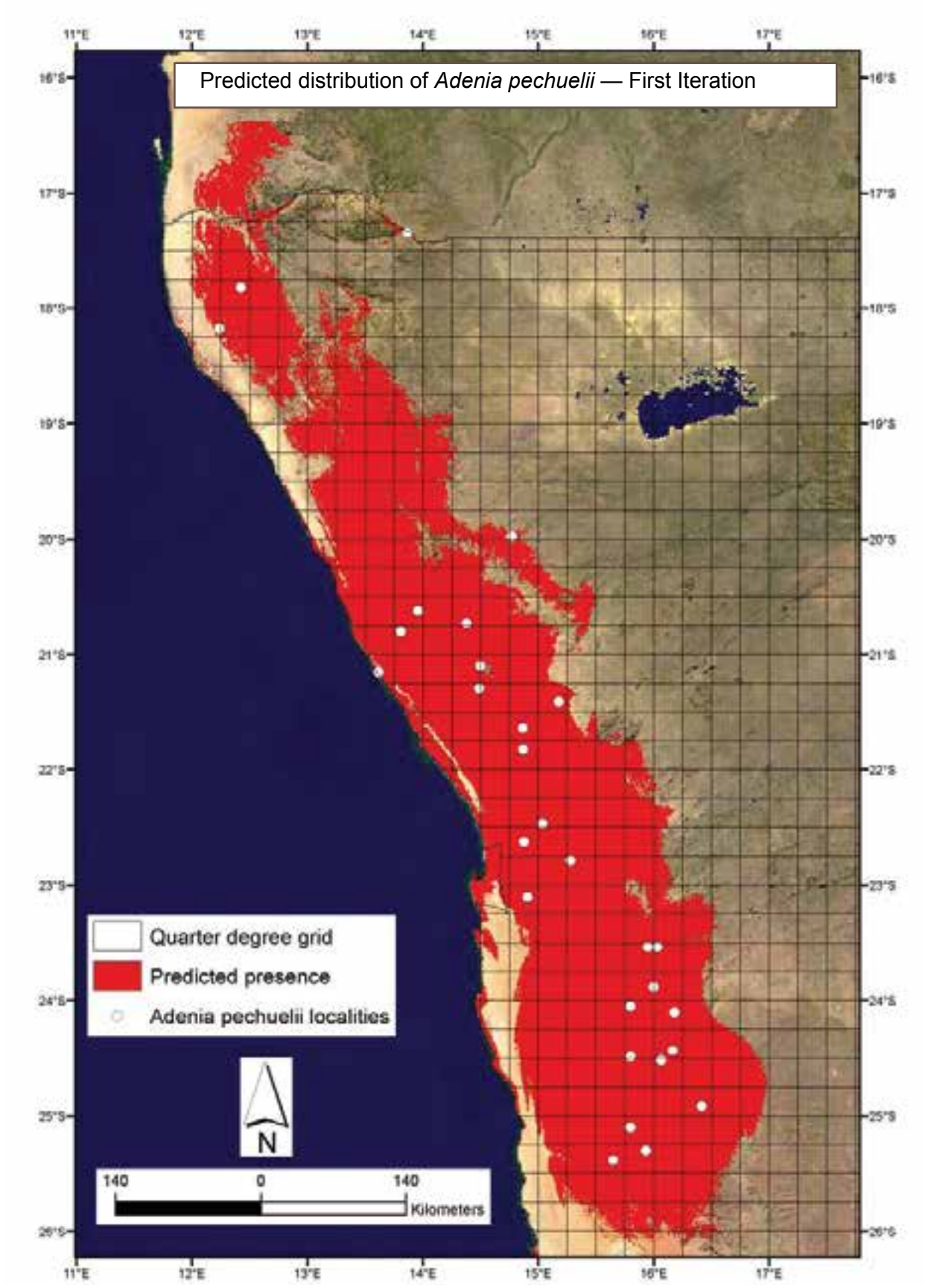

Figure 3a: Model outputs for Adenia pechuelii *showing first iteration of the model. Red areas show predicted habitat suitability. White dots show georeferenced herbarium specimens.*

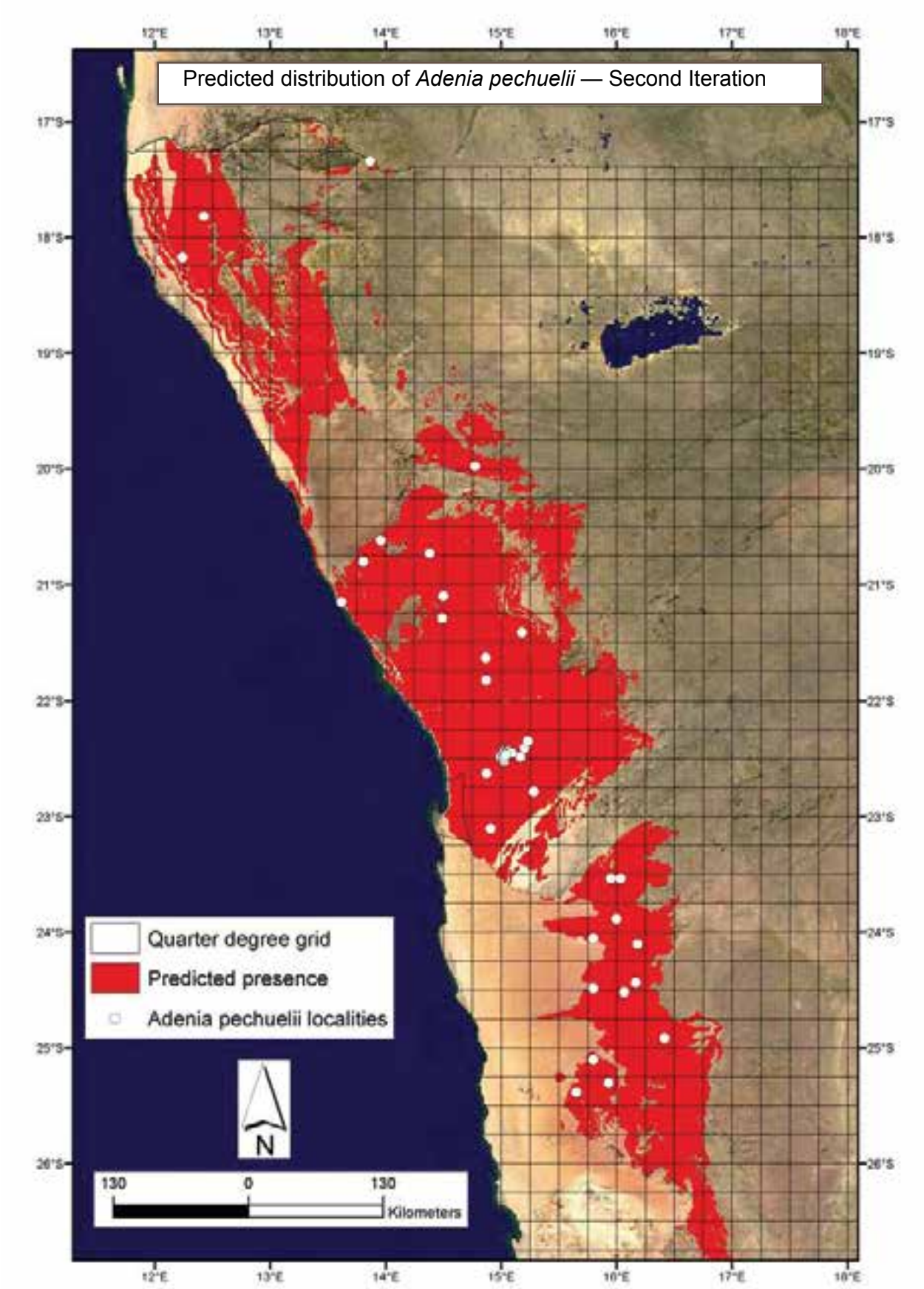

Figure 3b: Model outputs for Adenia pechuelii *showing second iteration of the model. Red areas show predicted habitat suitability. White dots show georeferenced herbarium specimens.*

Discussion

For many plant species there is incomplete knowledge of the distribution and the occurrence of populations. Specimen collections provide verifiable data for the occurrence of a species, but it is much more difficult to say with certainty where a species does not occur. Systematic sampling of entire regions is impractical in many cases, so alternative approaches have been sought such as range prediction models. These models identify areas of suitable habitat based on the combination of environmental variables at known occurrence points. In this study, range prediction models have been produced for *A. pechuelii* and *L. ruschiorum*.

The first iteration of both models shows large areas to be predicted as suitable habitat. Even with only a rudimentary knowledge of the species it is clear that the ranges predicted here are over estimates. It should be noted that the maps depict areas where conditions are suitable, not necessarily where the species presently occurs. There may be many reasons why the species has not filled these suitable areas including competition with other species, failure to disperse, or it could be locally extinct.

Clearly these models need to be interpreted whilst considering existing knowledge of the species. *L. ruschiorum*, although collected across a large extent in Namibia, usually only occupies small patches where a combination of substrate and micro-climatic conditions provides suitable habitat. A small distance away the conditions may no longer be suitable. The modelling is at a resolution of 1 km cells, meaning a single value is given across a 1 x 1 km square. This may not be at a fine enough scale to capture the niche for this species.

In the broader sense the models may still be useful. The models became more refined with the addition of more data from fieldwork and the addition of more environmental data that may have helped to capture the niche, e.g. soils and geology. By continuing the iterations the models should continue to improve and will provide a more useful tool for field work prioritisation.

As a tool to assist in the prioritisation of fieldwork the models still provide a useful output – a map of areas where conditions are predicted to be suitable. Priority must first be with monitoring areas where these species are known to have occurred, but after that these maps can be used to search areas that have no known collections, but appear to have suitable habitat.

Recommendations

The use of range prediction models to help understand the distributions of *A. pechuelii* and *L. ruschiorum* have been investigated here. Many other factors contribute to the prioritisation and planning of field work including cost, resources, accessibility and time. It is recommended that these maps could contribute to, although not dictate the prioritisation process. Some further recommendations are given below.

It is essential that all available specimen and observation data is added to the model. Accuracy of geo-referencing is also important, although most populations and specimen collections should have accompanying GPS derived co-ordinates.

If all known populations have been surveyed the models may provide guidance on suitable areas to investigate where the target species have not been collected previously. Even if no further populations are found, this is still useful information to feed back into the models.

References

Atlas of Namibia Project, 2002, Directorate of Environmental Affairs, Ministry of Environment and Tourism. www.dea.met.gov.na

Data downloaded from: http://209.88.21.36/Atlas/Atlas_web.htm

Dudík, M., S. J. Phillips and R. E. Schapire 2004. Performance guarantees for regularized maximum entropy density estimation. Proceedings of the 17th Annual Conference on Computational Learning Theory.

Fielding, A.H, & Bell, J.F. A review of methods for the assessment of prediction errors in conservation presence/absence models. Environmental Conservation **24**: (1) 38-49

Phillips, S. J., R. P. Anderson and R. E. Schapire 2006. Maximum entropy modelling of species geographic distributions. Ecological Modelling. **190**: 231-256.

APPENDIX 8:
Long-term monitoring form for monitoring squares of *Lithops ruschiorum*

LITHOPS LONG-TERM MONITORING FORM			
Site #:		RUL site name:	Date:
Latitude	Longitude		Altitude
Names of assessors:			
Site description:			
Describe state of habitat / signs of disturbance:			
Describe actual or potential threats present:			
Original number of plants in the square:	Number of plants in previous monitoring session:	Number of plants currently:	% of original number of plants:
Notes:			

APPENDIX 9:

Long-term monitoring form for monitoring squares of *Adenia pechuelii*

ADENIA LONG-TERM MONITORING FORM		
Site #:	Page #:	Date
Latitude	Longitude	Altitude
Site description:		
Describe state of habitat:		
Describe actual or potential threats present:		
Notes:		

PLANT #	HEIGHT	DIAMETER	CIRCUMFERENCE	CONDITON	MALE / FEMALE	DAMAGED	NOTES	PHOTO NUMBERS

APPENDIX 10:

Report on the contribution of the Millennium Seed Bank Project (Namibia) to the Rio Tinto-Rössing Uranium Limited–NBRI–Kew Project

Compiled by Herta KOLBERG, MSBP country co-ordinator
January 2009

Background

The contribution of the Millennium Seed Bank Project (MSBP) of Namibia to the above project was confined to Output 3 of the project matrix which focused on *ex situ* conservation through seed collecting and storage (see text box 1).

Output 3: Seed from target species and other Rössing endemics collected and banked	
Activities:	
1.	Confirm list of target species for seed collection
2.	Produce a key guide of target species at Rössing for utilization by Rössing staff
3.	Train Rössing staff to identify the appropriate seed collection time
4.	Provide an early warning alert to NBRI when target species are flowering
5.	Collect seed from target species during Red List field assessments
6.	Train MET and Rössing staff to collect seed of target species
7.	Undertake opportunistic collections of target species if NBRI cannot reach the site in time
8.	Process and bank seed at NPGRC and MSB for long term storage
9.	Determine seed storage behaviour (orthodox/recalcitrant)
10.	Elucidate germination protocols

Text box 1: Planned activities of Output 3

Methodology

Activity 1: Confirm list of target species for seed collection
The initial list of target species included in the project protocol, was derived by selecting species endemic to Namibia from the list produced by Burke (2005) for the Rössing Uranium Limited (RUL) mine area. After consulting specimen records from the database of the National Herbarium (WIND), this list was adjusted. Subsequent to a visit to the area in March 2006 and identification of specimens collected by RUL staff after good rains in 2006, the final list of target species for seed collecting was confirmed.

Activity 2: Produce a key guide of target species at Rössing for utilisation by Rössing staff
Information and images were collected for the target species from various sources. The main contribution was made by herbarium specimens in WIND, which was complemented by information from literature and personal experience. Images were obtained during visits to the area and from the NBRI slide collection or literature.

Activity 3: Train Rössing staff to identify the appropriate seed collection time
A two-day training course was prepared including the basic principles of seed collecting and a day's practice in the field.

Activity 4: Provide an early warning alert to NBRI when target species are flowering
Contact details were provided to RUL staff.

Activity 5: Collect seed from target species during Red List field assessments
The MSBP was no longer involved in Red List assessments.

Activity 6: Train MET and Rössing staff to collect seed of target species
See Activity 3
Activity 7: Undertake opportunistic collections of target species if NBRI cannot reach the site in time
RUL staff was trained in seed collecting (see Activity 3).

Activity 8: Process and bank seed at NPGRC and MSB for long term storage
Collected seed was processed and stored according to international standards at NPGRC and MSB.

Activity 9: Determine seed storage behaviour (orthodox/recalcitrant)
The seed storage behaviour was determined at MSB as part of routine data collected on seed accessions banked there.

Activity 10: Elucidate germination protocols
As for Activity 9.

Results

Activity 1: Confirm list of target species for seed collection
The initial list of target species for seed collecting in the Rössing mine area was based on the species list of Burke (2005) supplemented by herbarium records at the National Herbarium of Namibia (WIND). Species of which seed had already been collected by the MSBP-Namibia and deposited at the NPGRC and MSB-UK, were excluded (see Table 1). After a visit to the Rössing mine area in March 2006 and collection of specimens by RUL staff (identified in August and December 2006 - see Appendix 10b), the final list of target species for seed collecting was compiled (Table 1).

Activity 2: Produce a key guide of target species at Rössing for utilization by Rössing staff
In October 2007 a guide was compiled with information that would assist RUL staff in locating, identifying and collecting seed of these species (Appendix 10c). One hardcopy was laminated and bound and forwarded to RUL staff together with a CD with an electronic copy of the guide. The guide was divided into two sections. The first section contained 12 species for which no seed had yet been collected and banked and which were thus of higher priority. The second part consisted of 11 species for which seed had already been banked, but not necessarily from the Rössing area.

Activity 3: Train Rössing staff to identify the appropriate seed collection time
On 28 to 29 March 2006, a basic seed collecting course was presented to four RUL staff members. The course covered the basic principles of seed collecting, including the collection of data and herbarium specimens. The processing and storage of collected seed was briefly described. On the second day, a practical exercise in seed collecting was conducted in the mine area. This included pointing out of target species, what to collect and at what stage and completion of a data form. Unfortunately the vegetation had not developed sufficiently for mature seed to be present, and no seed could be collected during the practical.

Target species initially considered	Final list of target species	Comment
Adenia pechuelii	*Adenia pechuelii*	
	Aloe asperifolia	endemic succulent, common in Rössing area
Aloe namibensis		excluded because species does not occur in Rössing licence area
Aizoanthemum galenioides	*Aizoanthemum galenioides*	
Aizoanthemum membrumconnectens	*Aizoanthemum rehmannii*	name changed
	Anticharis imbricata	endemic dwarf shrub; included after specimens from area were collected
	Arthraerua leubnitziae	endemic shrub, common in Rössing area; initially excluded because seed had been collected
Calostephane marlothiana	*Calostephane marlothiana*	
	Cleome carnosa	endemic annual
Commiphora oblanceolata		excluded because species was thought not to occur in licence area
	Commiphora saxicola	endemic shrub, common in Rössing area; initially excluded because seed had been collected
Commiphora virgata	*Commiphora virgata*	
	Euphorbia damarana	endemic succulent, common in Rössing area
Euphorbia giessii	*Euphorbia giessii*	
Geigeria rigida		excluded because species was thought not to occur in licence area
	Hermbstaedtia spathulifolia	endemic dwarf shrub; included after specimen collected from area
Hoodia pedicellata		excluded because plants are rare, difficult to locate and difficult to collect seed from
	Lithops ruschiorum	initially excluded because seed had already been collected from Rössing area
Monechma desertorum	*Monechma desertorum*	
Pelargonium otaviense		excluded because difficult to collect good quality seed
	Petalidium canescens	endemic shrub; initially excluded because seed had been collected

Target species initially considered	Final list of target species	Comment
Polygala guerichiana	*Polygala guerichiana*	
Sarcocaulon marlothii	*Sarcocaulon marlothii*	
Senecio alliariifolius	*Dauresia alliariifolia*	name changed
	Sesamum marlothii	endemic shrub; included after specimen from area was collected
Sesbania pachycarpa subsp. *dinterana*	*Sesbania pachycarpa* subsp. *dinterana*	
Zygophyllum cylindrifolium	*Zygophyllum cylindrifolium*	
	Zygophyllum stapffii	endemic shrub, common in Rössing area; initially excluded because seed had been collected

Table 1: Initial and confirmed target species list for seed collecting

Activity 4: Provide an early warning alert to NBRI when target species are flowering
The MSBP co-ordinator has not been notified of any flowering or seeding target species during the project period. This may be because the area did not receive sufficient rain in the period since 2006 to result in considerable vegetation development.

Activity 5: Collect seed from target species during Red List field assessments
This was not done because the MSBP was no longer involved in Red List assessments.

Activity 6: Train MET and Rössing staff to collect seed of target species
See Activity 3. MET staff were not trained because of not responding on an offer to attend such training.

Activity 7: Undertake opportunistic collections of target species if NBRI cannot reach the site in time
Four seed collections were made by RUL staff in 2006. Seed of *Sarcocaulon marlothii*, *Orthanthera albida* (2 samples) and *Aizoanthemum dinteri* were received and banked at the NPGRC and some also at MSB (see Activity 8).

Activity 8: Process and bank seed at NPGRC and MSB for long term storage
Besides the four seed samples collected by RUL staff in 2006 (see Activity 7) the Namibian MSBP did not collect seed on the Rössing mining licence area. Two collections, one of *Orthanthera albida*, one of *Sarcocaulon marlothii,* were duplicated at the MSB. *Aizoanthemum dinteri* was not duplicated at the MSB because this species was already represented at that bank. In August 2007 we were notified by the MSB that the seed of *Sarcocaulon marlothii* that was sent for banking there, was not viable and therefore "transferred to history" i.e. not accessioned to the MSB collection. A further attempt will therefore have to be made to collect seed of this species. The MSBP and other collectors did, however, collect and bank some of the target species from other areas in Namibia (Appendix D).

Activity 9: Determine seed storage behaviour (orthodox/recalcitrant)
The storage behaviour of only three of the target species has thus far been determined (Appendix 10e). *Sesamum marlothii, Sesbania pachycarpa* and *Zygophyllum stapffii* were all found to have orthodox storage behaviour. For four species seed was not available to the MSB or in insufficient numbers to conduct any storage behaviour tests. Since accessions of the target species have only been stored fairly recently, storage behaviour tests, which are normally done after at least 2 years of storage, have not been carried out.

Activity 10: Elucidate germination protocols
Germination data for 12 of the target species are available (Appendix 10e). Five species needed some pre-sowing treatments (scarification, gibberellic acid, surface sterilisation) to achieve some germination. For five species seed was not available to the MSB or in insufficient numbers to conduct any germination tests. Six species' seed is at the MSB but no test results are available yet.

Discussion

Seed of all target species was collected and banked except *Euphorbia giessii* . Some Euphorbia species are known to be difficult to collect seed from, because they set few seed or the seed shatter explosively. *Sarcocaulon marlothii* was collected but could not be banked because the seed was not viable. Setting few viable seeds seems to be a problem with many of the Geraniaceae species. This, coupled with the fact that *S. marlothii* produces only a few flowers at a time, spread throughout the year, makes getting sufficient numbers of viable seed very difficult.

Accessions of *Monechma desertorum*, *Polygala guerichiana* and *Zygophyllum cylindrifolium* were not banked at the NPGRC. Because of small numbers of seed, these were sent to MSB so that storage behaviour and germination tests could be done. An attempt will be made to re-collect more seed of these species for the NPGRC.

Only seed of *Adenia pechuelii*, *Commiphora virgata*, *Lithops ruschiorum* and *Dauresia alliariifolia* were collected from the Rössing Uranium mining licence area. All other species, except *Polygala guerichiana*, were collected in the Central Namib, often not too far away from Rössing mine but not within the licence area.

The seed collections are in most cases not very large and therefore not suited for re-seeding, one of the reasons for which seed from the Rössing area was supposed to have been collected. The fact that these collections are not from the Rössing area also make them unsuitable for re-vegetation of the mine after closure. The banked accessions therefore purely serve the purpose of genetic conservation of the species.

An effort must be made to collect more seed of the target species and the target list could be expanded to include other endemic or prominent species that occur in the Rössing mining licence area. Seed collecting will always remain problematic in this desert area because vegetation, especially annual species, responds only to sufficient rainfall which occurs very sporadically. Also including seed collecting in the activities of mine staff will be difficult due to the high priority of other duties and the few people available for this. For MSBP staff collecting more seed of the endemic species in the Rössing mining licence area is also not of a high priority due to these species mostly having already been banked at the MSB and therefore not counting towards the target of the project.

Conclusion

The target of Output 3 was not completely met. The main shortcomings were low seed numbers collected and collection of seed outside the Rössing Uranium mining licence area. Some species could not be collected and banked at all due to them not producing any or sufficient viable seed. If seed is to be used for restoration of the Rössing Uranium mine area upon mine closure, more seed of the target species and other prominent species in the area needs to be collected on site.

Not all seed data (storage behaviour, germination) generated by the MSB was available at the end of this project, but will become available over time for those species that have been banked at MSB in sufficient numbers. This process is ongoing and data will be accessible on the Seed Information Database on the Kew website (http://www.kew.org/data/sid).

References

Burke, A. 2005. Rössing's Biodiversity Strategy. Biotope mapping and analysis to determine impacts on Biodiversity. Unpublished report. EnviroScience, Windhoek. Prepared for Rössing Uranium Limited, Swakopmund. pp. 11

Liu, K., Eastwood, R.J., Flynn, S., Turner, R.M., and Stuppy, W.H. 2008. Seed Information Database (release 7.1, May 2008) http://www.kew.org/data/sid

Acknowledgements

The following are acknowledged for their support:
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R. Moses
S. Müller

APPENDIX 10a:
Hand-out for Seed Collecting Training at Rössing Uranium

Y. Mupupa
R. Schneeweiss
T. Tholkes

Training for seed collecting

Rössing Uranium Mine, 28 - 29 March 2006
By Herta Kolberg, Millennium Seed Bank Project, Namibia

Why collect seeds?

- Collection and long-term storage of seed is a complimentary conservation method; it compliments conservation of habitats and species *in situ* or in botanic gardens
- Seeds are an "easy" unit for storage (small, therefore cost-effective; designed for storage) and enables re-generation of a complete organism
- Seed banks make access to seeds and therefore plants, relatively easy globally for other uses (research, development)
- Seeds are ideal for restoration and re-vegetation, compared to live plants
- Enables conservation of not only species but also genes, which vary from place to place and individual to individual
- Idea of seed banking started in agriculture; example of rice, resistance to virus in India

How to collect seed?

- Seed of one population should be collected for a sample; need to define population
- Seed should be collected at random within the population; generally not strictly possible
- Ideally seed of 50 individual plants per sample; often not that many plants in a population
- The above three are difficult to achieve in practice
- Seed must be mature = viable, want to store live seed to be able to re-generate plants
- Timing is crucial; seed either immature or shattered; particularly a problem with wild plants
- Collected into cloth or paper bags (not plastic!) to prevent moulding, high temperature and humidity causing death of seeds

What else to collect with seed?

- *Data*
  - » Form to be filled in (see attached)
  - » Minimum data: collector, date, exact place (describe in detail, GPS reading if possible)
  - » Other information will be useful in management of seeds in seed bank or once regenerating plants
- *Soil sample*
  - » More or less at root level
  - » Describe soil colour
  - » Could be useful pointer when trying to grow plants from seed
- *Herbarium specimen*
  - » Serves as voucher for positive identification; seeds look similar and cannot identify species of plant from seeds alone
  - » Stored in herbarium; long-term record; available for study
  - » All of the above are often used by other scientists, projects, studies

How to collect herbarium specimens?

- Whole plant for annuals, small perennials, grasses (especially important); part for large plants
- Must be flowering or fruiting
- Choose typical plant/part
- If possible in duplicate
- Data important (at least who, when where); description of especially aspects that will no longer be visible on the specimen e.g. size, colour
- Press (practical demonstration)
- Dry in sun or oven (70°C)

What happens next?

- *Processing of seed*
  - » Clean manually since machines cause microscopic damage
  - » Dry (5-7 percent moisture content) at 15°C; every 1 percent lowering of moisture content doubles life span of seed
  - » Seal airtight to keep dry
  - » Store at -20°C (deep freezer); for short term storage, 4°C (fridge) is sufficient
- *Processing of data*
  - » Enter onto database
- *Determine soil texture and pH*
- *Herbarium voucher specimen*
  - » Identify / verify

APPENDIX 10b:
Plants collected by and identified for Rössing Uranium Limited staff

» Mount on cardboard with information label
» Storage in herbarium

Rössing Uranium Limited Collections
Att. Y. Mupupa

Collection no.		
1	*Enneapogon desvauxii* P.Beauv.	
2	*Heliotropium tubulosum* E.Mey. ex DC.	
3	*Eragrostis nindensis* Ficalho & Hiern	
4	*Cleome* sp.	need flower
5	*Monechma genistifolium* (Engl.) C.B.Clarke subsp. *genistifolium*	
6	*Tripteris microcarpa* Harv. subsp. *microcarpa*	
7	*Stipagrostis ciliata* (Desf.) De Winter	
8	*Stipagrostis obtusa* (Delile) Nees	
9	*Hermannia amabilis* Marloth ex K.Schum.	
10	*Fagonia isotricha* Murb.	
11	*Aizoanthemum rehmannii* (Schinz) H.E.K.Hartmann	
12	*Heliotropium tubulosum* E.Mey. ex DC.	
13	*Brachiaria glomerata* (Hack.) A.Camus	
14	cf. *Ruellia* sp.	no flower or fruit
15	*Stipagrostis giessii* Kers	
16	*Gisekia africana* (Lour.) Kuntze	
17	*Cleome foliosa* Hook.f.	
18	*Hermbstaedtia spathulifolia* (Engl.) Baker	
19	*Tripteris microcarpa* Harv. subsp. *microcarpa*	
20	*Petalidium variabile* (Engl.) C.B.Clarke	
21	no specimen	
22	*Hermannia solaniflora* K.Schum.	
23	*Limeum argute-carinatum* Wawra & Peyr.	
24	*Forsskaolea hereroensis* Schinz	
26	*Microcharis disjuncta* (J.B.Gillett) Schrire	
27	*Lotononis platycarpa* (Viv.) Pic.Serm.	
27	*Lotononis bracteosa* B.-E.van Wyk	
28	*Kohautia caespitosa* Schnizl. subsp. *brachyloba* (Sond.) D.Mantell	
29	*Heliotropium* cf. *tubulosum* E.Mey. ex DC.	no flowers
30	*Stipagrostis hirtigluma* (Trin. & Rupr.) De Winter subsp. *patula* (Hack.) De Winter	
31	*Sesuvium sesuvioides* (Fenzl) Verdc.	
32	*Hermbstaedtia spathulifolia* (Engl.) Baker	
33	*Tephrosia dregeana* E.Mey.	
34	no specimen	
35	no specimen	
36	*Indigofera* cf. *auricoma* E.Mey.	no flowers or fruit
37	*Geigeria ornativa* O.Hoffm. subsp. *ornativa* var. *ornativa*	
38	*Microcharis disjuncta* (J.B.Gillett) Schrire	
39	*Enneapogon scaber* Lehm.	
40	*Anticharis imbricata* Schinz	
41	*Indigofera auricoma* E.Mey.	
42	no specimen	
43	*Monechma desertorum* (Engl.) C.B.Clarke	
44	no specimen	
45	*Monechma cleomoides* (S.Moore) C.B.Clarke	
46	*Hermannia* sp.	need flowers
47	*Calostephane marlothiana* O.Hoffm.	
48	no specimen	
49	*Stipagrostis schaeferi* (Mez) De Winter	
50	*Aristida parvula* (Nees) De Winter	
51	*Monechma desertorum* (Engl.) C.B.Clarke	
52	no specimen	
53	*Chascanum garipense* E.Mey.	
54	*Tripteris microcarpa* Harv. subsp. *microcarpa*	
55	*Cleome* cf. *paxii* (Schinz) Gilg & Benedict	need flowers
56	*Kohautia cynanchica* DC.	
57	no specimen	

58	no specimen	
59	*Euphorbia phylloclada* Boiss.	
60	no specimen	
61	*Stipagrostis giessii* Kers	
62	*Pergularia daemia* (Forssk.) Chiov.	
63	*Tribulus zeyheri* Sond. subsp. *zeyheri*	
64	*Brachiaria glomerata* (Hack.) A.Camus	
65	*Microcharis disjuncta* (J.B.Gillett) Schrire	
66	no specimen	
67	*Cleome* sp.	need fruit
68	*Limeum argute-carinatum* Wawra & Peyr.	
69	*Indigofera auricoma* E.Mey.	
70	no specimen	
71	*Hermannia solaniflora* K.Schum.	
72	no specimen	
73	*Helichrysum roseo-niveum* Marloth & O.Hoffm.	
74	no specimen	
75	*Calostephane marlothiana* O.Hoffm.	
76	no specimen	
77	no specimen	
78	*Cleome* sp.	no flowers or base of plant
79	no specimen	
80	*Petalidium variabile* (Engl.) C.B.Clarke	
81	no specimen	
82	*Monsonia umbellata* Harv.	
83	*Cryptolepis decidua* (Planch. ex Hook.f. & Benth.) N.E.Br.	
84	no specimen	
85	*Euphorbia glanduligera* Pax	
86	*Microcharis disjuncta* (J.B.Gillett) Schrire	
87	no specimen	
88	no specimen	
89	no specimen	
90	no specimen	
91	*Dyerophytum africanum* (Lam.) Kuntze	
92	*Sericocoma heterochiton* Lopr.	
93	*Sesamum triphyllum* Welw. ex Asch.	
94	no specimen	
95	*Stipagrostis hirtigluma* (Trin. & Rupr.) De Winter subsp. *hirtigluma*	
96	*Dauresia alliariifolia* (O.Hoffm.) B.Nord. & Pelser	
97	no specimen	
98	*Nolletia ericoides* Merxm.	
99	*Stipagrostis uniplumis* (Licht.) De Winter	
100	*Stipagrostis hochstetteriana* (L.C.Beck ex Hack.) De Winter	
101	*Jamesbrittenia maxii* (Hiern) Hilliard	
102	*Trichodesma africanum* (L.) Sm.	
103	*Psilocaulon salicornioides* (Pax) Schwantes	
104	*Chascanum garipense* E.Mey.	
105	*Jamesbrittenia hereroensis* (Engl.) Hilliard	
106	*Lotononis pachycarpa* Dinter ex B.-E.van Wyk	
107	*Nolletia gariepina* (DC.) Mattf.	
108	*Enneapogon desvauxii* P.Beauv.	
109	*Tephrosia dregeana* E.Mey.	
110	*Heliotropium* cf. *tubulosum* E.Mey. ex DC.	no flowers
111	cf. *Hermannia* sp.	poor specimen
112	no specimen	
113	*Stipagrostis hirtigluma* (Trin. & Rupr.) De Winter subsp. *hirtigluma*	
114	*Rhus* cf. *marlothii* Engl.	no fruit
115	no specimen	
116	no specimen	
117	*Sesbania pachycarpa* DC. subsp. *dinterana* J.B.Gillett	
118	*Cleome suffruticosa* Schinz	
119	*Ornithogalum stapffii* Schinz	
120	*Kohautia cynanchica* DC.	
121	no specimen	
122	no specimen	
123	no specimen	
124	*Stipagrostis hirtigluma* (Trin. & Rupr.) De Winter subsp. *hirtigluma*	
125	*Cleome* sp.	no fruit
126	*Stipagrostis damarensis* (Mez) De Winter	
127	*Stipagrostis schaeferi* (Mez) De Winter	

128	*Hermbstaedtia spathulifolia* (Engl.) Baker	
129	*Ophioglossum polyphyllum*	fern
130	*Stipagrostis hirtigluma* (Trin. & Rupr.) De Winter subsp. *hirtigluma*	
131	*Monechma desertorum* (Engl.) C.B.Clarke	
132	*Petalidium canescens* (Engl.) C.B.Clarke	
133	*Adenolobus pechuelii* (Kuntze) Torre & Hillc. subsp. *mossamedensis* (Torre & Hillc.) Brummitt & J.H.Ross	
134	*Polygala guerichiana* Engl.	
135	*Enneapogon scaber* Lehm.	
136	no specimen	
137	*Emilia marlothiana* (O.Hoffm.) C.Jeffrey	
138	*Sericocoma heterochiton* Lopr.	
139	*Tephrosia monophylla* Schinz	
140	*Aristida parvula* (Nees) De Winter	
141	*Anticharis inflata* Marloth & Engl.	
142	*Solanum rigescentoides* Hutch.	
143	*Calostephane marlothiana* O.Hoffm.	
144	*Ornithogalum bakerianum* (Bolus) J.C.Manning & Goldblatt	
145	*Brachiaria glomerata* (Hack.) A.Camus	
146	*Euphorbia giessii* L.C.Leach	
147	*Avonia albissima* (Marloth) G.D.Rowley	
148	no specimen	
149	*Tripteris microcarpa* Harv. subsp. *microcarpa*	
150	cf. *Heliophila* sp.	
151	*Anticharis inflata* Marloth & Engl.	
152	*Calostephane marlothiana* O.Hoffm.	
153	*Eriospermum* sp.	no flowers
154	*Indigofera heterotricha* DC.	
155	*Corallocarpus* sp.	no fruit
156	*Enneapogon scaber* Lehm.	
157	*Anticharis inflata* Marloth & Engl.	
158	*Tribulus zeyheri* Sond. subsp. *zeyheri*	
159	no specimen	
160	*Sesamum marlothii* Engl.	
161	*Microcharis disjuncta* (J.B.Gillett) Schrire	
162	*Aizoanthemum rehmannii* (Schinz) H.E.K.Hartmann	
163	*Stipagrostis schaeferi* (Mez) De Winter	
164	*Rogeria longiflora* (Royen) J.Gay ex DC.	
165	*Mollugo cerviana* (L.) Ser. ex DC.	
166	*Cucumis africanus* L.f.	
167	*Engleria africana* O.Hoffm	
168	*Anticharis inflata* Marloth & Engl.	
169	*Heliotropium tubulosum* E.Mey. ex DC.	
170	*Fagonia isotricha* Murb.	
171	*Datura ferox* L.	
172	*Heliotropium ovalifolium* Forssk.	
173	indeterminate	no flowers or fruit
174	*Hermbstaedtia odorata* (Burch.) T.Cooke	
175	*Cleome foliosa* Hook.f.	

Identifications by:
Herta Kolberg, 19 August 2006

APPENDIX 10c:
Seed Collecting Guide prepared for Rössing Uranium Limited staff



Collecting Guide for the Rössing Uranium mine area

Compiled by Herta Kolberg
Millennium Seed Bank Project
Namibia




Background

This Guide contains a selection of plant species that are endemic or near-endemic to Namibia (i.e. occur only within the political borders of Namibia or nearly so) and occur in the mining licence area of Rössing Uranium Limited (RUL). It is a compilation of available information on these plants and intended to assist RUL staff to collect seed of these species as part of their biodiversity strategy and for conservation at the National Plant Genetic Resources Centre of the National Botanical Research Institute (NBRI) in Windhoek. Any seed collected would be available to RUL, for instance for restoration activities.

This forms part of the "Assessment and management of red list and endemic species at Rössing Uranium Mine, Namibia" project, a Rio Tinto – Royal Botanic Gardens, Kew – Rössing Uranium Limited – National Botanical Research Institute initiative. The first part of the Guide contains species that were prioritised by this project for seed collecting, the second part other species of interest in the RUL area.

The Namibian Millennium Seed Bank Project, which is associated with the NBRI, provided the expertise and funds to compile this Guide. Information was obtained from the NBRI's library and herbarium database (Spmndb). Photographs are by the author, except for the following:

Species	Description	Photographer
Aloe asperifolia	plants	NBRI collection
Anticharis imbricata	plant	I. Dinter
Anticharis imbricata	flowers	I. Dinter
Euphorbia damarana	fruit	I. Dinter
Euphorbia giessii	plant	W. Giess
Petalidium canescens	plant	I. Dinter
Petalidium canescens	flowers	I. Dinter
Polygala guerichiana	plant	P. Craven
Zygophyllum stapffii	plant	NBRI collection
Zygophyllum stapffii	fruit	NBRI collection
Zygophyllum stapffii	fruit	I. Dinter

Biotope numbers are those used by A. Burke in her consultancy report "Rössing's Biodiversity Strategy. Biotope mapping and analysis to determine impacts on biodiversity" (2005). See table below.

The conservation status categories are according to the Red Listing system of the World Conservation Union (IUCN), versions of 1994 and 2001.

The assistance of the following persons and institutions is gratefully acknowledged:

A. Burke, P. Craven, S. Kruger, J. Le Hanie, S. Loots, S. Müller, Y. Mupupa, T. Tholkes

NBRI, RUL, MSBP / RBG,Kew

Herta Kolberg

October 2007

Biotopes at Rössing according to Burke, 2005.

Biotope number	Biotope description
1	*Aloe asperifolia* plains
2	*Arthraerua* plains
3	Central hills
4	Eastern Hills
5	*Euphorbia virosa* belt
6	Gorges
7	Khan river mountains
8	Khan river
9	Marble hill
10	Marble ridge
11	Northern dome
12	Plain drainage lines
13	South-western granite hills
14	Undulating granite hills
15	Western granite hills
16	*Zygophyllum stapffii* plains

PART 1

Target species for seed collection

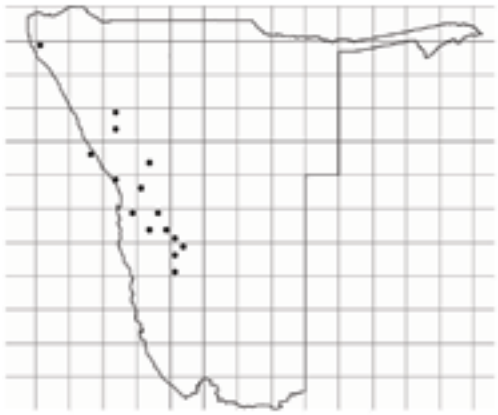
Family: Passifloraceae

Adenia pechuelii
(Engl.) Harms

Common Names: elephant's foot (E); Wüstenkohlrabi (G)

Conservation status: Near Threatened (IUCN, 2001)

Distribution:



Description:
perennial with enlarged, turnip-like stem, to 1 m high and more than 1 m in diameter; branches short, erect, terminate in sharp point; leaves lanceolate, only on fresh growth, deciduous; flowers cream-greenish, maroon outside in bud; fruit green, turning red; flattened-spherical, breaking into 3 wedge-shaped sections; seed covered by red, fleshy tissue when mature, brown, pitted

Ecology:
seems to prefer rocky ridges, often growing from cracks in bare rock; don't seem to prefer any aspect; often associated with *Commiphora* spp. and *Aloe asperifolia*

Seed Biology:
male and female plants separate; flowering March to June; seed maturity April to July; low fruit set; high number of empty fruit or aborted seed; high seed predation by rodents or birds

Distribution on RUL concession:
Biotopes 3,4,5,9,11,13,14,15

Other information:
near-endemic to Namibia, also found in Angola; very slow growing; many ants are often seen on plants

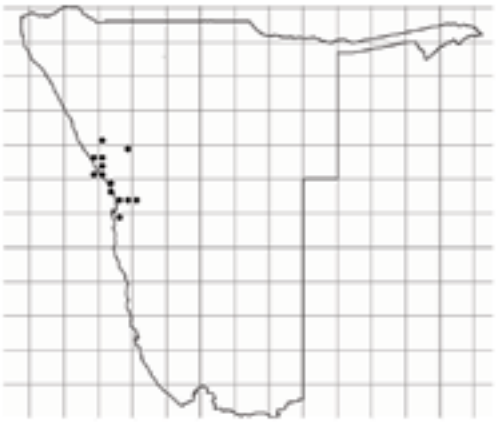
Family: Aizoaceae

Aizoanthemum galenioides
(Fenzl ex Sond.) Friedrich

Common Names: : none known

Conservation status: Lower Risk – least concern (IUCN, 1994)

Distribution:



Description:
annual succulent covered in shiny blister cells, stems much branched, forming dense cushions to 0.2 m high and 0.5 m in diameter; leaves oval, with short petiole, to 20 mm long x 7 mm broad; flowers yellow, about 3 mm long and 2 mm in diameter, stamens 25-30

Ecology:
in sandy soil of coastal desert and river beds, washes and drainage lines where water collects; may occur in large numbers after rain

Seed Biology:
mesemb-type capsule, to 1.5 mm in diameter, almost spherical, with 5 locules; retains seed well and can therefore still be collected long after maturing (June to December), but preferably before next rain

Distribution on RUL concession:
Biotope 8

Other information:
endemic to Namibia's central Namib

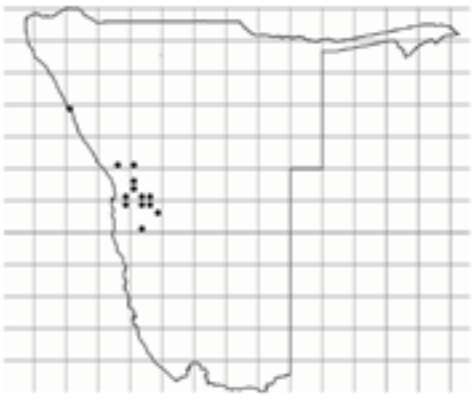
Family: Aizoaceae

Aizoanthemum rehmannii (Schinz) H.E.K.Hartmann

Common Names: : none known

Conservation status: Lower Risk – least concern (IUCN, 1994)

Distribution:



Distribution on RUL concession:
Biotopes 3, 6, 10, 11, 13

Description:
annual succulent herb densely covered in blister cells; stems spreading, to 15 cm long; leaves oval to pointed, to 2 cm long and 0.8 cm broad, petiole very short; flowers mostly solitary, yellow, to 1 cm long, 1.5 cm in diameter, styles 10

Ecology:
On plains, in watercourses and next to roads; only appears after sufficient rainfall

Seed Biology:
mesemb-like capsule with 10 locules; retains seed long after maturity; seeding around April/May

Other information:
endemic to Namibia's central Namib; could be confused with *Aizoanthemum dinteri*, but the flowers of the latter are in compound inflorescences, only up to 0.7 cm long and <1 cm in diameter with 7-8 styles, plants are usually much larger and more upright and capsules are 7-8-locular

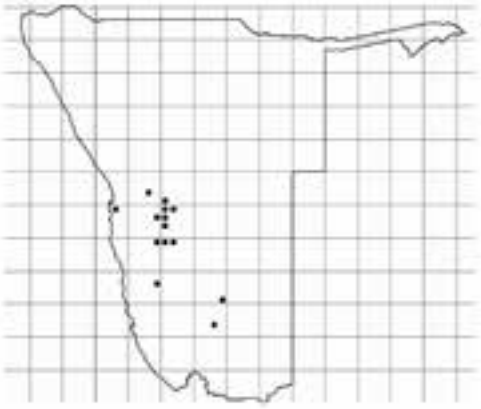
Family: Asteraceae

Calostephane marlothiana O.Hoffm.

Common Names: : none known

Conservation status: Lower Risk- least concern (IUCN, 1994)

Distribution:



Distribution on RUL concession:
Biotopes 3, 5, 12, 14, 15

Description:
sub-shrub with woody, perennial base and annual shoots; stems not winged, erect; leaves lanceolate with toothed margin, often folded along midrib; flower heads with yellow, tubular florets only; fruit with 5 white, membranous bracts at tip, looks like a papery flower

Ecology:
mostly in rocky outcrops in shelter of large rocks

Seed Biology:
flowering occurs in response to rain; seed matures April to June; wind dispersed

Other information:
endemic to Namibia, mainly central Namib; seems to be browsed by wildlife; similar to the more wide-spread *Calostephane divaricata* which has petal-like ray florets

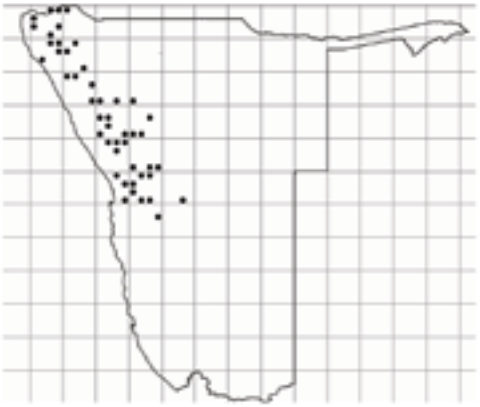
Family: Burseraceae

Commiphora virgata Engl.

Common Names: slender commiphora (E); antob, soba, haira, |anas|n, ||hoes (K); omumbara (H); slapkanniedood (A)

Conservation status: Lower Risk – least concern (IUCN, 1994)

Distribution:



Description:
spreading shrub, to 0.5 m high; bark silvery, peeling; branch tips long and slender, reddish-brown; leaves with 3 oval to elliptic leaflets; flowers very small, green; fruit ovoid, green, turning red, about 1 cm long; seed with a pseudo-aril consitinig of 4 fleshy, red or whitish arms

Ecology:
often in rocky areas but also found on gravel plains and in watercourses

Seed Biology:
male and female flowers are on separate plants, thus seed will not be found on all plants in a population; usually only few seeds are produced per plant and mainly after some rainfall; high competition for fruit from birds and rodents

Distribution on RUL concession:
Biotopes 3,4,5,7,9,10

Other information:
near-endemic to Namibia (central and northern Namib), also found in Angola

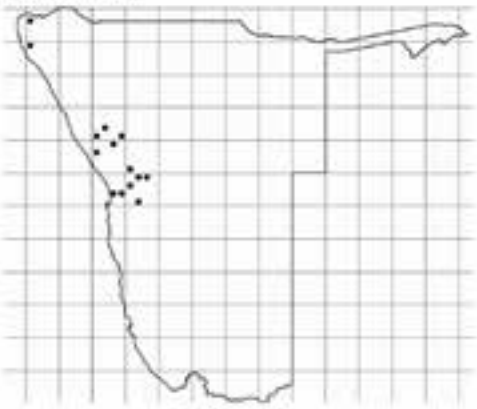
Family: Asteraceae

Dauresia alliariifolia
(O.Hoffm.) B.Nord. & Pelser

Common Names: none known

Conservation status: Lower Risk – least concern (IUCN, 1994)

Distribution:



Description:
shrub, to 1 m high and 1 m in diameter; older stems whitish; leaves roundish to kidney-shaped with heart-shaped base, slightly fleshy, margin shallowly toothed, veins arising at attachment of to 5 cm long petiole; white hairs in leaf axils; flower heads clustered at tips of branches, to 1 cm long and wide, florets all tubular, white

Ecology:
often in rocky areas, hill slopes or cliffs; plants may arise from cracks in large rocks

Seed Biology:
seed hairy, cylindrical, with white plume at tip; wind-dispersed; usually produced in large numbers per plant

Distribution on RUL concession:
Biotope 3, 5, 6

Other information:
endemic to Namibia's central and northern Namib, but may also occur in southern Angola (no records yet)

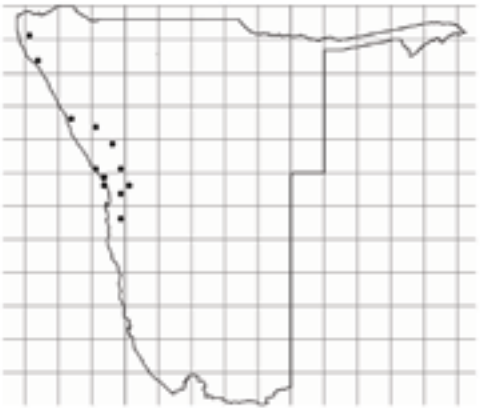
Family: Euphorbiaceae

Euphorbia giessii L.C.Leach

Common Names: none known

Conservation status: Lower Risk – least concern (IUCN, 1994)

Distribution:



Description:
shrub, dense branching from base, to 0.5 m high; branches thin, erect, dark green; leaves fall off early; flowers at branch tips, pale green; fruit a 3-lobed, globular, hairy capsule

Ecology:
found in coastal areas, usually close to the ocean; often in rocky boulder outcrops

Seed Biology:
male and female flowers on separate plants, not every plant will therefore produce seed; capsules split open explosively to release seed; seed should be collected just before capsules split; it is problematic for most *Euphorbia* species to find seed of adequate quantity and quality

Distribution on RUL concession:
Biotopes 9

Other information:
endemic to Namibia's central and northern Namib; may be in southern Angola as well (no records yet)

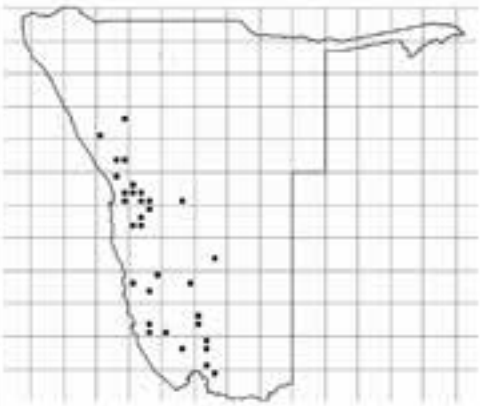
Family: Acanthaceae

Monechma desertorum
(Engl.) C.B.Clarke

Common Names: none known

Conservation status: Lower Risk – least concern (IUCN, 1994)

Distribution:



Distribution on RUL concession:
Biotopes 3 ,5, 6, 12, 14

Description:
annual herb, to 20 cm high; branches spreading, hairy; leaves fringed with white hairs; flowers white, bi-lipped, lower lip 3-lobed with purple fish-bone pattern, upper lip much smaller, 2-lobed; fruit a spoon-shaped capsule that splits open; seed hemispherical with one flat side

Ecology:
found only after rain; in good years can form large stands; mainly on gravel plains and in dry watercourses

Seed Biology:
seed expelled from capsule explosively, seed collection needs to be well timed

Other information:
endemic to central and southern Namib

Family: Polygalaceae

Polygala guerichiana Engl.

Common Names: none known

Conservation status: Lower Risk – least concern (IUCN, 1994)

Distribution:

Description:
shrub, to 1 m high; many thin, slender branches from base; branches blue-green; leaves linear-elongate, 10-20 x 2-3 mm; flowers with two lateral sepals much enlarged, pinkish with darker venation; petals magenta, lower petals united into a boat-shaped structure with a fringed tip; fruit flattened, oval; seed elongate with a caruncula

Ecology:
found mostly in dry watercourses

Seed Biology:
seed set seems to be low; two seeds per fruit; mature April to May

Distribution on RUL concession:
Biotopes 5,10,11,14,15

Other information:
near-endemic to Namibia, also found in southern Angola

Family: Geraniaceae

Sarcocaulon marlothii Engl.

Common Names: Bushman's candle (E); #goub, ||nora, |nubu#goub, sorab (K); Buschmannskerze (G); boesmanskers (A)

Conservation status: Least Concern (IUCN, 2001)

Distribution:

Description:
shrub, to 1.4 m high; stems upright to leaning, with thick bark of hard, yellow resin and rows of blunt spines; leaves circular, margins toothed, petiole remains on stem as whitish spine; flowers pink, to 3 cm in diameter; seed 5 united in a fruit, cone-shaped with feather-like flag of which the base is spirally twisted

Ecology:
mostly in rocky areas, often limestone-based rocks

Seed Biology:
mostly only a few flowers per plant, but throughout year; seed wind dispersed; collection needs to be timed well; due to flowering nature, only a few seeds can be collected at any time; quality of seed seems to be mostly poor, necessitating collection of large amounts of seed

Distribution on RUL concession:
Biotopes 1, 3, 5, 9, 10, 14, 15, 16

Other information:
endemic to Namibia's central Namib

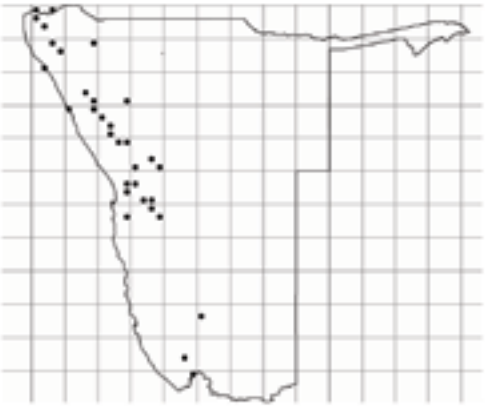
Family: Fabaceae

Sesbania pachycarpa DC. subsp. *dinterana* J.B.Gillett

Common Names: none known

Conservation status: Lower Risk – least concern (IUCN, 1994

Distribution:



Description:
shrub, to 1.2 m high with many branches from base; leaves to 20 cm long, pinnately divided; flowers bright yellow, outer surface of large, upper petal (standard) with maroon mottling; fruit an elongated, arched pod that splits open lengthwise; seed brown, cylindrical

Ecology:
found only in larger watercourses

Seed Biology:
pods dehisce to release seed and collecting needs to be carefully timed to find mature seed on plants; plants produce many seeds but spread over time; seed predation by insects may be a problem

Other information:
near-endemic to Namibia, also in southern Angola and possibly South Africa; heavily browsed by game

Distribution on RUL concession:
Biotope 8

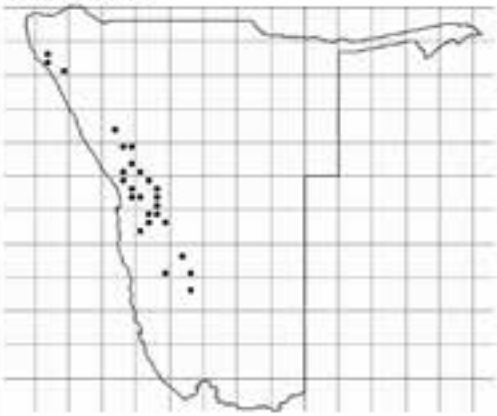
Family: Zygophyllaceae

Zygophyllum cylindrifolium
Schinz

Common Names: none known

Conservation status: Lower Risk – least concern (IUCN, 1994)

Distribution:



Description:
low, spreading shrubs, to 25 cm high, woody base with seasonal branches; leaves fleshy, cylindrical; flowers white; fruit ovoid, fleshy, yellow-green, to 8 x 4 mm

Ecology:
found on gravel plains and along watercourses

Seed Biology:
fruit splits into 5 sections but usually remains on plant for a long time; care must be taken when collecting the fleshy fruit, that these don't rot or get mouldy; fruiting October to December

Distribution on RUL concession:
Biotopes 1 ,3, 4, 5, 7, 9, 10, 13, 14

Other information:
endemic to Namibia's central and northern Namib

PART 2

Additional species for seed collection

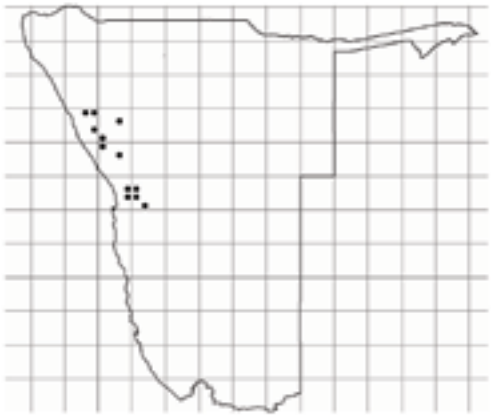
Family: Asphodelaceae

Aloe asperifolia
A.Berger

Common Names: rough-leaved aloe, sandpaper aloe (E); ||gores (K); rauhblättrige Aloe (G); skurweblaar-aalwyn (A)

Conservation status: Lower Risk – least concern (IUCN, 1994)

Distribution:



Description:
succulent leaf rosettes at tip of horizontally spreading stems which are covered with old leaves; leaves rough to touch,to 25 x 7 cm, brownish-green, margins with triangular, brown teeth; flowers orange-red in horizontal inflorescences; capsules oval, with 3 valves that split open; seed dark grey with papery wing

Ecology:
plants often form circles; occurs in a variety of habitats, mostly on plains

Seed Biology:
dispersed by wind, collection of seed needs to be timed precisely, May to June; seed of most *Aloe* species tends to be heavily parasitised by insects and thereby rendered inviable, which means large amount needs to be collected; easily propagated through seed

Distribution on RUL concession:
Biotopes 1,3,5,9,10,12,14,15,16

Other information:
endemic to Namibia's central Namib; protected under Nature Conservation Ordinance 4 of 1975

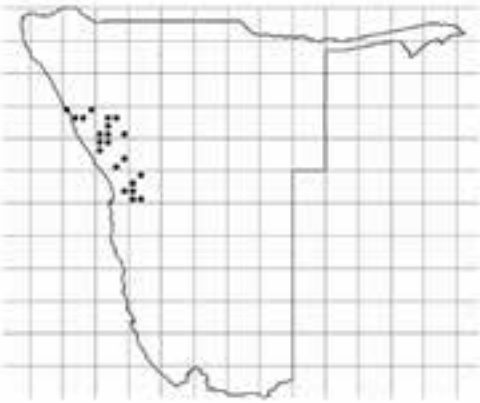
Family: Scrophulariaceae

Anticharis imbricata Schinz

Common Names: |gom|gom, |homexare (K)

Conservation status: Lower Risk – least concern (IUCN, 1994)

Distribution:



Description:
small shrub, to 40 cm high; leaves roundish, 4-10 mm long and wide, densely arranged and overlapping, covered with sticky glands; flowers tubular, 15-17 mm long, deep blue with blue-black throat ; capsules papery, oval-pointed, splitting down middle; seed whitish

Ecology:
often found in small watercourses and along road verges

Seed Biology:
seed small and cream-coloured; mature May to July; some flowers throughout year but mostly after rain

Distribution on RUL concession:
Biotopes 6, 12, 13, 14, 15

Other information:
endemic to Namibia's central Namib

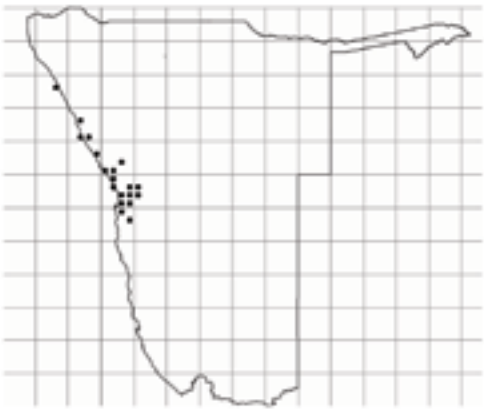
Family: Amaranthaceae

Arthraerua leubnitziae (Kuntze) Schinz

Common Names: pencil bush (E); saris, |haisaris (K); Bleistiftpflanze (G)

Conservation status: Lower Risk – least concern (IUCN, 1994)

Distribution:



Distribution on RUL concession:
Biotopes 2, 3, 5, 6, 12, 14, 15, 16

Description:
shrub, to 80 cm high; stems much branched, dark green, with fine longitudinal grooves; leaves much reduced, triangular, opposite, soon falling off; flowers inconspicuous, surrounded by grey silky hairy bracts, in spikes at branch tips

Ecology:
found on plains and in watercourses in the fog-zone (up to 80 km from coast) of the central Namib; hummock-forming; dominant species in some areas

Seed Biology:
wind dispersed; seed may be collected from below shrubs where it accumulates, May/June

Other information:
endemic to Namibia's central Namib

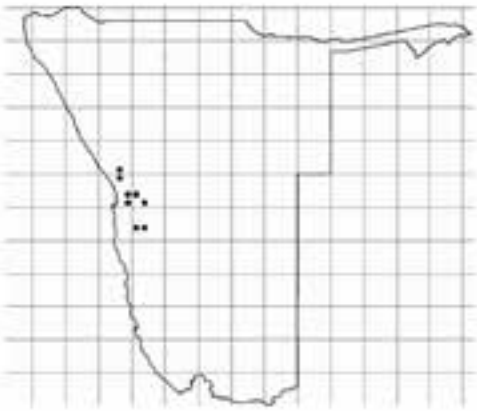
Family: Capparaceae

Cleome carnosa
(Pax) Gilg & Benedict

Common Names: none known

Conservation status: Lower Risk – least concern (IUCN, 1994)

Distribution:



Distribution on RUL concession:
Biotope 16

Description:
annual herb, erect to spreading, 8 to 30 cm high, densely covered with sticky glands and hairs; leaves compound with 3 rounded to oval leaflets; flowers yellow, to 15 mm long, few per plant, 12-14 stamens, all fertile, 4 longer than rest and longer than petals; capsule 15-20 mm long, 4-5 mm wide, on 2 mm stalk, upright, sticky-glandular, splits open

Ecology:
appears only after sufficient rainfall; in watercourses and on plains, often in large stands

Seed Biology:
seed roundish, dark grey, microscopically sculpted; matures April to May

Other information:
endemic to Namibia's central Namib; flowering plants may sometimes be only 10 cm high with a single stem

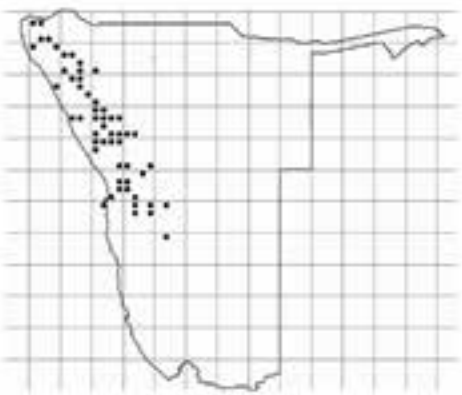
Family: Burseraceae

Commiphora saxicola Engl.

Common Names: rock commiphora, rock corkwood (E); #gauga-ame, |oohais, po-e, ||gai (K); Felsenmyrrhe (G); rotskanniedood (A)

Conservation status: Lower Risk – least concern (IUCN, 1994)

Distribution:



Description:
shrub to small tree; stems often swollen, bark grey, rough, not peeling; leaves compound with 2-6 leaflet pairs and 1 terminal leaflet, leaflet roundish, shiny, margins scalloped, petiole to 3 cm long; flowers very small, inconspicuous, greenish-yellow, male and female flowers on separate plants; fruit oval with pointed tip, reddish, splits into two halves; seed black with bright orange-red aril at base

Ecology:
mostly in rocky areas

Seed Biology:
only female plants bear seed (roughly 50% of a population); flowering around January, mature seed around May

Other information:
near-endemic to Namibia, also found in Angola; easy to transplant or propagate from truncheons/cuttings

Distribution on RUL concession:
Biotopes 1,3,4,5,6,7,9,11,12,13,14, 15, 16

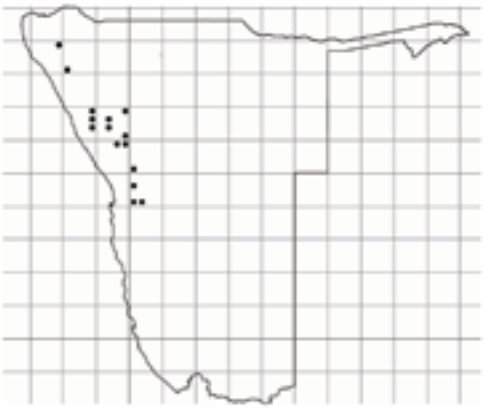
Family: Euphorbiaceae

Euphorbia damarana
L.C.Leach

Common Names: Damara euphorbia (E); kauimp, kuib, ||haos (K)

Conservation status: Lower Risk – least concern (IUCN, 1994)

Distribution:



Description:
shrub, to 2.5 m high, 3 m diameter; stems many, upright, cylindrical, sparsely branched, 6-12 mm in diameter, grey-green, mostly leafless; flowers greenish-yellow, at tips of branches, male and female on separate plants; capsule flattened-spherical, yellow-green, velvety, 20 mm in diameter, 4-6-locular, does not readily split open; seed oblong to 3-angled, pale brown with darker blotches

Ecology:
common on plains and hill slopes, often the dominant species

Seed Biology:
seed only on female plants; seed is not produced every season; capsule not dehiscing fully, but may drop off as a whole; matures May to July; eaten by rodents

Distribution on RUL concession:
Biotopes 5, 11

Other information:
endemic to Namibia's central and northern Namib

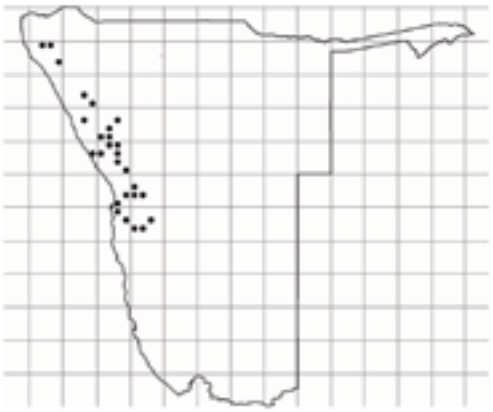
Family: Amaranthaceae

Hermbstaedtia spathulifolia (Engl.) Baker

Common Names: none known

Conservation status: Lower Risk – least concern (IUCN, 1994)

Distribution:



Description:
small shrub, to 30 cm high, often spreading to a diameter of 40 cm, much branched; branches angular; leaves spathulate, 10 x 3 mm, folded along middle, without clear petiole; flowers in spherical clusters on branch tips, with white to pale pink, papery bracts, filaments and style deep pink; seed small, shiny black, bi-convex

Ecology:
common along watercourses and roadsides

Seed Biology:
produces copious amounts of shiny black seed per flower; flowering almost all year round; best time for seed collection April to June

Distribution on RUL concession:
Biotopes 5, 6, 8, 12

Other information:
endemic to Namibia's central and northern Namib; browsed by wildlife

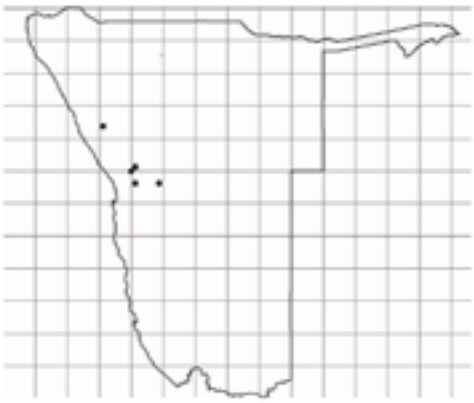
Family: Mesembryanthemaceae

Lithops ruschiorum
(Dinter & Schwantes) N.E.Br.

Common Names: flowering stone (E); beeskloutjies (A)

Conservation status: Least Concern (IUCN, 2001)

Distribution:



Description:
perennial, consisting of one to many plant bodies composed of a succulent leaf pair, flattened on top, pink-grey with darker net pattern, surrounded by dry, old leaves; most parts underground; flowers yellow, produced from between two leaves

Ecology:
on hill and mountain slopes, usually on south-west facing slopes where fog is blown through wind

Seed Biology:
mesemb capsule that retains seed; can be collected long after first maturing; germinates easily; propagation from seed relatively successful

Other information:
endemic to Namibia's central Namib; protected under Nature Conservation Ordinance 4 of 1975; highly sought after by collectors

Distribution on RUL concession:
Biotopes 14,15

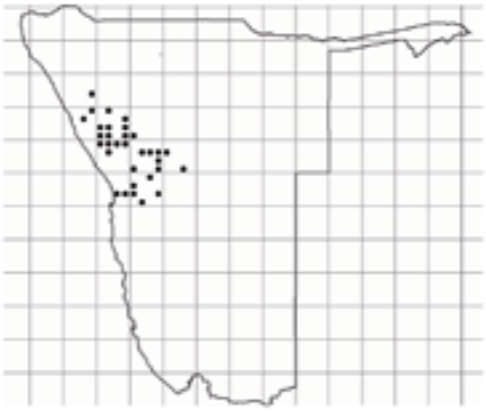
Family: Acanthaceae

Petalidium canescens
(Engl.) C.B.Clarke

Common Names: Grauer Futterbush (G)

Conservation status: Lower Risk – least concern (IUCN, 1994)

Distribution:



Description:
small shrub, to 50 cm high and in diameter, usually smaller; leaves spoon-shaped, grey-green due to dense short hairs; flowers in dense clusters at base of plant, tubular, widening towards mouth with 5 lobes, to 23 mm long, pink with darker throat and may have two yellow lines on inside of lower lobe

Ecology:
widespread and common, on gravel plains and in drainage lines

Seed Biology:
some seed is retained on plant; can be collected any time of year; seed highly parasitised by insects

Distribution on RUL concession:
Biotopes 14,15

Other information:
endemic to Namibia's central Namib

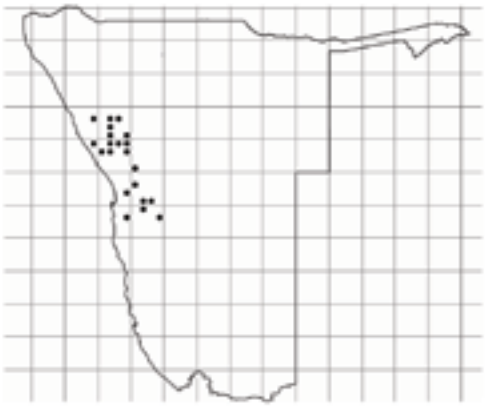
Family: Pedaliaceae

Sesamum marlothii Engl.

Common Names: none known

Conservation status: Lower Risk – least concern (IUCN, 1994)

Distribution:



Description:
shrub, to 50 cm high; all parts softly hairy; leaves compound near base with 3 leaflets that may be assymmetrical at the base; single near branch tips; petiole 5-10 cm long; flowers bell-shaped with broad seam around mouth, 3-5 cm long, pale pink with darker pink throat, often also a yellow patch; capsule upright, narrow with sharp point, at least 3 cm long, splits down middle

Ecology:
often in sandy places like riverbeds or between rocks of outcrops

Seed Biology:
seed flat, black, not winged; some seed is retained in capsule and can be collected any time; flowering almost all year round

Distribution on RUL concession:
Biotope 6

Other information:
endemic to Namibia's central Namib; related to commercial sesame

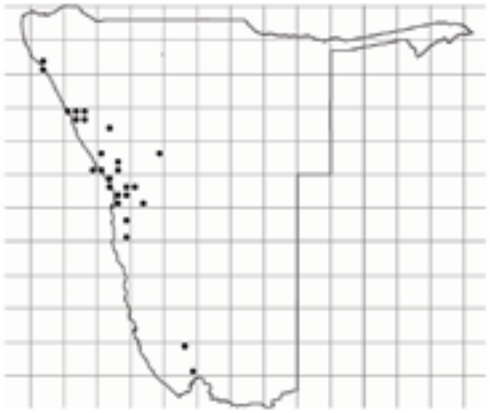
Family: Zygophyllaceae

Zygophyllum stapffii Schinz

Common Names: dollar bush (E); Talerpflanze (G)

Conservation status: Lower Risk – least concern (IUCN, 1994)

Distribution:



Description:
shrub, to 60 cm high, often hummock-forming; leaves with 2 oval to round, succulent leaflets on short petiole; flowers grouped in leaf axils, white; fruit drooping, elongate, 5-winged; seed pear-shaped, light brown

Ecology:
in dry watercourses and on plains, rocky slopes and near coast in saline soils; dominant species in places

Seed Biology:
fruit drops off plant and is blown about by wind, splits open to release seed

Distribution on RUL concession:
Biotopes 1,2,3,4,5,6,7,9,10,11,12,13,14,15,16

Other information:
near-endemic to Namibia, also found in southern Angola

APPENDIX 10d:
Seed Collections of Target Species Banked

Target Species	NPGRC accession no.	MSB serial no.
Adenia pechuelii	3409, 3426, 3531	333575
Aloe asperifolia	2949	235130
Aizoanthemum galenioides	3232	334767
Aizoanthemum rehmannii	3235	335041
Anticharis imbricata	2942	235026
Arthraerua leubnitziae	2952	235163
Calostephane marlothiana	3213, 3226	333667
Cleome carnosa	3234	335030
Commiphora saxicola	2327	179704
Commiphora virgata	3210, 3227	334664
Euphorbia damarana	2945	235059
Euphorbia giessii		
Hermbstaedtia spathulifolia	2941	235015
Lithops ruschiorum	2452, 2478, 3315, 3365	235071, 217095
Monechma desertorum		342812
Petalidium canescens	2944	235048
Polygala guerichiana		273093
Sarcocaulon marlothii	3414	(376086) TTH
Dauresia alliariifolia	3298	342720
Sesamum marlothii	2309	179531
Sesbania pachycarpa subsp. *dinterana*	collected by Kew, 1990	82482
Zygophyllum cylindrifolium		335915
Zygophyllum stapffii	collected by Kew, 1990	82507

Species	Average 1000-seed-weight (g)	Storage behaviour	Germination
Adenia pechuelii	Not sufficient	seed at MSB to do tests	
Aloe asperifolia	3.58		100% germination; germination medium = 1% Agar; germination conditions = 20 °C, 8/16; (RBG Kew, Wakehurst Place 100% germination; germination medium = 1% Agar; germination conditions = 25 °C, 8/16; (RBG Kew, Wakehurst Place 87% germination; germination medium = 1% Agar; germination conditions = 35/20 °C, 8/16; (RBG Kew, Wakehurst Place
Aizoanthemum galenioides	0.07		100% germination; pre-sowing treatments = Chipped with scalpel; germination medium = 1% Agar; germination conditions = 20 °C, 8/16; (RBG Kew, Wakehurst Place) 100% germination; pre-sowing treatments = Chipped with scalpel; germination medium = 1% Agar; germination conditions = 35/20 °C, 8/16; (RBG Kew, Wakehurst Place) 100% germination; pre-sowing treatments = Chipped with scalpel; germination medium = 1% Agar; germination conditions = 25 °C, 8/16; (RBG Kew, Wakehurst Place)
Aizoanthemum rehmannii	0.08		100% germination; pre-sowing treatments = Chipped with scalpel; germination medium = 1% Agar; germination conditions = 20 °C, 8/16; (RBG Kew, Wakehurst Place) 100% germination; pre-sowing treatments = Chipped with scalpel; germination medium = 1% Agar; germination conditions = 25 °C, 8/16; (RBG Kew, Wakehurst Place) 100% germination; pre-sowing treatments = Chipped with scalpel; germination medium = 1% Agar; germination conditions = 35/20 °C, 8/16; (RBG Kew, Wakehurst Place)
Anticharis imbricata	0.03		7% germination; germination medium = 1% Agar; germination conditions = 20 °C, 8/16; (RBG Kew, Wakehurst Place
Arthraerua leubnitziae	4.83		100% germination; germination medium = 1% Agar; germination conditions = 25 °C, 8/16; (RBG Kew, Wakehurst Place) 100% germination; germination medium = 1% Agar; germination conditions = 35 °C, 8/16; (RBG Kew, Wakehurst Place) 100% germination; germination medium = 1% Agar; germination conditions = 30 °C, 8/16; (RBG Kew, Wakehurst Place)
Calostephane marlothiana	0.37		tests not yet done
Cleome carnosa	0.12		80% germination; pre-sowing treatments = Chipped with scalpel; germination medium = 1% Agar; germination conditions = 20 °C, 8/16; (RBG Kew, Wakehurst Place) 63% germination; pre-sowing treatments = Chipped with scalpel; germination medium = 1% Agar; germination conditions = 35/20 °C, 8/16; (RBG Kew, Wakehurst Place) 58% germination; pre-sowing treatments = Chipped with scalpel; germination medium = 1% Agar; germination conditions = 25 °C, 8/16; (RBG Kew, Wakehurst Place)
Commiphora saxicola	64.68		tests not yet done
Commiphora virgata	40.13		not sufficient seed to do tests
Euphorbia damarana	119.62		tests not yet done
Euphorbia giessii	No seed at	MSB to do tests	
Hermbstaedtia spathulifolia	0.13		tests not yet done

Species	Average 1000-seed-weight (g)	Storage behaviour	Germination
Lithops ruschiorum	0.12		100% germination; germination medium = 1% Agar; germination conditions = 15 °C, 8/16; (RBG Kew, Wakehurst Place) 58% germination; germination medium = 1% Agar; germination conditions = 10 °C, 8/16; (RBG Kew, Wakehurst Place) 100% germination; germination medium = 1% Agar; germination conditions = 20 °C, 8/16; (RBG Kew, Wakehurst Place)
Monechma desertorum	1.44		71% germination; germination medium = 1% Agar; germination conditions = 35/20 °C, 8/16; (RBG Kew, Wakehurst Place) 100% germination; germination medium = 1% Agar; germination conditions = 25 °C, 8/16; (RBG Kew, Wakehurst Place) 100% germination; germination medium = 1% Agar; germination conditions = 20 °C, 8/16; (RBG Kew, Wakehurst Place)
Petalidium canescens	5.02		95% germination; germination medium = 1% Agar; germination conditions = 20 °C, 8/16; (RBG Kew, Wakehurst Place 94% germination; germination medium = 1% Agar; germination conditions = 25 °C, 8/16; (RBG Kew, Wakehurst Place
Polygala guerichiana	Not sufficient	seed at MSB to do tests	
Sarcocaulon marlothii	No seed at	MSB to do tests	
Dauresia alliariifolia			tests not yet done
Sesamum marlothii	0.98	Orthodox Storage Conditions: 100 % viability following drying to mc's in equilibrium with 15 % RH and freezing for 4 years at -20ºC at RBG Kew, WP.	100% germination; germination medium = 1 % Agar with 250 mg/l gibberellic acid (GA3); germination conditions = 33/19 °C, 12/12; (RBG Kew, Wakehurst Place)
Sesbania pachycarpa subsp. dinterana	22.7	Orthodox Storage Conditions: Long-term storage under IPGRI preferred conditions at RBG Kew, WP. Oldest collection 2 years	90% germination; pre-sowing treatments = seed sterilised (immersed in saturated calcium hypochloride for 5 mins), seed scarified (chipped with scalpel); germination medium = 1 % Agar; germination conditions = 21 °C, 12/12; (RBG Kew, Wakehurst Place)
Zygophyllum cylindrifolium	18.92		tests not yet done
Zygophyllum stapffii	4.95	Orthodox Storage Conditions: Long-term storage under IPGRI preferred conditions at RBG Kew, WP. Oldest collection 2 years	94% germination; pre-sowing treatments = seed scarified (chipped with scalpel); germination medium = 1 % Agar; germination conditions = 26 °C, 12/12; (RBG Kew, Wakehurst Place)
			Format for germination conditions: = temperature (constant or day/night); hours light/hours dark;

APPENDIX 11:

Contributors / collaborators to the partnership project

Name	Institution
Klaassen, E.	NBRI
Lucas, E.	NBRI
Kwembeya, E.	NBRI
Moses, R.	NBRI
Rügheimer, S.	NBRI
Strohbach, B.	NBRI
Maggs-Kölling, G.	NBRI
Irish, J.	NBRI
Hochobes, M.	NBRI
Haufiku, H.	NBRI
Lutombi, D.	NBRI
Engelbrecht, A.	Ministry of Environment and Tourism, Directorate Parks and Wildlife Management
Kolberg, H.	Millennium Seed Bank Project
Tholkes, T.	Millennium Seed Bank Project
Mupupa, Y.	Rössing Uranium Limited
Schneeweiss, R.	Rössing Uranium Limited
Bachman, S.	RBG Kew
Marchant, G.	RBG Kew
Laws, S.	Rio Tinto
Mannheimer, C.	NBRI associate
Burke, A.	EnviroScience
Menge, L.	Namib Rand Nature Reserve
Shaw, D.	Namib Rand Nature Reserve
Tsoubeb, M.	Namib Rand Nature Reserve
Groves, S.	Angel Helicopter Services
Nott, K.	Private individual
Mannheimer, J.	Private individual
Loots, A.	Private individual
Calitz, B.	Brandberg Rest Camp
Rusch, M.	Private individual