National conservation assessment and management of Adenia pechuelii, with specific reference to the Rio Tinto Rössing Uranium Mine

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Abstract
Rössing Uranium Limited’s (RUL) biodiversity strategy recognised the importance of managing plant species of conservation importance occurring within the license area of the mine. Based on its conservation importance, Adenia pechuelii was selected for conservation assessment. Of the 2671 individuals of A. pechuelii recorded over its distribution range in Namibia, some 226 are from RUL. This account for approximately 8% of the total number of plants recorded and shows that the RUL population is the third-most important with respect to population size. In terms of density, however, this population is rated one of the lowest, as the plants are scattered over a large area. The conservation status for A. pechuelii is here down-listed from Near Threatened to Least Concern. 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 conducted.

Key Words: Adenia pechuelii; conservation assessment; Rössing Uranium Mine; monitoring

Introduction

As part of Rössing Uranium Limited’s (RUL) Biodiversity Action Plan and their commitment to achieve 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 license area. A partnership was thus formed between the National Botanical Research Institute (NBRI), Rössing Uranium Limited (RUL), the Rio Tinto mining group and the Royal Botanic Gardens at Kew, incorporating the Millennium Seed Bank Project (MSBP) in order to carry out the investigations in this regard.

Among Namibia’s wealth of plant diversity, a significant number of species are of conservation importance. Over 1,400 species have been evaluated against the IUCN Red List criteria to date, and of these, some 170 are currently threatened with extinction, Near Threatened (NT) or Rare (R), with an additional 360 taxa being recorded as endemic to Namibia (NBRI 2012; Loots 2005; Craven & Loots 2001).

Undertaking field assessments on populations of species that are of conservation concern enormously contributes to our knowledge, as well as their conservation and management. It is the most reliable way to monitor numbers of plants in a population and provides a basis for scientists to detect changes in population size over time, one of the criteria for Red List assessments (IUCN 2001).

Initial research was carried out on botanical diversity within and around the RUL license area by Burke (2005), but this work was not mandated to focus 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 that are of conservation concern and/or endemic to Namibia from this list were identified as priority species and used to rate biotopes in the mine’s license area (Burke 2005). This list
includes *Adenia pechuelii* (Engl.) Harms of the family Passifloraceae also known as Elephant’s foot (English) or Wüstenkohlrabi (German) and given its desirability to succulent collectors, its vulnerability to potential habitat destruction, and its current status of Near Threatened (Loots 2005), the species became a subject of conservation concern. These reasons provided the motivation for choosing *A. pechuelii* as a subject of the survey.

The proportion of the global populations of *A. pechuelii* occurring within RUL’s license area was not known. Curtis & Mannheimer (2005) validly state that the species is worthy of protection, preferably under the Nature Conservation Ordinance.

*A. pechuelii* is a dwarf tree with very large, squat, swollen, almost-round trunk and succulent, green, finger-like branches, orientated in all directions. The bark is smooth, cream to light grey-green. Leaves are few, small and grey-green. The flowers are small, greenish and the fruit is a three lobed capsule, red when ripe, and usually with three seeds. The flowers are inconspicuous but the fruit is conspicuous when ripe (Curtis & Mannheimer 2005).

Potential threats to the species include habitat destruction in some populations, especially through mining activities; the international pachycaul trade; plants are unisexual, which could mean skewed sex ratios in some populations and this could result in poor recruitment. In at least some populations, male and female plants seem to flower at different times (pers. obs.), and this would result in female flowers not being pollinated. It is not certain if and to what extent international trade is affecting the species and the impacts of climate change have not been assessed.

Figure 1 indicates the distribution of *A. pechueli* in Namibia, based on specimen records from the National Herbarium of Namibia (WIND 2006). Craven & Vorster (2006) reported that *A. pechuelii* specimens were also recorded in Angola.

The anticipated short-term outcome of the project was to increase knowledge and improve management of *A. pechuelii* recorded on the RUL mine licence area. The long-term goal was to improve 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*.

The most important target conservation outcome of the project was to improve awareness of the conservation status and national distribution of *A. pechuelii* and the relevant importance of sites found at RUL. An important output of this project was to develop a simple species management and long-term monitoring strategy for *A. pechuelii* (See Appendix 1).

This paper focuses on comparing the population of *A. pechuelii* at RUL, with populations that were surveyed over the rest of the distribution range of the species, in terms of distribution, abundance, density and relative importance for conservation. Two main questions had to be answered at the end of the survey: 1) What percentage of the national population of *A. pechuelii* occurs within the license area, and 2) How important is the population at RUL compared to the rest of the populations across the distribution range of the species in Namibia?

**Methods**

The national study area was defined as the natural distribution area of *A. pechuelii* (Figure 1) by querying the Specimen Database of the National Herbarium (WIND 2006). In many cases, people who work or live in the vicinity of the recorded localities were consulted as to the whereabouts of the plants.

The work on biotopes done by Burke (2005) indicated where *A. pechuelii* is present in the RUL license area. This was used to define the study area at RUL and as a guide to sample the area. The study area at RUL was divided into 1 km grid squares and some 68 corresponding waypoints at the grid nodes, hereinafter referred to as “sampling sites”, were entered into a GPS (Figure 2).
These 68 sites were then systematically surveyed as described below, to locate and assess *A. pechuelii*. In addition to the sampling sites, *A. pechuelii* specimens were recorded whenever they were encountered within the license area.

**Figure 1.** National distribution of *A. pechuelii*.

**Figure 2.** Biotopes (Burke 2005) and sampling sites in the RUL license area.
For the purposes of the survey, it was necessary to distinguish between a site and a population. A site is therefore defined as a group of plants that occur together on the same topographic feature for example a ridge, slope, plain, outcrop or hillside and the plants are not separated by unsuitable habitat. A population is defined as a group of sites occurring together at the same general location for example the RUL license area or the Garden Route. Sites within a population can be separated by unsuitable habitat but cross pollination between the sites is possible, as they are not separated by long distances. Most populations are separated from one another by a distance of at least ten kilometres as well as 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.

During the course of the project a total of 35 sites of *A. pechuelii* were surveyed across the distribution range of the project (including RUL, regarded here as one population for comparison) and they constitute some 24 populations (Figure 3).

![Figure 3. Distribution of surveyed *A. pechuelii* sites.](image)

A data sheet was designed onto which all relevant data for each site were recorded. This included the presence or absence of *A. pechuelii*, as well as a site description and relevant habitat information such as altitude, soil type, soil colour, lithology, aspect and gradient, which were measured consistently in the immediate surrounds of the plant, using a compass and a clinometer,
respectively. At a number of sampling sites, specimens were collected and photographs were taken of *A. pechuelii* (See Appendix 2).

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 analysed to produce results. Maps were produced using Arc View GIS version 3.2a. Graphs were generated using MS Excel 2003.

Soil samples were taken at 55 sampling sites and brought back to the NPGRC where they were analysed for colour, texture and pH. Soil texture was determined using a manual process according to a standard procedure used by ICRAF. Soil pH was determined using a Hannah microprocessor pH meter. These data were used to help determine the habitat preference of *A. pechuelii* over its distribution range.

Within a sampling site or a population, *A. pechuelii* plants were recorded individually, unless more than one plant occurred at the same coordinates, in which case only one set of coordinates were recorded with the number of plants present there. Photographs were taken of the habitat and some plants from close-up to demonstrate the growth habit and habitat as well as damage to the plants. Associated plant species were recorded and where the plants could not be identified, specimens were collected and deposited in WIND according to standard practice.

The density of *A. pechuelii* populations was calculated using the Nearest Neighbour method (Cottam & Curtis 1956), a plot-less sampling method. Henderson & Seaby (1999) developed Density from Distances, a software programme that calculates density using plot-less density estimators upon entering of the data. Density was not calculated for sites with fewer than 40 plants. 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.

For populations outside the RUL license area, sampling started as soon as specimens of *A. pechuelii* could be located. Each new site was given a new site number. Some 400 *A. pechuelii* individuals from four populations were tagged with metal tags to facilitate future monitoring. An additional 100 plants were tagged at RUL in 2010 as part of the management and monitoring plan.

Small plants were observed in all populations, but details were only recorded if they were tagged for monitoring. Plants were considered “small” when the height of the main stem was measured to be less than 20 cm. This does not necessarily mean that they are not mature yet. Establishing whether a plant is mature or juvenile was not part of the mandate of the survey as information on determining the current age of the plants, the age at which they start to flower, set seed and their size upon maturity is not currently available.

Field work and data analyses were conducted from April 2006 to December 2008.

**Results**

*A. pechuelii* was found to occur 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. Plants are mostly found in exposed situations, but sometimes in half shade under overhanging rocks. Figure 4 indicates the vegetation types (Giess 1971) in which the surveyed populations of *A. pechuelii* occur.
Over its entire distribution range, *A. pechuelii* occurs in association with a wide range of plant species, including *L. ruschiorum*, a range of *Aloe*, *Commiphora*, *Euphorbia*, *Zygophyllum* and other species as well as *Welwitschia mirabilis*. Plants are often covered in ants, especially when in flower and occasionally with hairy caterpillars, which browse the leaves. Branches are often browsed by animals, especially rodents and the main stems are often damaged, possibly by porcupine. This should not be confused with dents and hollows in the main stem caused by rocks that were pushed out over time.

Some 226 *A. pechuelii* plants were recorded at 30 of the 68 sampling sites surveyed in the RUL licence area and on roads and tracks between sampling sites, which were then assigned new site numbers. All the plants recorded at RUL are regarded as belonging to a single population. Figure 5 indicates the distribution of *A. pechuelii* in the RUL license area.
Field work revealed that individual plants at RUL occur mostly alone or in small groups of up to nine plants (Figure 6). Only six sampling sites had ten or more plants (Figure 6). Within RUL these six sites contain some 113 individuals in total. The density of A. pechuelii in the RUL license area was calculated as 7.024 plants per km². Small populations like the ones in the Namib Rand Nature Reserve therefore do not feature in the comparisons, but they are important in indicating the extent of the distribution of the species. The populations in the Namib Rand Nature Reserve possibly indicate the southern boundary of the species’ range, at close to 26° latitude (Figure 3). Over the plant’s range most sites had fewer than 100 plants, as indicated for the 13 largest A. pechuelii populations (Figure 7). In terms of numbers of plants recorded, RUL rated third.
A total of 2671 individuals of *A. pechuelii* were recorded over the distribution range of the species, of which 226 are from the RUL license area. This gives the proportion of *A. pechuelii* at RUL as approximately 8% of the total population 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 8). 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. It also has the highest percentage of small plants recorded among the 100 plants that were tagged in 5 populations (Figure 9).
Figure 9. Percentage of small tagged *A. pechuelii* plants in selected populations.

Figure 10 shows the rock types, in which *A. pechuelii* occurs over its distribution range, indicating that granite is overwhelmingly preferred over any other lithology. *A. pechuelii* occurs on all aspects, but has a preference for NW- and W-facing slopes (Figure 11) and most plants prefer to grow on slopes with a gradient of less than 20° (Figure 12). Most plants were found between 501m and 750m above sea level, which can be explained by the fact that most of the largest populations are distributed within that range (Figure 13).

Figure 10. Lithology preference for *A. pechuelii*. 
Soil pH ranged between 7.9 and 9.8 over the distribution range of *A. pechuelii* indicating slight to moderate alkalinity. A strong preference for clay-loam was indicated (Figure 14). Where *A. pechuelii* occurred, the soil predominantly had a light brown colour.
Table 1 lists the 13 most prominent sites of *A. pechuelii*, ranking them according to their density and the number of plants recorded. They are all regarded as important for conservation. Only four populations have a high density as well as a large population size (highlighted in green). RUL and Hoopverloor do not have high densities but they do have a relatively large population size (highlighted in yellow). Sites with a high density but a small population size are highlighted in blue.

**Table 1.** Sites of *A. pechuelii* that should be targeted for conservation.

<table>
<thead>
<tr>
<th>Population name</th>
<th>Density (plants / km²)</th>
<th>Number of plants recorded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torra Conservancy</td>
<td>4.669</td>
<td>43</td>
</tr>
<tr>
<td>RUL</td>
<td>7.024</td>
<td>226</td>
</tr>
<tr>
<td>Hoopverloor</td>
<td>48.37</td>
<td>111</td>
</tr>
<tr>
<td>Garden route</td>
<td>110.7</td>
<td>111</td>
</tr>
<tr>
<td>Drainage divide - Nadas &amp; Munitum</td>
<td>123.6</td>
<td>76</td>
</tr>
<tr>
<td>Terrace Fountain - Gai Ais</td>
<td>133.3</td>
<td>45</td>
</tr>
<tr>
<td>Gai Ais - Huab River</td>
<td>149.3</td>
<td>58</td>
</tr>
<tr>
<td>Tsiseb Conservancy</td>
<td>179</td>
<td>123</td>
</tr>
<tr>
<td>Valencia</td>
<td>213.8</td>
<td>412</td>
</tr>
<tr>
<td>Munitum valley - SKP boundary</td>
<td>282.1</td>
<td>72</td>
</tr>
<tr>
<td>Usakos-Henties Bay road</td>
<td>443.7</td>
<td>43</td>
</tr>
<tr>
<td>Leeukop</td>
<td>2111</td>
<td>871</td>
</tr>
<tr>
<td>Urikos-West</td>
<td>Not calculated</td>
<td>159</td>
</tr>
</tbody>
</table>

**Green:** High density/Large population  
**Yellow:** Low density/Large population  
**Blue:** High density/Small population

Appendix 3 maps the distribution of *A. pechuelii* on ETM Landsat 7 images. Figure f maps RUL and the prospective Valencia Uranium mine, respectively, and demonstrates how the densities at the two populations compare. From this image it appears that the distribution of the plants at Valencia is highly clumped, as opposed to the plants at RUL which appear to be widely scattered at this distance. At ground level, *A. pechuelii* plants occur in small groups of usually between 2 and 10 plants, and in many cases solitary. In the population at RUL, these groups or single plants are much further apart than those in the Valencia population and this is evident in the satellite images.
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 to conduct a detailed survey on any species of conservation concern makes it expensive to undertake. The funding received for this project therefore presented a rare opportunity to conduct a detailed survey on *Adenia pechuelii*. The project also highlighted the importance of conducting field assessments. At the start of the project, it was thought that individuals of *A. pechuelii* are few and far between, but current information reveals that there are large populations in terms of numbers of individuals and the size of the area that they occupy (Figure 3, Table 1). However, it should be noted that in addition to herbarium records (WIND 2006), few new localities of *Adenia pechuelii* were investigated. It is therefore most likely that other populations exist, especially in more remote areas.

Surveying populations of *A. pechuelii* was revealed to be more challenging than anticipated at the start of the project. At the time when the concept note was developed, the available information about *A. pechuelii* indicated that plants are few and scattered. This created the impression that it would be feasible to count all individuals in a population. This idea was enhanced when field work at RUL started because within the license area, *A. pechuelii* does indeed occur either individually, or in small groups of 2-10 plants. It was therefore possible to get a fairly accurate indication of the number of *A. pechuelii* plants within the RUL license area, despite the fact that workers had to cover long distances over rugged terrain in order to survey the population. However, once assessments started in other areas, it became apparent that most populations extend over several kilometres, covering large areas, and it became very difficult to record every single individual. The populations at Leeukop in the Namib Naukluft Park, RUL and Valencia were the only large populations for 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 that this would be difficult to achieve for all populations that were surveyed. Absolute counts were obtained for only four populations, namely Leeukop, Valencia, RUL and the one in the Munitum valley on the Skeleton Coast Park (SCP) boundary.

The high density of *A. pechuelii* at Leeukop can be explained by the fact that all the plants occur on a single inselberg which covers a very small area. In contrast, the population at RUL, with most plants being far apart, has the second-lowest density of the surveyed populations (Table 1).

The population at the Valencia Uranium mine is the only one for which the height of all the individuals were measured and therefore the percentage of small plants recorded here (17%) is fairly accurate. It is reasonable to say that the recruitment in this population seems to be fairly healthy.

The way that *A. pechuelii* plants are distributed over the RUL license area naturally spreads the risk of the plants being damaged or destroyed. This is not the case at Valencia, where the impacts of mining activities could have a devastating effect on that important population.

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

The Red List assessment that was conducted on *A. pechuelii* for the Red Data Book (Loots 2005) was largely based on data from literature, herbarium specimens and expert opinion. It suggested that plants are mostly uncommon to rare and occur in small groups. It was inferred that there are at most 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. It was also suspected that there is a continuing decline in the number of mature individuals and that no sub-population contained more than 70 mature plants. Based on this information, a Red List status of NT was assigned.
The more detailed knowledge that was accumulated during this survey revealed that there are at least 2,671 individual plants left in the wild and that the largest population contains more than 800 plants. Strengthened by the current knowledge that some populations occupy extensive areas, the number of mature plants left in the wild is now estimated to be between 3,000 and 5,000. 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%. There is currently no evidence that there is 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 is therefore down-listed from NT to LC. This simply means that a taxon has been evaluated against the current IUCN criteria and does not qualify for the Critically Endangered, Endangered, Vulnerable or Near Threatened categories (IUCN 2001). A regional assessment will strengthen this status as the species is not endemic to Namibia.

The fact that A. pechuelii is not threatened with extinction, does not mean that it is not of conservation importance. 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, field work that was conducted suggests that seed setting is poor (Jankowitz & Loots 2008) in all the populations that were surveyed which would result in poor recruitment of juvenile plants as well. Indeed in most populations, less than 10% of the plants were small and in the long term, 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 and possibly climate change (Loots 2005). The IUCN Red List classification system does not currently take poor recruitment into account.

The work conducted through the partnership has resulted in an increase in important information on A. pechuelii. 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.

The support provided by Rio Tinto, 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 A. pechuelii. The trend to tag plants as a means of monitoring populations can be applied to other species of conservation concern, especially threatened species, as an ongoing activity of the Threatened Plants Programme of the NBRI.

The support provided by RUL enabled them to make a valuable contribution to the conservation and management of A. pechuelii, both inside and outside their license area. It is hoped that the commitment by RUL and Rio Tinto will serve as an example to be followed by other mining companies.

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 (T. Hoffmann Pers. comm.).

More work could be conducted on population biology and demography, for example determining the age of plants, at what age they begin their reproductive cycle and what the size of the main stem is at this stage. A study could be carried out on the differences between the flowering times of male and female plants to shed light on the reasons for poor seed setting in many populations.

Further studies could be carried out to determine population boundaries in A. pechuelii. This would aid in estimating population sizes which in turn would be valuable in reviewing the conservation status of the species.

Molecular studies could reveal the degree of genetic diversity within and between populations of A. pechuelii, which is important in genetic conservation. Populations that are genetically very diverse have a better chance of survival than those that are genetically more uniform or that have lost a significant portion of their gene pool.
Conclusion

The following key findings should be noted:

- Some 2671 individuals of *A. pechuelii* were recorded during the survey;
- RUL harbours approximately 8% of these, scattered over a large area;
- The prospective Valencia Uranium mine harbours approximately 17% of these, all concentrated in a rather small area;
- Leeukop harbours approximately 32% of these, also concentrated in a very small area;
- Conserving these three populations, which together harbour almost 60% of the plants recorded during the survey, is critical;
- The national Red List status is changed from Near Threatened to Least Concern;
- *A. pechuelii* remains a conservation concern due to its slow growth rate, poor seed production and subsequent poor recruitment;
- It is highly likely that there are more populations yet unrecorded;
- Research efforts are needed to investigate various aspects, including genetic diversity, demographic aspects and monitoring survival rate.

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Appendix 1

Management and monitoring plan for A. pechuelii

Background

This study provided more clarity with respect to where the densest and some of the largest populations of A. pechuelii are located and how the populations at RUL compare to other populations across the distribution range of this species.

An important output of this project was to develop a simple species management and long-term monitoring strategy for A. pechuelii.

The species management and monitoring plan aims to capture the results from both conservation assessments and seed conservation activities and make specific in-situ and ex situ 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 any reasons for changes in the populations of target species and make subsequent recommendations to RUL and MET accordingly.

Management, Conservation and Monitoring Recommendations

These recommendations focused on protecting the plants in situ, as the preferred conservation measure, complemented by ex situ conservation actions and the long-term monitoring of the species.

In situ management and conservation:

The following recommendations are made:

1. RUL management should consider special protection of areas that were identified as important for A. pechuelii (Figure 5).

2. Maps should be distributed and appropriate staff or contractors informed on locations of important areas for A. pechuelii, in order to ensure that as many as possible plants are protected from destructive activities like bulldozing for road construction, sand and gravel harvesting etc.

3. The Ministry of Environment and Tourism should be made aware of the importance of the population at Leeukop in the Namib Naukluft Park. This responsibility should be taken up by the NBRI.

Ex situ management and conservation:

During the course of the project, 5 accessions of A. pechuelii were collected and banked at either the NPGRC or the Millennium Seed Bank in the UK, but none of them contained more than 50 seeds, which is nowhere near the international standard of 1,000 seeds to be banked by the NPGRC and duplicated at the MSB in the UK. To facilitate future restoration work (post mine closure) and to provide a long-term insurance strategy for these plants, banking of seeds is 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 and events where most plants in a population are setting fruit at the same time are rare. In addition, capsules are often empty or seeds not fully developed (pers. obs). Flowering occurs between February and June (Curtis & Mannheimer 2005), but was also observed during July and August (pers. obs). Plants were found
in fruit in March, May, June and August. Plants will probably flower and fruit after good rains, but it is possible that flowering and fruiting can take place on a small scale throughout the year.

The following recommendations are made:

1. Finding a sufficient number of seeds to bank would mean monitoring of the population at RUL on a regular basis, e.g. once a month to ensure that optimal use can be made of the opportunity when a population is in fruit, especially after every rainy season. Following that, seeds should be collected whenever they are available. It should also be kept in mind that the large red fruit is attractive to birds.

2. If any A. pechuelii plants are in the way of development taking place at RUL – i.e. not be possible to leave them in their natural habitat – they should be carefully removed so that the root system remains as intact as possible. Arrangements should then be made with the NBRI, for them to be planted in the desert house, or distributed to other botanic gardens or to be transplanted on the site.

3. A good number of plants are easily accessible along routes and tracks in the license area and they could be pointed out to RUL environmental staff if necessary.

Long-term monitoring of Adenia pechuelii

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

After the project ended, 100 plants were tagged at RUL in 2010. The tagged plants are spread over several different zones of use e.g. the Tailings area, the visitors parking area, the sand pit area and the dome gorge. This ensured that the tags are distributed over several biotopes. A field data sheet was designed to capture data for each of the plants that were tagged at RUL. A photograph was taken of each tagged plant for later comparisons during monitoring sessions. A RUL staff member participated in this exercise.

The following recommendations are made for the A. pechuelii population at RUL:

1. The data sheet should be adapted for future monitoring sessions. The NBRI should take responsibility for this.

2. The first round of monitoring of the tagged plants should be conducted between 2013 and 2015 and thereafter every five years. This should also be done in other populations that were tagged at roughly the same time. RUL and the NBRI should take responsibility for this.

3. A map should be produced of all the tagged plants at RUL and forwarded to RUL. The NBRI will take responsibility for this.
Appendix 2

Photographs of *Adenia pechuelii* taken at various populations over the distribution range of the species

a) 

b) 

c) 

d)
a) Caterpillar browsing on leaves of *Adenia*, b) One of the larger specimens at RUL, c) A small plant at Rössing, d) Specimens with leaves are not often observed, e) An unusual form, growing out of a rock face, f) A very small plant, growing out of a rock face, & g) View onto Munitum valley with *Adenia*. 
Appendix 3

Satellite images indicating the location of surveyed populations of *Adenia pechuelii*

Figures a to g indicate the location of some of the surveyed populations of *A. pechuelii* as they were mapped on ETM (Landsat 7) satellite images, starting from the northernmost populations and then proceeding southward.

a. Populations of *A. pechuelii* north of the Munitum River on the SKP boundary and between the Munitum and Nadas Rivers

b. Populations of *A. pechuelii* in the “Garden Route” north of the Khumib River and south of the Ogams Fountain
c). Populations of *A. pechuelii* in the vicinity of the Terrace Fountain north and south of the Huab River

d) Population of *A. pechuelii* north of the Omaruru River in the Tsiseb conservancy
e) Populations of *A. pechuelii* south-west of the Spitzkoppe and on the road between Hentiesbay and Usakos

f) Populations of *A. pechuelii* at RUL and the Valencia Uranium mine
g) Population of *A. pechuelii* at Leeukop in the NNP, NE of the Vogelfederberg